REVIEW OF BIOLOGICAL IMPACTS ASSOCIATED WITH SEDIMENT MANAGEMENT AND PROTECTION OF CALIFORNIA COASTAL BIOTA

In Support of the CALIFORNIA SEDIMENT MANAGEMENT MASTER PLAN

Prepared for:
California Coastal Sediment Management Workgroup
Under Contract with: BEACON

SAIC

DRAFT REPORT

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Under Contract With:
Beach Erosion Authority for Clean Oceans and Nourishment (BEACON)

Science Applications International Corporation
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March 2007

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Draft Review of Biological Impacts Associated with Sediment Management and Protection of California Coastal Biota.
Prepared for the California Coastal Sediment Management Workgroup, under contract with the Beacon Erosion
Authority for Clean Oceans and Nourishment (BEACON).

TABLE OF CONTENTS

LIST OF FIGURES ix
LIST OF TABLES x

EXECUTIVE SUMMARY ES-1
ACRONYMS A-1
GLOSSARY G-1

1.0 INTRODUCTION 1-1
1.1 Study Purpose 1-1
1.2 Study Questions 1-2
1.3 Study Goals and Objectives 1-2
1.4 Methodology 1-3
1.5 Report Organization 1-6

2.0 RELEVANT BACKGROUND INFORMATION 2-1
2.1 Overview of Potential Future Locations of Sediment Management Activities 2-1
2.2 Overview of Types of Sediment Management Activities and Methods 2-12
2.2.1 Pre-Construction Phase 2-12
2.2.2 Construction Phase 2-13
2.2.3 Post construction Phase 2-19
2.2.4 Maintenance 2-19
2.3 Overview of Oceanographic Conditions and Coastal Processes Affecting Beach and Nearshore Environments 2-20
2.3.1 Natural Sediment Supply and Sinks 2-20
2.3.2 Currents, Tides, and Waves 2-27
2.3.3 Upwelling and Downwelling 2-27
2.3.4 Climate Oscillation Patterns 2-28
2.4 Water Quality Objectives and Natural Water Characteristics 2-29
2.4.1 Water Quality Objectives for Ocean Waters 2-29
2.4.2 Water Quality Objectives for Enclosed Bays and Estuaries 2-33
2.5 Overview of Potential Biological Impacts Associated with Sediment Management Activities 2-42
2.5.1 Equipment and Disturbance 2-42
2.5.2 Habitat Burial and Sedimentation 2-44
2.5.3 Water Quality 2-46
2.6 Overview of Applicable Laws and Regulations 2-47
2.6.1 Federal Environmental Regulations 2-47
2.6.2 State Environmental Regulations 2-49

3.0 REVIEW OF HABITATS POTENTIALLY AFFECTED BY SEDIMENT MANAGEMENT ACTIVITIES 3-1

3.1 Habitats Where Sediment Management May Occur 3-1
3.2 Habitat Functions and Values 3-5
3.3 Review of Habitats and Impact Responses to Natural Disturbance and Sediment Management Activities 3-9
3.3.1 Coastal Dune and/or Strand 3-12
3.3.2 Sandy Beach 3-31
3.3.3 Sandy Subtidal 3-47
3.3.4 Rocky Intertidal 3-55
3.3.5 Rocky Subtidal 3-70
3.3.6 Kelp Forest and/or Bed 3-83
3.3.7 Surfgrass Bed 3-103
3.3.8 Eelgrass Meadow 3-113
3.3.9 Shallow-Inlet Embayments 3-131
3.3.10 Deepwater Inlet Embayment 3-141

4.0 REVIEW OF SPECIES POTENTIALLY AFFECTED BY SEDIMENT MANAGEMENT ACTIVITIES 4-1
4.1 Overview of Species and Sediment Management Impact Concerns 4-1
4.2 Review of Invertebrates and Impact Responses to Natural Disturbance and Sediment Management Activities 4-4
4.2.1 Abalone 4-4
4.2.2 California Spiny Lobster 4-12
4.2.3 Dungeness Crab 4-18
4.2.4 Pismo Clam 4-25
4.2.5 Sea Urchins 4-32
4.2.6 Sandy Beach Invertebrates 4-39
4.2.7 Sandy Subtidal Invertebrates 4-59
4.2.8 Rocky Intertidal Invertebrates 4-80
4.2.9 Rocky Subtidal Invertebrates 4-89
4.3 Review of Fish Species Responses to Natural Disturbance and Sediment Management Activities 4-100
4.3.1 California Grunion 4-100
4.3.2 Pacific Herring 4-108
4.3.3 Salmonids 4-118
4.3.4 Bottom-Dwelling Fish 4-127
4.3.5 Nearshore Water Column Fish 4-135
4.3.6 Subtidal Reef Fish 4-142
4.3.7 Tidepool Fish 4-152
4.4 Review of Bird Species Responses to Natural Disturbance and Sediment Management Activities 4-159
4.4.1 California Brown Pelican 4-159
4.4.2 California Least Tern 4-166
4.4.3 Western Snowy Plover 4-173
4.4.4 Gulls, Skimmers, and Terns 4-182
4.4.5 Shorebirds 4-189
4.4.6 Wading Birds 4-197
4.4.8 Waterfowl and Seabirds 4-202
4.5 Review of Marine Mammal Species Responses to Natural Disturbance and Sediment Management Activities 4-208

4.5.1 Sea Otters 4-208
4.5.2 Pinnipeds 4-214
4.5.3 Cetaceans 4-220

5.0 REVIEW AND SUMMARIES OF BENEFICIAL AND ADVERSE BIOLOGICAL EFFECTS OF SEDIMENT MANAGEMENT ACTIVITIES 5-1
5.1 Review of Potential Beneficial Biological Effects of Sediment Management Activities 5-2
5.1.1 Habitats 5-8
5.1.1.1 Coastal Dune and/or Strand....5-8
5.1.1.2 Soft Substrate 5-8
5.1.1.3 Hard Substrate 5-10
5.1.1.4 Submerged Aquatic Vegetation 5-10
5.1.1.5 Embayments 5-12
5.1.2 Species 5-13
5.1.2.1 Invertebrates 5-13
5.1.2.2 Fishes....5-13
5.1.2.3 Birds 5-14
5.1.2.4 Marine Mammals....5-15
5.2 Review of Adverse Impact Issues and Concerns....5-16
5.2.1 Types of Adverse Effects....5-16
5.2.1.1 Direct Impact Concerns....5-17
5.2.1.2 Indirect Impact Concerns 5-17
5.2.1.3 Cumulative Impact Concerns 5-18
5.2.2 Scientific Bases of Concern....5-19
5.2.2.1 Habitats 5-20
5.2.3.2 Species 5-23
5.2.3 Short-Term, Long-Term, and Significant Impact Issues 5-27
5.2.3.1 Project Design....5-29
5.2.3.2 Sediment Characteristics and Compatibility....5-32
5.2.3.3 Project Duration and Work Schedule 5-35
5.2.3.4 Location and Proximity to Sensitive Resources 5-36
5.2.3.5 Project Timing and Seasonal Considerations 5-37
5.2.3.6 Natural Recovery and Resilience....5-38
5.2.3.7 Frequency of Disturbance 5-42
5.3 Equipment and Disturbance Impacts 5-45
5.3.1 Types of Equipment Used During Sediment Management....5-46
5.3.1.1 Beach Nourishment....5-46
5.3.1.2 Dredging....5-46
5.3.2 Summary of Different Types of Equipment Impacts 5-47
5.3.2.1 Vehicles....5-48
5.3.2.2 Dredging....5-52
5.3.2.3 Dredge Entrainment 5-55
5.3.2.4 Vessel Anchoring and Transit 5-57
5.3.2.5 Pipeline Placement/Removal 5-60
5.3.2.6 Noise 5-62
5.3.2.7 Artificial Lighting 5-71
5.3.2.8 Accidental Leaks and Discharges 5-73
5.3.3 Equipment Impacts to Habitats....5-73

5.3.3.1 Coastal Dune and/or Strand....5-73
5.3.3.2 Soft Substrate....5-77
5.3.3.3 Hard Substrate....5-80
5.3.3.4 Submerged Aquatic Vegetation....5-81
5.3.3.5 Embayments....5-83
5.3.4 Equipment Impact Concerns to Species....5-84
5.3.4.1 Invertebrates....5-84
5.3.4.2 Fishes....5-86
5.3.4.3 Birds....5-93
5.3.4.4 Marine Mammals....5-95
5.4 Burial and Sedimentation Impacts....5-97
5.4.1 Overview of Burial and Sedimentation Impact Issues....5-97
5.4.1.1 Source Materials and Placement Method....5-99
5.4.1.2 Rates of Sedimentation....5-102
5.4.1.3 Sediment Load and Thickness....5-103
5.4.1.4 Sedimentation Duration....5-105
5.4.1.5 Natural Environmental Adaptations....5-108
5.4.2 Lessons Learned from Large-Scale Sedimentation Events....5-109
5.4.3 Burial and Sedimentation Impact Concerns to Habitats....5-111
5.4.3.1 Coastal Dunes and/or Strand....5-111
5.4.3.2 Soft Substrate....5-113
5.4.3.3 Hard Substrate....5-115
5.4.3.4 Submerged Aquatic Vegetation....5-120
5.4.3.5 Embayments....5-129
5.4.4 Sedimentation Impact Concerns to Species....5-130
5.4.4.1 Invertebrates....5-130
5.4.4.2 Fishes....5-138
5.4.4.3 Birds....5-143
5.4.4.4 Marine Mammals....5-146
5.5 Water Quality Impacts....5-147
5.5.1 Overview of Water Quality Impact Issues....5-148
5.5.1.1 Overview of Turbidity Generating Activities....5-148
5.5.1.2 Overview of Factors Affecting Turbidity and Particle Deposition....5-149
5.5.2 Water Quality Criteria and Monitoring Requirements Associated with Sediment Management Projects....5-150
5.5.2.1 Monitoring Requirements and Criteria....5-151
5.5.2.2 Comparison and Biological Relevance of Different Suspended Sediment/Turbidity Monitoring Methods....5-156
5.5.3 Comparison of Turbidity During Sediment Management Activites With Natural and/or Baseline Conditions....5-160
5.5.3.1 Total Suspended Sediment....5-161
5.5.3.2 Turbidity Values....5-168
5.5.3.3 Water Clarity Values....5-171
5.5.3.4 Light Transmission....5-171
5.5.3.5 Turbidity Plumes....5-175
5.5.3.6 Summary of Turbidity Plume Characteristics During Sediment Management Activities....5-179

5.5.4 Suspended Sediment and/or Turbidity Impacts on Habitats and Species 5-181
5.5.4.1 Coastal Dune and/or Strand 5-184
5.5.4.2 Submerged Aquatic Vegetation 5-184
5.5.4.3 Invertebrates 5-189
5.5.4.4 Fishes 5-191
5.5.4.5 Birds 5-198
5.5.4.6 Marine Mammals 5-198

6.0 REVIEW OF IMPLEMENTED IMPACT SIGNIFICANCE THRESHOLDS AND MITIGATION MEASURES 6-1
6.1 Review of CEQA/NEPA Thresholds of Significance 6-2
6.1.1 Federal-listed, State-listed, and/or Other Special Status Species 6-3
6.1.2 Essential Fish Habitat 6-5
6.1.3 Native Habitats and/or Other Sensitive Resources 6-6
6.1.4 Wildlife Movement 6-9
6.1.5 Commercial Fishing 6-9
6.1.6 Environmental Policies 6-10
6.2 Overview of Mitigation Measures 6-11
6.3 Pre-Construction Phase Mitigation Measures 6-13
6.3.1 Sediment Compatibility and Quality 6-13
6.3.1.1 Minimize Difference in Sediment Characteristics Unless Enhancement is Conducted 6-15
6.3.1.2 Minimize Change in Surface Substrate Characteristics of Beach and/or Dredge Areas Unless Enhancement is Conducted 6-16
6.3.2 Environmental Design 6-17
6.3.2.1 Avoid Direct Impacts to Sensitive Habitats 6-17
6.3.2.2 Match Project Size to Environmental Constraints 6-18
6.3.2.3 Maintain Hydrodynamics Unless Enhancement is Conducted 6-19
6.3.2.4 Avoid Steep Scarps and Slopes 6-20
6.3.3 Environmental Implementation Strategies 6-22
6.3.3.1 Avoid Repetitive Disturbance in Same Year 6-22
6.3.3.2 Multiple Small Rather than One Large Receiver Site 6-22
6.3.3.3 Incorporate Refuge Areas to Minimize Recovery Rates 6-24
6.3.4 Reduce Maintenance Frequency Over Time 6-25
6.3.4.1 Incorporate Dune Restoration 6-25
6.3.4.2 Use Sedimentation Basins and Source Control 6-26
6.3.5 Habitat Buffers 6-26
6.3.5.1 Buffer to Minimize Turbidity Impacts to Sensitive Habitats 6-27
6.3.5.2 Buffer to Minimize Sedimentation Impacts 6-30
6.3.6 Buffer to Avoid and Minimize Impacts to Sensitive Species 6-31
6.3.6.1 Buffer to Protect Fishery Spawning Grounds 6-32

6.3.6.2 Buffer to Avoid and Minimize Impacts to Sensitive Bird Species 6-32
6.3.6.3 Buffer to Avoid and Minimize Impacts to Marine Mammals 6-36
6.3.7 Environmental Coordination and Notifications 6-36
6.3.7.1 Prepare Hazardous Materials Management Plan 6-37
6.3.7.2 Prepare Inlet Monitoring and Response Plan 6-37
6.3.7.3 Conduct Environmental Training Program 6-38
6.3.7.4 Conduct Coast Guard Notification to Minimize Environmental Hazards 6-38
6.3.8 Mitigation and Monitoring Plan 6-39
6.3.8.1 Finalize Mitigation and Reporting Plan 6-39
6.3.8.2 Pre-Construction Surveys and Monitoring 6-39
6.4 Construction Phase Mitigation Measures 6-41
6.4.1 Location Controls 6-41
6.4.1.1 Avoid use of equipment, pipelines, and construction materials in sensitive habitats 6-41
6.4.1.2 Avoid anchoring and/or operation of dredges, drill rigs, and/or barges in or above SAV habitats 6-43
6.4.1.3 Single-Point, Surf-Zone Discharge 6-43
6.4.1.4 Hydraulic Discharge on Upper Beach 6-45
6.4.1.5 Limit Intentional Approaches Within 300 ft (91 m) and Use Slow Vessel Speed Around Sensitive Marine Mammals 6-45
6.4.2 Schedule and/or Seasonal Restrictions 6-47
6.4.2.1 Eelgrass 6-50
6.4.2.2 Invertebrates 6-50
6.4.2.3 Fishes 6-52
6.4.2.4 Birds 6-56
6.4.2.5 Marine Mammals 6-59
6.4.3 Construction Equipment and Operational Controls 6-59
6.4.3.1 Dredge Equipment Selection 6-59
6.4.3.2 Dredging Operational Controls – Entrainment 6-61
6.4.3.3 Dredging Operational Controls – Turbidity 6-63
6.4.4 Construction Methods and BMPs 6-67
6.4.4.1 Use Silt Curtains or Gunderbooms to Minimize Turbidity 6-67
6.4.4.2 Use Dikes or Swales to Minimize Turbidity 6-68
6.4.4.3 Use Dikes to Protect Sensitive Resources 6-69
6.4.4.4 Minimize Potential Hazardous Materials Leaks or Spills 6-70
6.4.4.4 Reduce Noise Levels Below Sensitive Wildlife Harassment Thresholds 6-71
6.4.4.5 Minimize Artificial Lighting in Sensitive Wildlife Areas 6-72
6.4.5 Construction Monitoring 6-74
6.4.5.1 Conduct Sediment Compatibiltiy Inspections and Testing to Ensure Substrate Characteristics Match Permit Requirements 6-74

6.4.5.2 Conduct Water Quality Compliance Monitoring and Modify Activities if Necessary to Meet Turbidity Requirements 6-75
6.4.5.3 Monitor Inlet Status and Take Action if Necessary to Maintain in Open Condition 6-75
6.4.5.4 Monitor Grunion Spawning and Modify Activities if Necessary to Avoid Impacts 6-76
6.4.5.5 Monitor Sensitive Bird Species and Modify Activities if Necessary to Avoid Impacts 6-77
6.4.5.6 Monitor Marine Mammals and Modify Activities if Necessary to Avoid Impacts 6-78
6.5 Post Construction Phase Mitigation Measures 6-79
6.5.1 Verify Impact Significance in Areas Where There is a Potential to Impact Sensitive Habitat Resources 6-79
6.5.2 Compensatory Mitigation 6-79
6.6 Summary of Mitigation Measures 6-80
6.6.1 Considerations of Mitigation Effectiveness 6-81
6.6.1.1 Available Information on Effectiveness 6-81
6.6.1.2 Considerations Relevant to Prohibition Zones 6-82
6.6.1.3 Considerations Relevant to Environmental Windows 6-82
6.6.2 EFH and Sensitive Species Coordination and Mitigation Measures 6-84
6.6.2.1 Essential Fish Habitat 6-86
6.6.2.2 Other Sensitive and/or Managed Fish 6-87
6.6.2.3 Sensitive Bird Species 6-88
6.6.2.4 Marine Mammals 6-91
6.6.3 Mitigation Measures by Sediment Management Activity, Impact of Concern, Habitats, and Species 6-91
6.6.3.1 Summary of Measures by Sediment Management Activity 6-92
6.6.3.2 Summary of Measures by Impact of Concern 6-92
6.6.3.3 Summary of Mitigation Measures by Habitats and Species 6-95

7.0 REVIEW OF RESOURCE MANAGEMENT AND MONITORING APPROACHES 7-1
7.1 Overview of Ecosystem- and Species-Based Resource Management Approaches 7-2
7.2 Overview of Monitoring Considerations 7-5
7.2.1 Monitoring Program Elements 7-6
7.2.2 Scale and Duration of Monitoring 7-8
7.2.3 Monitoring Study Design and Impact Detection 7-10
7.2.4 Use of Indicator Species and/or Indices 7-12
7.2.5 Monitoring Objectives 7-16
7.3 Pre-Construction Surveys and/or Monitoring 7-21
7.3.1 Sediment Testing 7-21
7.3.2 Sensitive Resource Surveys 7-23
7.3.2.1 Sensitive Aquatic Resource Survey 7-23
7.3.2.2 Sensitive Habitat Boundaries Survey 7-24

7.3.2.3 Pismo Clam Bed Survey 7-25
7.3.2.4 Locally Important Fishery Grounds 7-26
7.3.2.5 California Grunion Habitat Suitability 7-26
7.3.2.6 Snowy Plover Occurrence Surveys 7-27
7.3.3 Caulerpa Surveys 7-28
7.4 Construction Monitoring 7-29
7.4.1 Sediment Compatibility Compliance 7-29
7.4.2 Water Quality Compliance 7-30
7.4.3 Turbidity Monitoring 7-30
7.4.3.1 Level of Monitoring 7-31
7.4.3.2 Types of Monitoring 7-32
7.4.3.3 Compliance Criteria 7-34
7.4.3.4 Turbidity Indicator Species 7-37
7.4.4 Open Inlet Status 7-37
7.4.5 Sensitive Species Occurrence 7-38
7.4.5.1 California Grunion 7-38
7.4.5.2 California Least Tern 7-39
7.4.5.3 Western Snowy Plover 7-40
7.4.5.4 Marine Mammal Occurrence 7-41
7.5 Post-Construction Monitoring and/or Impact Evaluations 7-42
7.5.1 Impact Significance Verification and/or Habitat Recovery Rates 7-42
7.5.2 Burial and Sedimentation 7-47
7.6 Summary and Recommendations 7-50

8.0 RECOMMENDATIONS 8-1
8.1 Methods to Minimize Impacts 8-2
8.1.1 Project Design 8-2
8.1.1.1 Environmental Constraints 8-2
8.1.1.2 Placement Location 8-3
8.1.1.3 Project Size and Configuration 8-3
8.1.2 Construction Schedule 8-3
8.1.3 Construction Implementation Controls and Monitoring 8-4
8.1.3.1 Pre-Construction Coordination 8-4
8.1.3.2 Standardized Monitoring 8-5
8.1.3.3 Monitoring Feedback Loop to Adaptive Management 8-5
8.1.3.4 Documentation of Mitigation Effectiveness 8-6
8.1.4 Frequency of Sediment Management Activity 8-6
8.2 Methods to Improve Impact Assessment and Streamlining Environmental Review and Permitting 8-7
8.2.1 Establish Standardized CEQA thresholds of significance 8-7
8.2.2 Incorporate Protective Measures in Project Description 8-8
8.2.3 Establish Guidelines for Impact Significance Thresholds, Protective Measures, and Monitoring 8-8
8.2.4 Fill Critical Information Gaps 8-8
8.2.4.1 Beach Nourishment Sediment Compatibility 8-8
8.2.4.2 Turbidity and Sedimentation 8-9

8.2.4.3 Validate and Improve Accuracy of Sediment Transport Models....8-10
8.3 Regional Management of Cumulative Impacts and Ecosystem Benefits 8-11
8.3.1 Expand Regional Databases and GIS Tools to Facilitate Protection of Biological Resources and Management of Cumulative Impacts 8-11
8.3.1.1 Regional Biological Resource Database....8-11
8.3.1.2 Regional Cumulative Projects Database....8-11
8.3.2 Minimize Multi-Use Cumulative Impacts....8-11
8.3.4 Incorporate Ecosystem Benefits into Regional Sediment Management Planning....8-12
8.3.5 Documentation of Environmental Benefits....8-13

9.0 PREPARERS AND CONTRIBUTORS....9-1

10.0 LITERATURE CITED 9-1

APPENDIX A – LIST OF REVIEWED PERMITS

APPENDIX B – ANNOTATED SUMMARIES OF REPORTED IMPACTS FROM SEDIMENT MANAGEMENT ACTIVITIES

APPENDIX C – WATER QUALITY TECHICAL SUPPORT INFORMATION

APPENDIX D – REPRESENTATIVE SIGNIFICANCE CRITERIA AND MITIGATION MEASURES APPLIED TO CALIFORNIA SEDIMENT MANAGMENENT PROJECTS

LIST OF FIGURES

2.1-1 Locations of potential future sediment management activities in northern California 2-9
2.1-2 Locations of potential future sediment management activities in central California 2-10
2.1-3 Locations of potential future sediment management activities in southern California 2-11
2.2-1 Examples of beach nourishment techniques 2-18
2.3-1 Diagram of the beach shorezone and associated coastal features 2-22
2.3-2 Littoral cells and estimated erosion rates offshore California 2-23
2.3-3 Example of seasonal beach change on Leucadia Beach prior to sand nourishment and condition of beach after nourishment 2-26
3.1-1 Cross reference between coastal terminology and biological habitat boundaries 3-3

3.3-1 Beach-dune system relationships and terminology 3-15
5.2-1 Conceptual diagram of recovery process after disturbance 5-40
5.3-1 Illustration of different dredge types 5-47
5.4-1 Illustration of different open water placement methods 5-102
5.4-2 Example of beach profile one year after beach nourishment 5-106
5.4-3 Sediment thickness and volume reduction after hydraulic discharge 5-108
5.5-1 Maximum total suspended sediment concentrations measured around commonly used mechanical and hydraulic dredges 5-161
5.5-2 Representative total suspended solids concentrations during sediment dredging activities 5-162
5.5-3 Representative total suspended solids concentrations during nearshore placement activities 5-164
5.5-4 Schematic of hydraulic pipeline discharge 5-165
5.5-5 Representative total suspended solids concentrations during beach placement activities 5-166
5.5-6 Representative turbidity measurements during sediment dredging activities in California 5-169
5.5-7 Representative water quality measurements during sediment placement activities in California 5-170
5.5-8 Representative water quality measurements during sediment dredging activities in California 5-172
5.5-9 Representative water quality measurements during sediment placement activities in California 5-173
5.5-10 Representative light transmittance measurements during sediment management activities in California 5-174
5.5-11 Illustration of decay of TSS concentrations with increasing distance from clamshell dredging operations 5-176
5.5-12 Categories of potential impact risk from turbidity 5-182
5.5-13 Estimated range of turbidity exposure of sessile organism during cutterhead dredging 5-183
7.2-3 Example hard bottom indicator species 7-15

LIST OF TABLES

1.3-1 Biological study goals and objectives 1-3
1.4-2 List of useful information sources relevant to sediment management projects and California resources 1-5

2.1-1 Types and locations of potential future sediment management projects in California 2-5

2.2-1 Agencies involved with review and/or approval of sediment management projects 2-14

2.4-1 California Ocean Plan water quality objectives 2-30

2.4-2 Comparison of Ocean Plan and AB-II bacteriological standards 2-31

2.4-3 California Ocean Plan effluent limitations 2-33

2.4-4 Numeric water quality objectives for enclosed bays and estuaries 2-34

2.4-5 Comparison of fecal coliform bacteria objectives for enclosed bays and estuaries 2-35

3.1-1 Regional distribution of habitats in California 3-4

3.2-1 Beneficial uses and relative values of coastal habitats 3-7

3.3-1 Federal and/or state-listed endangered and/or threatened species associated with coastal dune and/or strand habitat in California 3-19

4.4-1 List of sensitive species and types of species in areas where sediment management activities 4-2

5.1-1 Reported biological benefits from beach nourishment and/or sand placement projects 5-3

5.1-2 Potential benefits to California habitats and species from beach nourishment ..5-4

5.1-3 Potential benefits to California habitats and species from dredging activities 5-7

5.2-1 Potential effects of disturbance across different levels of biological organization 5-18

5.2-2 Summary of scientific basis of concern for potential adverse impacts to coastal habitats associated sediment management activities 5-22

5.2-3 Summary of scientific basis of concern for potential adverse impacts to species associated with sediment management activities.....5-25

5.2-4 Examples of short- and long-term impacts associated with sediment management activities.....5-28

5.2-5 Reported adverse effects by project size for representative sediment management projects 5-32

5.2-6 Conceptual summary of influential factors with respect to recovery rates of coastal habitats 5-40

5.3-1 Noise levels associated with operation of different types of construction and marine equipment.....5-64

5.3-2 Potential equipment impact concerns to habitats and species from beach nourishment activities 5-73

5.3-3 Potential equipment impact concerns to habitats and species from dredging and sand delivery activities.....5-74

5.3-4 Reported and/or estimated soft substrate invertebrate recovery rates after equipment disturbance 5-86

5.4-1 Potential burial and sedimentation impacts to habitats and species from sediment management activities.....5-111

5.4-2 Generalized invertebrate community recovery rates after beach nourishment5-137

5.5-1 Water quality monitoring conducted during representative California sediment management projects 5-152

5.5-2. Total suspended solids concentrations during storms and/or high river runoff in bays and the nearshore zone.....5-163

5.5-3 Comparison of total suspended solids concentrations during beach nourishment and storm conditions off New Jersey.....5-167

5.5-4 Potential turbidity impacts to habitats and species from sediment management activities.....5-185

6.3-1 Types of pre-construction phase mitigation measures to avoid and minimize impacts during sediment management projects.....6-14

6.4-1 Types of construction phase mitigation measures to reduce direct and indirect impacts during sediment management projects.....6-42

6.4-2 Sensitive species environmental window restricted periods specified by the USACE for California sensitive species that have the potential to be affected by sediment management projects 6-48

6.4-3 Seasonal recruitment, breeding, and/or spawning periods for representative and high interest California marine resources.....6-49

6.6-1. Types of pre-construction phase mitigation measures to avoid and minimize impacts by type of sediment management project 6-93

6.6.2 Types of construction phase mitigation measures to avoid and minimize impacts by type of sediment management project.....6-94

6.6-3 Summary of mitigation measures with demonstrated and/or likely effectiveness to protect biological resources during sediment management activities 6-97

7.2-1 Example management questions relevant to biological resource protection and monitoring 7-6

7.2-2 Example monitoring elements for representative sediment management projects.....7-9

7.2-3 Example hard bottom indicator species.....7-15

7.2-4 Representative monitoring programs during beach nourishment projects 7-17

Executive Summary

The California Coastal Sediment Management Workgroup (CSMW) is conducting several planning efforts to facilitate regional approaches to protecting, enhancing, and restoring California's coastal beaches and watersheds through federal, state, and local cooperative efforts. A major part of this effort is development of a comprehensive Sediment Management Master Plan (SMP) for California. Goals include better coordination of coastal sediment management issues such as dredging, sediment flow through watersheds, coastal erosion, and beach nourishment activities through the development of strategies that streamline application of sediment opportunities to needs to facilitate conservation and restoration of California's coastal beaches and watersheds. An integral element of the SMP is protection of California's unique habitats, sensitive resources, coastal fisheries, and ecosystem values.

The CSMW conducted an initial assessment of issues and concerns associated with development of the SMP and identified a need to better understand the actual effects of sediment management activities on coastal biota, particularly related to beach nourishment. Beach nourishment, which involves the addition of sand to the shore, has become a widely used management method around the world to reduce coastal erosion and increase shoreline protection. This method provides a "soft" solution that may be favored because of less disruption to natural coastal processes than hard structures such as seawalls, breakwaters, and rock groins.

Several sediment management activities may provide source material opportunities for beach nourishment, including beneficial use of sands dredged during routine maintenance of ports and harbors, bay and estuary restoration projects, and/or maintenance of flood control basins and channels. Sands excavated during coastal development projects (opportunistic sand sources) or mined from offshore sand deposits (borrow sites) represent other commonly used source materials for beach nourishment. Sediment testing guidelines developed by the U.S. Environmental Protection Agency and U.S. Army Corps of Engineers require sediments used for beach nourishment to be free of hazardous contaminants and compatible with biological and recreational beneficial uses.

The physical activities of beach nourishment and related sediment management activities involve the use of a variety of dredges and construction equipment that disturb sediment, water, and biological resources. The addition or removal of sediment in aquatic environments has the potential to result in environmental damage if not properly managed. Incomplete knowledge of impacts and a general lack of understanding about coastal ecosystems have led to a disparity in permit requirements regulating coastal sediment management projects in California. The CSMW identified that a more complete understanding and better scientific data are needed regarding biological resources and impacts to support environmentally sound decision-making by policy-makers, the regulatory community, and project proponents with respect to coastal sediment management.

In response to this need, the CSMW authorized this biological impacts analysis study to identify and assess literature sources relating to potential biological impacts of coastal sediment management activities in California, and develop science-based recommendations to address relevant concerns as they relate to sensitive biota, habitats or ecosystems.

The purpose of this study is three-fold:

- Summarize available information and prepare a balanced critical evaluation of potential and documented impacts to biological resources associated with sediment management activities,
- Summarize available information on California's coastal habitats and biological resources in a manner that contributes to an understanding of how sediment management activities may affect them (positively or negatively), and
- Develop science-based recommendations to address relevant concerns and facilitate sediment management activities without negatively impacting coastal biota, including consideration of ecosystem and/or species approaches to resource protection.

The foundation of this study is a comprehensive review of available literature and reports associated with sediment management activities. Information was gathered from a variety of sources, including published literature, unpublished reports, regulatory permits, and coordination with resource and regulatory agency personnel. Results of the review are organized in several document sections that provide background on sediment management practices, coastal processes, biological information for coastal habitats and special interest species, and integrated technical summaries of beneficial effects and adverse impacts. The impact discussions distinguish between effects associated with equipment use, removal and placement of sediment, turbidity, and potential cumulative impact concerns. In addition, significance thresholds, mitigation measures, and monitoring commonly applied to sediment management projects are reviewed. Highlights of these reviews are given below.

Beach nourishment may be accomplished using different methods, involving different placement locations and/or construction techniques. Locations may range from the beach backshore to nearshore zone, and may involve use of dredges that hydraulically pump sands through temporary pipelines to the receiver site or trucks to deliver sand loads. Sands placed on the beach using either method are spread and leveled using earthmoving equipment.

Beach nourishment will alter the appearance and may affect local hydrodynamics of the receiver site until the beach fill adjusts from wave action. Sand placement on the shore will result in a wider beach that may have a steeper profile until the beach equilibrates. As sand erodes from the fill, it will seasonally move off- and onshore and downcurrent, indirectly nourishing adjacent areas in a process referred to as sand transport sedimentation in this document. Discharge of sands in the nearshore portion of the beach profile will result in an elevated mound, which will seasonally erode and also indirectly nourish onshore and downcurrent beaches as sands are transported in the littoral zone.

Dredging and conveyance of sand to receiver sites may involve use of hydraulic dredges and pipelines or a combination of mechanic dredges, dump scows, and/or pipelines. At the dredge site, sediment removal may affect local hydrodynamics depending on depth and extent of dredging.

Sediment management activities result in beneficial and adverse impacts. Impacts to coastal habitats and resources from sediment management projects are unavoidable, simply due to equipment-related effects on wildlife, burial or removal of sediment and associated biota living in the sediment, and turbidity generated from sediment-disturbing activities. Some of

the key facts about beach nourishment and related sediment management activities include:

- Beach nourishment provides shoreline protection benefits, recreational benefits, and can help protect ecosystem benefits of sandy beach and dune habitats, and associated fisheries, shorebirds, vegetation, and terrestrial species.
- Dredging maintains navigable waters and safe harbors, maintains tidal exchange of coastal wetlands, and can help maintain ecosystem functions and values of bays and estuaries.
- Beach nourishment and dredging both result in similar impacts to water quality, turbidity effects to aquatic animals and visual predators, equipment-related impacts to mobile wildlife, and involve impacts to sediments and sediment associated biota, although there are some specific differences that relate to the impact being either burial or removal of existing substrate.

The following table compares types of potential beneficial and adverse impacts associated with beach nourishment and dredging.

Types of Impacts from Sediment Management Activities

	Beach Nourishment	**Dredging**
Benefits		
Economic	Protect shoreline.	Maintain navigable waters and safe harbors.
Social	Enhance recreation.	Enhance recreation and education.
Ecosystem	Maintain and/or restore ecosystem functions and values of sandy beach and dune habitats and associated species.	Maintain and/or restore ecosystem functions and values of bay and estuarine habitats and associated species.
Impacts		
Water	Reduction in water quality.	Reduction in water quality.
	Turbidity effects on aquatic species and fish-eating predators.	Turbidity effects on aquatic species and fish-eating predators.
Equipment	Equipment-related disturbance and displacement of mobile wildlife.	Equipment-related disturbance and displacement of mobile wildlife.
Sediment Burial or Removal	Burial of any sedentary animals, which provides new surface for recolonization.	Removal of any sedentary animals and/or plants that is present in the dredged sediment, with exposure of a new surface substrate for recolonization, and entrainment of animals during removal of water along with sediment.
Sedimentation	Sedimentation enhancement and/or impacts to downcurrent habitats.	Sedimentation enhancement and/or impacts to downcurrent habitats.

Impacts may be distinguished as temporary, short-term disturbances that result in minor or negligible disturbance and from which resources fully recover. Long-term adverse impacts may occur when critical thresholds are exceeded, prolonged recovery periods degrade ecosystem functions, or recovery has not occurred between sediment management projects leading to a cumulative degradation of habitat. Thus, there is an important counter-balance of benefits and impacts associated with sediment management projects.

With either beach nourishment or dredging, impacts vary depending on project size, which largely relates to duration and extent of project influence. Proximity to sensitive resources also is an important consideration. Beach nourishment effects may also relate to substrate characteristics of source sands compared to existing conditions at the receiver site. Dredging effects may be additionally influenced by depth of excavation and hydrodynamics of dredged area (e.g., in area with restricted circulation or areas where there is substantial mixing by tides and currents). Effects also may vary depending on project schedule due to seasonal differences in productivity and biological use patterns of plants and animals, similar to what is observed on land.

Comprehensive reviews of available data and reports of the primary impact factors related to equipment, burial, sedimentation, and turbidity indicate the following biological impact responses and issues of concern.

The primary direct impact during beach nourishment projects is burial of invertebrates within the receiver site footprint. Birds and other mobile animals typically move away from increased human activity and equipment disturbance. However, shorebirds and surf zone fishes may feed elsewhere until the local forage base at the receiver site recovers. The consequence of this impact has not been well studied; however, it is generally assumed that the nature of effect relates to the recovery rate of the forage base and the size of the receiver site relative to total available foraging area.

Sandy beach invertebrate communities display a natural seasonality in resource development with more developed communities on the beach during spring-summer and limited development during fall-winter due seasonal accretion and erosion of sand. Numerous studies show that recovery of sandy beach invertebrates after beach nourishment may coincide with natural seasonal development, if the project is completed before the peak, spring-early summer recruitment. However, recovery may be delayed or incomplete if activities occur during or after peak recruitment periods.

A few field and laboratory studies indicate that invertebrate communities may be altered by deposition of sediments with relatively high silt/clay or coarse sand content. Placement of material with too high a shell content also has been shown to interfere with shorebird foraging. Thus, use of sands that closely match sediment characteristics in the area of the receiver site is the most often cited recommendation to minimize impacts to secondary consumers.

Other direct burial concerns depend on the presence of sensitive habitats (coastal strand) or sensitive species, which generally are more vulnerable to adverse impact during their spring-summer reproductive periods. For example, there is concern that sand placement or vehicles could affect beach spawning success of California grunion (e.g., bury fish eggs) and/or crush eggs and chicks of threatened snowy plover, which breed at some beaches. These concerns may or may not apply to a project site depending on existing conditions. In areas where these concerns do exist, impacts have been avoided by use of buffers and monitoring to ensure resources are protected or conducting work outside the sensitive season.

Impacts and recovery characteristics from dredging share some similarities to that described above for beach nourishment, particularly with respect to recovery of benthic invertebrates after sediment removal. However, recovery rates may vary over a greater range spanning months to years depending on the existing disturbance frequency in the project area.

Invertebrate recovery rates may occur in the same year for highly energetic, shallow nearshore and/or frequently disturbed, dredged channels.

In contrast, recovery may take two or more years at less energetic, offshore borrow sites and/or infrequently disturbed embayment areas with longer-lived species. Dredge depth, degree of change between exposed substrate characteristics from that removed, as well as dredge method and size of impacted area may influence recovery rates. Slower recovery (> 3 years) or altered communities have been reported when borrow sites resulted in deep pits that accumulated fine sediments and resulted in depressed oxygen levels. Relatively faster recovery rates (>1-3 years) have been reported with shallower dredging and/or methods that left undredged areas between dredged furrows.

Indirect impacts may arise from equipment use, turbidity generated during removal or placement of sediment in the aquatic environment, and sedimentation associated with sediment disturbance and transport after placement. Equipment related disturbance often results in displacement of mobile wildlife, which may have negligible consequence if movement distances are not far and conditions are suitable at the new location. Concerns arise when movement from disturbance increases risk of impact. Displacement impacts are of particular concern for endangered and/or threatened species. They also are of concern for species that have a high degree of site fidelity to sensitive habitats (e.g., reefs, submerged aquatic vegetation - SAV), particularly in areas where the habitat is limited and travel distance to other suitable habitat substantially increases vulnerability to predation.

Dredging and/or beach nourishment will result in turbidity and sedimentation impacts associated with removal and/or addition of sand to aquatic habitats. Turbidity generally dissipates rapidly after construction ceases, unless substrate includes high silt/clay content. Therefore, turbidity concerns are primarily a short-term impact associated with the period of construction.

Turbidity concerns include the potential to degrade sensitive, perennial reef and SAV habitats from light reduction, interference with foraging and/or migration of sensitive visual predators from water clarity reduction (e.g., California least tern, salmonids), delayed recruitment of invertebrates to beaches, and/or critical stress to early life stages of fish and/or sessile animals from abrasion, smothering, and/or foraging interference. However, few critical impact thresholds have been identified and considerable uncertainty remains with respect to actual effects of turbidity and sedimentation associated with exposure concentrations and durations typical of sediment management activities. However, there is general consensus that the potential for impacts increases as concentration and/or exposure duration increase, which is a function of project size and sediment characteristics of source and/or existing sediments.

Sedimentation concerns include the potential to bury or degrade sensitive, perennial reef, SAV, and/or spawning sites of fishery species. Reef height and quality as well as project size appear to be an important considerations with respect to potential beach nourishment impacts on hard bottom habitats.

Several aspects of the above impact processes are poorly understood, including:

- Definition of sediment compatibility to meet shoreline protection needs and to minimize adverse environmental impacts.
- Appropriate project scales and maintenance frequencies to minimize impacts.

- Effective management of sediment management projects to avoid adverse impacts to essential fish habitat and critical or essential habitat for shorebirds and seabirds.
- Effective management of sediment management projects to avoid cumulative impacts.

Understanding the scales at which impacts override benefits is an important key to effective management. However, little information is available with respect to critical impact thresholds. An important aspect of effective management is how the uncertainties are managed so that needed sediment management projects can be conducted in a timely and fiscally responsible manner while protecting ecosystem values, essential fish habitat, and sensitive species.

Several recommendations are made to address information gaps and to assist planning decisions with respect to:

- Minimizing impacts through improved environmental design of sediment management projects,
- Protective project implementation,
- Design of monitoring to fill critical information gaps with respect to impact processes and project performance to provide an important feedback loop to design of future projects,
- Developing tools to facilitate effective cumulative impact analysis to enable future fine-tuning of sediment management strategies on a regional basis, and
- Streamlining environmental review and permitting.

Recommendations of impact reduction strategies focus on how to appropriately match project locations and sizes to environmental constraints. This approach aims to avoid environmental mistakes with ecosystem consequences by keeping projects below critical thresholds with respect to physical and temporal scales of impact. Until critical gaps are filled with respect to thresholds, it is recommended that introduction of sediment be kept small in areas with sensitive biological habitats. This may be accomplished by use of several smaller projects rather than a single large project and/or use of upcurrent feeder beaches to more slowly nourish downcurrent beaches at natural rates of coastal processes.

Environmental project design is a process that seeks to appropriately match project scales of impact below critical thresholds associated with site-specific environmental constraints. Another important consideration is minimizing ecosystem disturbance associated with future operations and maintenance activities. Effective management strategies should account for natural disturbance regimes to ensure that maintenance activities do not occur at a frequency higher than recovery periods from natural disturbance.

Protective mitigation measures during construction focus on effective use of buffers, best management practice construction methods, and compliance monitoring to ensure project implementation meets permitted requirements. Seasonal restrictions also are an effective measure for protecting sensitive spawning and nesting areas and recruitment periods. However, broad application of environmental work windows (outside seasonal restricted periods) regardless of impact risk may overly constrain necessary sediment management activities when other measures such as buffers and monitoring may be as effective in avoiding and minimizing impacts.

Each project area has a unique combination of environmental functions and values that require protection. As such, it is outside the scope of this document to be prescriptive in providing a standardized set of mitigation measures that will fit every sediment management scenario. However, it is possible for such measures to be developed over time at smaller regional scales such as littoral cells and locations of recurring sediment management activities. Recommendations include development of interim guidelines with respect to mitigation measures in coordination with resource agencies to facilitate a more standardized approach to selection and implementation of effective impact reduction strategies at local and project levels.

Monitoring recommendations for before, during, and after monitoring are focused on obtaining information to improve environmental design and performance of sediment management projects. Pre-construction monitoring data objectives support project design with respect to project location controls and buffers to avoid and minimize impacts. Construction monitoring objectives address obtaining data to support real-time decisions on the effectiveness of operational controls to meet water quality compliance objectives, verify sediment characteristics meet permitted requirements, and ensure sensitive resources if in the vicinity are not harmed in the process. Post-construction monitoring objectives focus on verification of impact significance if sensitive habitats are in the vicinity so that there is a feedback loop to improve future management projects.

Environmental consequences are similar among different geographic areas, particularly with respect to impact processes. In addition, similar impact issues apply when projects are implemented in areas with similar environmental conditions. These commonalities facilitate objectives aimed at streamlining environmental review and permitting of sediment management projects.

There also are differences among projects that result depending on site-specific constraints associated with sensitive habitats and/or species. Often the impact assessment and minimization considerations are similar for sites that share common types of environmental constraints. While more careful environmental review is warranted to ensure appropriate project design and implementation in environmentally constrained areas, there are enough similarities in approach that if established in guidelines could facilitate streamlined environmental review and permitting of more complex projects.

A streamlined environmental planning and review process is recommended that addresses SMP objectives to ensure protection of California's biological resources, including:

- Strategic planning to maintain balance between shoreline protection, recreational benefits, and healthy ecosystem functions,
- Regional data and models to improve project design and impact assessments relevant to California's coastal processes and resources,
- Tools to facilitate meaningful cumulative impact assessments as feedback loop to regional sediment management planning, and
- Cooperative stakeholder process to fill information gaps, enhance information exchange, and streamline environmental review and acceptability of sediment management projects.

ASBS	Areas of Special Biological Significance
BA	Biological Assessment
BEACON	Beach Erosion Authority for Clean Oceans and Nourishment
BMPs	Best Management Practices
BO	Biological Opinion
Caltrans	California Department of Transportation
CCC	California Coastal Commission
CDFG	California Department of Fish and Game
CDHS	California Department of Health Services
CEQ	Council of Environmental Quality
CEQA	California Environmental Quality Act
CERES	California Environmental Resources Evaluation System
CESA	California Endangered Species Act
CFR	Code of Federal Regulations
CNPS	California Native Plant Society
CSMW	California Coastal Sediment Management Workgroup
cm	Centimeter
cy	Cubic yards
CWA	Clean Water Act
CWZA	Coastal Zone Management Act
DBW	Department of Boating and Waterways
DFG	Department of Fish and Game
DPR	Department of Parks and Recreation
DO	Dissolved oxygen
EFH	Essential Fish Habitat
EA	Ecological Assessment
EHW	Extreme high water
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ft	Feet
FMP	Fishery Management Plan
FONSI	Findings of No Significant Impacts
FTU	Formazin turbidity unit
JTU	Jackson turbidity unit
km	Kilometer
in	Inch
L	Liter
LIDAR	Light Detection and Ranging
m	Meter
mg	Milligram
mg/L	Milligrams/liter
MHHW	Mean higher high water
ml	Milliliter
MLW	Mean low water
MLLW	Mean lower low water
MLPA	Marine Life Protection Act
mm	Millimeter

MMRP	Mitigation, Monitoring, and Reporting Plan
MMS	Minerals Management Service
MND	Mitigated Negative Declaration
MPN	Most probable number
MSL	Mean sea level
ND	Negative Declaration
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Association
NPDES	National Pollution Discharge Elimination System
NTU	Nephelometer turbidity unit
OPC	Ocean Protection Council
ppm	Parts per million
ppt	Parts per thousand
PDO	Pacific decadal oscillation
RGP	Regional general permit
RPM	Reasonable and prudent measure
RSM	Regional sediment management
RWQCB	Regional Water Quality Control Board
SANDAG	San Diego Association of Governments
SAS	Sensitive aquatic site
SAV	Submerged aquatic vegetation
SCC	State Coastal Conservancy
SCL	State Lands Commission
SCOUP	Sand Compatibility and Opportunistic Use Program
SCUBA	Self-contained underwater breathing apparatus
SMP	Sediment Management Master Plan
SWRCB	State Water Resources Control Board
TOC	Total organic carbon
TSS	Total suspended solids
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WDR	Waste Discharge Requirement

Abundance	The number of individuals of a species inhabiting a given area.
Aeolian Transport	The movement of sand by winds.
Algae	Includes one-celled algae such as diatoms and dinoflagellates as well as multicellular seaweeds and kelps.
Algal Blooms	Sudden spurts of algal growth, which can adversely affect water quality and indicate potentially hazardous changes in local water chemistry.
Alongshore	Parallel to shore.
Ambient Concentration	Measured concentrations and/or unit values of water quality in a receiving water body that are representative of natural conditions at the time of sampling.
Anaerobic	A life or process that occurs in, or is not destroyed by, the absence of oxygen.
Annelid	Segmented worms of a phylum Annelida, including polychaetes.
Antidegradation Policy	Requires that existing high-quality waters be protected and maintained.
Anoxic	Lacking oxygen.
Anthropogenic	Relating to the effects of man on nature.
Areas of Special Biological Significance (ASBS)	Areas designated by the State Water Resources Control Board as requiring protection of species or biological communities to the extent that alteration of natural water quality is undesirable.
Assemblage	A group of organisms sharing a common habitat.
Attenuation	Loss or dissipation of energy, light, and/or noise.
Background Level	The concentration of a substance in an environmental media (water or soil) that occurs naturally or is not the result of human activities (also see ambient concentration).
Backshore	The upper part of the active beach above the normal reach of the tides (high water) and extending to the landward limit of high storm wave influence, usually a dune or sea cliff.
Backwash	Seaward return of water following wave uprush on the beach face; also may refer to water thrown back by an obstruction such as ship, breakwater, or cliff

Bacteria	Microscopic living organisms that metabolize organic matter, and can cause human, animal and plant health problems. Bacteria concentrations in waters used for beneficial uses are regulated by the state and local Regional Water Quality Control Boards.
Baitfish	Small, schooling pelagic fish (such as anchovy) which are preyed upon by larger game fish and hence are used as bait by sport fishermen. Baitfish also are preyed upon by seabirds.
Bar	Offshore ridge or mound of sand, gravel. or other unconsolidated material which is submerged at least at high tide.
Basin Plan (See Water Quality Control Plans)	
Bathymetry	The measurement of depths of waters in oceans, seas, and lakes.
Beach	Shoreline extending from landward end of backshore to the seaward limit of sand movement by waves (depth of closure). This includes both the subaerial and subaqueous .portions of the shoreface.
Beach Closure	An area of a beach that has been contaminated by pollution, determined to be a public health risk, and closed to the public by a local health department.
Beach Erosion	The carrying away of beach materials by wave action, tidal currents, littoral currents, or winds.
Beach Face	Sloping section of beach exposed to wave swash, occurring between low tide and the berm crest.
Beach Nourishment	Addition of sand to the beach where erosion or other mechanisms have depleted the native beach material. Construction of a sandy beach, where only a small beach, or no beach, previously existed.
Beach Placement	Addition of sand to the dry and/or intertidal portion of the beach, as in beach nourishment.
Beach Profile	A cross-section of beach slope, extending from the backshore through the nearshore zone to the closure depth.
Beach Profile Placement (Beach Nourishment)	Combination of nearshore and dry beach placement along the entire beach profile.
Beach Scarp	An almosts perpendicular slope, which is an erosional feature due to wave action, it may vary in height from a few centimeters to several meters.
Beach Width	The horizontal dimension of the beach measured normal to the shoreline

Beam Transmissometer	Instrument used to measure light beam attenuation or light transmission through water.
Bed	The bottom of a watercourse, or any body of water.
Bedload	Area where sediment moves in rolling and sliding mode on or near the bottom.
Beneficial Uses	Defined as the uses of water necessary for the survival or well being of man, plants, and wildlife. These uses are protected against degradation, such as: domestic, municipal, agricultural and industrial supply; power generation; recreation; aesthetic enjoyment; navigation and preservation of fish and wildlife, and other aquatic resources or preserves. Protected beneficial uses are designated in regional Basin Plans for all water bodies within the state. Examples include water contact recreation (REC-1), non-contact water recreation (REC-2), marine habitat (MAR), cold freshwater habitat (COLD), warm water aquatic habitat (WARM), shellfish harvesting (SHELL), fish spawning habitat (SPWN), and rare and endangered species (RARE).
Benthic	Living on or in the seafloor.
Benthos	The bottom of the ocean; also, collectively, the biota (animals and plants) living on or in the seabed.
Berm	Nearly horizontal part of beach that is adjacent to and above the beach face.
Berm Crest	Break in slope between the beach face and the berm; position marking the highest runup of the swash.
Best Management Practices (BMPs)	Methods or measures designed and selected to reduce or eliminate the discharge of pollutants from point and non-point source discharges. BMPs may include any type of treatment practice, operating procedure, maintenance practice, and pollution prevention and educational practice to control runoff, spillage or leaks, or drainage that may pollute and/or degrade quality of receiving waters.
Bight	A slight indentation in a coast forming an open bay, usually crescent shaped.
Bioaccumulation	The accumulation of a substance (usually a contaminant) in the tissues of an organism.
Biodiversity	The variety of life and its processes, including the variety of living organisms, the genetic differences among them, and the communities and ecosystems in which they occur.

Biological Assessment	A document prepared in compliance with the Endangered Species Act section 7 process to determine whether a proposed major construction activity under the authority of a federal action agency is likely to adversely affect listed species, proposed species, or designated critical habitat.
Biological Opinion	A document stating the opinion of the USFWS or NMFW on whether or not a federal action is likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of critical habitat.
Biomass	The weight of living tissue, of an organism or a group of organisms per unit area or volume.
Biota	The plants and animals found in a particular environment.
Bivalve	A mollusk having two shells hinged together, as the oyster, clam or mussel.

BMPs (see Best Management Practices)

Blowout	A gap in a dune caused by strong winds blowing sand out from under and around the vegetation, typified by loss of vegetation and loose sand, which can result in greater erosion of the dune during storm events.
Bluff	A high steep bank or cliff.
BOD	Biochemical Oxygen Demand or Biological Oxygen Demand; the amount of dissolved oxygen required by aerobic micorgansims to degrade organic matter in a sample of water usually held in the dark at 20°C for 5 days; used to assess the potential rate of substrate degradation and oxygen utilization in aquatic ecosystems.
Borrow Area (Site)	Location where sand is dredged (mined) to provide source material for beach nourishment.
Brackish Water	Water that is not fresh, but not as salty as ocean water.
Breaker	Sea surface wave that steepens and collapses across the surf zone and runs up the beach face.
Breaker Zone	Zone in which waves approaching the coastline commence breaking, typically in water depths between 15 and 30 ft (4.6 and 9.1 m).
Breakwater	Structure built in the sea, somewhat parallel to shore, designed to stop ordinary waves from breaking on the enclosed area.
Buffer	An area designated to protect an adjacent sensitive habitat.

Buoyant Plumes	Relatively thin layers of buoyant sediment-laden water issuing from a point source such as river mouth. Positively buoyant plumes disperse in the surface layer, negatively buoyant plumes disperse over the sea or river bed.
Bypassing, Sand	Hydraulic or mechanical movement of sand from the accreting updrift side to the eroding downdrift side of an inlet or harbor entrance.
California Environmental Quality Act (CEQA)	The established state policy of environmental protection, maintenance, and enhancement.
California Water Code	Porter-Cologne Water Quality Control Act.
Central California	Area of coastline between Point Conception and Santa Cruz County.
Cetacean	Whales, dolphins, and porpoises, all of which are sometimes placed in the order Cetacea.
Chlorophyll	The pigment which makes most plants green and enables them to produce organic substances in the process of photosynthesis.
Clamshell Dredge	Bucket-type dredge operated by a crane that is used to remove bottom sediments in confined areas such as around piers, docks, etc. and/or where the disposal area is too far for feasible use of a cutterhead dredge.
Clay	Fine grained sediment with a typical grain size less than 0.004 mm.
Clean Water Act (CWA)	Federal legislation enacted in 1972 to restore and maintain the chemical, physical and biological integrity of the surface waters of the United States. The stated goals of the Act are that all waters be fishable and swimmable. Discharge and/or removal of sediment from state or federal waters requires certification and/or permits under sections 401 and 404 of the CWA.
Closure Depth	Seaward extent of the change between winter and summer beach profiles. This depth represents the seaward end of the beach profile that essentially remains unchanged over the long term. Sand that moves beyond the depth of closure in a seaward direction is typically lost to the littoral cell.
Coastal Management	The development of a strategic, long-term and sustainable land use policy, sometimes also called shoreline management.
Coastal Processes	Collective term covering the action of natural forces on the shoreline, and the nearshore seabed.

Coastal Dunes	Accumulations of windblown sand on the backshore, usually in form of shore parallel ridges, which may be unvegetated (active dune), vegetated with pioneer vegetation (incipient foredune), and/or vegetated with perennial shrubs (established foredune).
Coastal Strand	A plant community most commonly comprised of low-lying succulent plants found on sand dunes and backshore close to the ocean.
Coastal Zone	Land and water adjacent to the coast that exerts an influence on the uses of the sea and its ecology.
Coastline	Boundary between land and water; generally used to describe the appearance or configuration of land along the coast.
Cobble	Rounded rocks ranging in diameter from approximately 64 to 256 mm.
Coliform	Relating to the colon bacillus bacteria.
Community	All plants and animals living in a particular place or habitat and which interact with one another.
Compatibility	When the natural distribution of material grain sizes from a potential source area lies within the envelope of grain sizes found at the receiver site, with certain allowances for exceedances of coarse and fine-grained sediments.
Compensation Depth	Depth at which photosynthetic oxygen production equals oxygen consumed by plant respiration; the lower part of the photic zone. Depth above which photosynthesis results in plant growth. Depth equals approximately 1 percent of surface radiation.
Constituent	An informal term used to describe a detectable element or component or attribute of waste or effluent.
Contaminant	An unnatural (man-made) substance found in the environment or a naturally occurring substance or compound which is found in unnaturally high concentrations; a health hazard; a pollutant.
Continental Shelf	The part of the continent extending from the low water line to a depth, generally 600 ft (200 m), where the Continental Shelf joins the Continental Slope (slope between Continental Shelf and deep ocean).
Copepods	Diverse group of small planktonic crustaceans representing an important component of oceanic food chains.
Coriolis Effect	Force due to the Earth's rotation, capable of generating currents. It causes moving bodies to be deflected to the right in the northern hemisphere and to the left in the southern hemisphere.

Corps	United States Army Corps of Engineers (USACE).
Cost-Benefit Ratio	Comparison of the price, disadvantages and liabilities of any project versus profit and advantages.
Creek	A stream, less predominant than a river, generally a tributary to a river.
Critical Habitat	Specific geographic areas, whether occupied by a listed species or not, that are essential for the conservation of the listed species and that have been formally designated by rule published in the Federal Register.
Cross-shore	Perpendicular to the shoreline.
Crustacean	An animal belonging to a class of organisms (Crustacea) that have a exoskeleton and jointed legs and body; includes crabs, lobster, amphipods, and shrimp.
Cumulative Effects (Impacts)	Incremental impact of a project when added to other past, present, or reasonably foreseeable future projects and can be the result of direct and/or indirect impacts.
Currents	Coherent horizontal movement of water.
Cutterhead Dredge	A hydraulic suction pipeline dredge with a rotating cutterhead attached to a suction intake to mechanically assist in the excavation of bottom sediments. Dredge material is hydraulically pumped as a slurry to a receiver site through a pipeline.
Debris Line	A line near the limit of storm wave uprush marking the landward limit of debris deposits.
Degrade	Degradation, as defined by the SWRCB, is determined by comparison of the waste field and reference site(s) for characteristic species diversity, population density, contamination, growth anomalies, debility, or supplanting of normal species by undesirable plant and animal species. Degradation occurs if there are significant. differences in any of three major biotic groups, namely, demersal fish, benthic invertebrates, or attached algae. Other groups may be evaluated where benthic species are not affected, or are not the only ones affected.
Demersal	Living on or near the bottom of the sea.
Density	1. A measure of how heavy a specific volume of a solid, liquid, or gas is in comparison to water. 2. Abundance of an organism per unit area.

Depth	The vertical distance from still-water level (or datum as specified) to the bottom.
Deposition	The laying down of material by erosion or transport and settling in water or air.
Detritus	Fine, disaggregated particles of inorganic and organic material (i.e. dead plant and animal matter), either in suspension or settled on the bottom of a water body. Forms the basis of an extensive food web in the ocean.
Detritivore	Animals that feed on detritus; also called deposit-feeders.
Diatom	Any of a class (Bacillariophyceae) of minute planktonic unicellular or colonial algae with a cell wall of overlapping silica plates.
Dike	Earth structure along sea or river to protect lands from flooding by high water; dikes along rivers are sometimes called levees.
Dinoflagellates	Important plantlike elements of plankton having two flagella. Some species are responsible for red-tides.
Direction of Current	Direction toward which current is flowing.
Direction of Waves	Direction from which waves are coming.
Direction of Wind	Direction from which wind is blowing.
Direct Effect (Impact)	Impacts that occur at the same time and within the same boundaries that are physically disturbed by the project.
Discharge Plume	The region of water affected by the discharge of waste which can be distinguished from the surrounding water.
Dispersion	The dissemination of discharged matter over large areas by natural processes; e.g., currents.
Dissolved Oxygen (DO)	The oxygen freely available in water. Dissolved oxygen levels are considered an important indicator of a water body's ability to support desirable aquatic life.
Diversity	1. The absolute number of species in an assemblage, community, or sample. 2. A measure of the number of species and their relative abundance.
Dominant Species	A species or group of species, which because of their abundance, size, or control of energy flow, strongly affect a community.
Downdrift	Movement of waters downstream.
Downstream	Waters downstream with respect to ocean or river currents.

Downwelling	Areas where waters sink; flows typically seaward near the seabed (downslope in the regional shelf-wide sense), and commonly accompanied by shoreward flows near the surface. Generally, southern winds push offshore waters towards the shore, moving nearshore surface waters downward and causing offshore waters to be warmer and of lower salinity than is typical.
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Dormant	Unexercised, not active, but capable of being exercised.
Dredge Entrainment	To remove water and associated animals during dredging.
Dredged Material	Any material excavated or dredged from the navigable waters of the United States, including material otherwise referred to as "spoil".
Dredging	Removal of sediment from the bottom of water bodies. This can impact the ecosystem. Dredging activities are regulated under state and federal laws.
Drying Beach	That part of beach uncovered by water (e.g., at low tide). Sometimes referred to as the subaerial beach.
Drought Conditions	Hydrologic conditions during a defined period when rainfall and runoff are much less than average.
Dunes	Accumulation of windblown sand beyond the backshore, usually in the form of small hills or ridges; may be stabilized by vegetation.
Dune Placement (Beach Nourishment)	Addition of sand above the water line as a stockpile for beach nourishment and/or to provide shoreline protection.
Ebb Current, Ebb Tide	Tidal current moving away from land or down a tidal stream.
Echinoderm	An invertebrate with radial symmetry and belonging to the phylum Echinodermata. Includes sand' dollars, sea cucumbers, starfish and sea urchins.
Ecosystem	A dynamic and interrelating complex of plant and animal communities and their associated nonliving (such as physical and chemical) environment.
Ecosystem Approach	A philosophy of resource management that focuses on protecting or restoring the function, structure, and species composition of an ecosystem, recognizing that all components are interrelated.
Eddy	A circular mass of water within a large water mass that is usually formed where currents pass obstructions, either between two adjacent currents flowing counter to each other, or along the edge of a permanent current.

Effluent	Generally, refers to wastes discharged into surface waters.
Effluent Limitation	Restrictions established by the State Water Resources Control Board, Regional Water Quality Control Boards, and/or U.S. Environmental Protection Agency on quantities, rates, and concentrations in wastewater discharges.
Ekman Transport	Resultant flow at right angles to and to the right of the wind direction (in the northern hemisphere), producing upwelling and downwelling.
El Niño	Global-scale climatic variations with a duration lasting approximately 2 to 7 years characterized by a decrease in atmospheric pressure in the eastern tropical Pacific Ocean, a decrease in the easterly trade winds, and an increase in sea level on the west coast of North and South America. The atmospheric disturbances associated with these events may cause abnormally warm water temperatures, reversal of westerly trade winds, increased sea levels, more vigorous winter storms with higher than average wave heights.
Embayment	Any recess from open coastline including mouths of creeks, esteros, estuaries, lagoons, rivers, sloughs, streams, harbors and coastal wetlands under tidal influence.
Enclosed Bays	Indentations along the coast which enclose an area of oceanic water within distinct headlands or harbor works. Enclosed bays include all bays where the narrowest distance between headlands or outermost harbor works is less than 75 percent of the greatest dimension of the enclosed portion of the bay. This definition includes but is not limited to: Humboldt Bay, Bodega Harbor, Tomales Bay, Drakes Estero, San Francisco Bay, Morro Bay, Los Angeles Harbor, Upper and Lower Newport Bay, Mission Bay, and San Diego Bay.
Endangered Species	Under the state or federal Endangered Species Acts, animal or plant species in danger of extinction throughout all or a significant portion of its range.
Endemic Species	A species native and confined to a certain region; generally used for species with comparatively restricted distribution.
Enterococcus	Any of a genus of non-motile, usually parasitic, gram-positive bacteria occurring in the intestine that divide only in one plane and which occur in pairs or chains.
Entrance	The entrance to a navigable bay, harbor, or channel, inlet or mouth separating the ocean from an inland body of water.
Environment	The sum of all external conditions affecting the life, development, and survival of an organism.

Environmental Impact Report (EIR)
A document required by the 1970 California Environmental Quality Act (CEQA) that assesses the environmental effects of a project.

Environmental Impact Statement (EIS)
A document required by the 1969 National Environmental Policy Act (NEPA) that analyzes the effects of major federal projects on the environment.

Epibiota — Organisms living on the surface of the seafloor.

Epifauna — Benthic animal living on the seafloor.

Equatorward — Southerly current and/or wind direction, towards the equator.

Erosion — The process in which a material is worn away by precipitation, a stream of water, winds, and/or waves. A volumetric measure of the amount of sand removed from a beach by waves, currents, or other processes.

Erosion Hot Spots — Areas of coastline where beach erosion is substantial and characterized by sea cliff notching, bluff collapse, and/or damage to roads and structures from waves and/or storm waves.

Essential Fish Habitat — Fishery management plans (FMPs) identify as essential fish habitat (EFH) those areas that are necessary to fish for their basic life functions. EFH is defined as "... those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." "Waters" include aquatic areas and their associated physical, chemical, and biological properties that are used by fish. "Substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities. "Necessary" means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle. California has three FMPs for: Pacific coast groundfish, commercial and recreational west coast salmon fisheries, and northern anchovy/coastal pelagics.

Estuary — A semi-enclosed body of water which has a free connection to the sea, commonly the lower end of a river, and within which the mixing of saline and fresh water occurs.

Eutrophication — The process whereby the concentration of nutrients in rivers, estuaries, and other bodies of water increases and results in anaerobic (lack of oxygen) conditions in the water column. The increase of nutrients stimulates algal "blooms" and as the algae decays and dies the availability of dissolved oxygen is reduced resulting in high BOD; as a result, creatures living in the water accustomed to aerobic conditions may perish.

Evolutionarily Significant Unit (ESU)
A Pacific salmonid stock that is substantially reproductively isolated from other stocks of the same species and which represents an important part of the evolutionary legacy of the species. Life history, ecological, genetic, and other information can be used to determine whether a stock meets these two criteria. NOAA Fisheries uses this designation.

Fauna — The animal life of a community, habitat, or ecosystem.

Fecal Coliform — A class of bacteria which are found in the intestinal tracts of mammals, including man.

Federal Register — The official daily publication for actions taken by the Federal government, such as Rules, Proposed Rules, and Notices of Federal agencies and organizations, as well as Executive Orders and other Presidential Documents.

Feeder Beach — An artificially widened beach serving to nourish downdrift beaches by natural littoral currents or other forces.

Filter-feeder — Animal that feeds (by filtering from water) on plankton and suspended particulate matter.

Fine Grained Materials (Fines = Silts/Clays)
Clays and silts, passing the #200 sieve or less than 0.074 millimeters in diameter.

Finfish — Term used to distinguish fish with fins from shellfish, usually in reference to commercially important species.

Flocculation — The process of aggregating a number of small, suspended particles into larger masses.

Flora The plant life of a community, habitat, or ecosystem.

Flood Current, Flood Tide
Tidal current moving toward land or up a tidal stream.

Food web — A description of the interdependence of the organisms of a community, based on who eats whom.

Foredune — Coastal dunes (vegetated and unvegetated) behind the backshore of the beach.

Foreshore — The beach between MHHW and MLLW (NOAA 2001a, USACE 2003); beach usually covered by the surf zone and its swash, extending from the surf breakpoint-bar to the berm crest (Shepard 1963, Inman and Masters 2003).

Formal Consultation	The required process under section 7 of the Endangered Species Act between USFWS or NMFS and a federal agency or applicant to determine whether the proposed action is likely to jeopardize the continued existence of a listed species or adversely modify critical habitat. This determination is stated in a Biological Opinion.
Gastropods	Mollusks that possess a distinct head, broad flat foot, and shell (e.g., snails).
Grab Sample	A single sample of water or sediment collected at a particular time and place.
Gradient	A change in value per unit distance.
Groin	A small jetty extending from the shore to prevent beach erosion.
Gyre	Generally circular, large-scale ocean flow patterns.
Habitat	A physical area characterized by a unique assemblage of species that constitute the biotic community that utilizes and/or inhabits the area and which provides some subset of essential or preferred ecological and biological needs (i.e., reproduction, feeding/foraging, cover/shelter) for each of those species.
Habitat Indicator	A physical attribute of the environment measured to characterize conditions necessary to support an organism, population, or community in the absence of pollutants (e.g., salinity, substrate).
Harass	Intentionally or negligently, through act or omission, create the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavior patterns such as breeding, feeding, and sheltering.
Harbor	A water area nearly surrounded by land, seawalls, breakwaters, or artificial dikes and forming a safe anchorage for ships.
Harm	To perform an act that kills or injures wildlife by significantly impairing essential behavioral patterns including breeding, feeding, or sheltering; may also include significant habitat modification or degradation.
Herbivore	An animal that mainly feeds on plants.
High Water Line	The intersection of mean high water with the shore.
Historic Range	Geographic area where a species was known to or believed to occur within historic time.
Hopper Dredge	Seagoing vessel that trails a hydraulic suction line and drag head for removal of bottom sediments.

Ichthyoplankton	Larval fish and eggs of the plankton community.
Impaired Water Body	Water body listed by the SWRCB as impaired by one or more pollutants of concern.
Indicator Species	An organism or ecological community associated with particular environmental conditions that its presence is indicative of the existence of these conditions.
Indigenous	Native; from a particular region or local ecosystem.
Indirect Effect (Impact)	An effect caused by a proposed action that takes place later in time than the action, but is still reasonably certain to occur.
Infauna	Collectively the invertebrates that live in, beneath, and just at the surface of soft sediments.
Informal Consultation	An optional process that includes all discussions, correspondence, etc., between USFWS or NMFS and the federal agency or project applicant regarding potential impacts to federally listed endangered and/or threatened species or critical habitat prior to formal consultation, if required.
Initial Dilution	Process which results in turbulent mixing of wastewater with ocean water around the point of discharge. Initial dilution is considered complete when the momentum induced velocity of the discharge ceases to produce significant mixing of the waste, or the diluting plume reaches a fixed distance from the discharge as specified by the RWQCB.
Inlet	A narrow strip of water connecting a stream or smaller water body with the ocean.
Inshore	Zone extending from low water line through the breaker zone.
in Situ	In the original or natural setting; in the environment.
Intertidal Habitat	The tidal area ranging from the splash zone to area exposed during minus tides; near to slightly above EHW to ELW.
Invertebrate	Animals lacking a backbone or internal skeleton.
Jetty	A structure extending into a body of water to direct and confine the stream or tidal flow to a selected channel; jetties are built at mouth of a river or entrance to a bay to help deepen and stabilize a channel.
Kelp Beds	Significant aggregations of marine algae of the genera *Macrocystis* and *Nereocystis*. Kelp beds include the total foliage canopy of *Macrocystis* and *Nereocystis* plants throughout the water column.

Lagoon	Shallow body of water usually with small entrance to the sea; often between a barrier and the mainland.
Landslide	General term for downslope slippage of land surface.
Larva	A young or juvenile stage (of some species) which differs in basic body form from that of the adult; the plural is larvae.
LC 50	Lethal concentration resulting in 50% mortality of organisms during an experimental test.
Lead Agency	An agency from among two or more agencies involved in a proposed project that is assigned lead responsibility for environmental documentation, agency coordination, and/or consultation.
Less-than-Optimum Beach Fill Material	Material that is not compatible with the dry beach but is compatible with material within the nearshore portion of the receiver site. This has been defined for the SCOUP program as being within 10% of that of the existing nearshore sediments that exist along a profile. For example, if the percent fines of the nearshore portion of a beach profile range from 5% to 35% fines, then the Less- than-Optimum Beach Fill Material may be defined as between 15% and 45% fines.
Light Attenuation	Reduced light transmission through water. The greater the attenuation of light, the lower the water clarity.
Listed Species	A species, subspecies, or distinct population segment that has been added to the federal list of endangered and threatened wildlife and plants.
Littoral	Pertaining to the beach or seashore, especially the region between tide lines.
Littoral Cell	Coastal compartment that contains a complete cycle of sedimentation including sources, transport paths, and sinks. A reach of shoreline in which all sediment transport processes are related. In theory, it has zero alongshore sediment flow past its updrift and downdrift boundaries. It may contain several sand sources and sinks.
Littoral Drift	Sediment that is moved in the surf zone, parallel to the shoreline by the longshore current.
Littoral Transport	The movement of littoral drift in the littoral zone by waves and currents.

Littoral Zone	A strip of land along the shoreline between the high and low water levels.
Longshore Bar	A sand ridge or ridges, extending along the shore outside the trough, that may be exposed at low tide or may occur below the water level in the offshore.
Longshore Currents	Transport of surf zone water parallel to shore and driven by breaking waves.
Longshore Trough	An elongate depression or series of depressions extending along the lower beach or in the offshore zone inside the breakers.
Low Tide Terrace	A flat zone of beach near the low water level.
Maintenance Dredging	Periodic dredging of a waterway, necessary for continued navigational use of waterway.
Managed Retreat	The deliberate setting back of the existing line of defense in order to obtain engineering and/or environmental advantages.
Mariculture	Culture of plants and animals in marine waters independent of any pollution source.
Marsh	A common term applied to describe treeless wetlands characterized by shallow water and abundant emergent, floating, and submergent wetland flora.
Mean High Water (MHW)	Arithmetic mean of all sea surface high water heights observed over a 19.7 year interval (National Tidal Datum Epoch).
Mean Low Water (MLW)	The average height of the low waters over 19-year period.
Mean Sea Level (MSL)	Arithmetic mean of hourly sea surface heights observed over a 19.7 year interval (National Tidal Datum Epoch).
Meroplankton	Planktonic eggs and larvae of invertebrates and fish.
Metabolism	The sum total of all chemical processes which go on in an organism and give it life.
Migration	1. Movement of a substance from one place to another through natural processes; 2. Movement of a bank, shoreline, bar, or other geomorphic feature over time; 3. Movement of fish and wildlife between breeding and non-breeding areas.
Mitigate	To make less severe.
Mixed Layer	Upper layer of ocean which is well mixed by wind and wave activity.

Mixing Zone	A limited volume of receiving water that is allocated for diluting a wastewater discharge without causing adverse effects to the overall water body.
Mollusc(k)	An invertebrate animal which belongs to the phylum Mollusca and which has an unsegmented body and usually with a hard outer shell. Includes clams, mussels, snails, chitons, squid, and nudibranchs.
Monitoring	Systematic collection of physical, biological, or economic data or a combination of these data in order to make decisions regarding project environmental effects, operation, or performance.
Mud Flat	A muddy, low-lying strip of ground by the shore.
National Geodetic Vertical Datum	Equivalent to Mean Sea Level, 1929.
National Environmental Quality Act (NEPA)	The established federal policy of environmental protection, maintenance, and enhancement.
National Pollutant Discharge Elimination System (NPDES)	Standards for waste discharges from point sources to surface waters (rivers, lakes, bays, oceans, etc.) controlled by state or federal agencies under provisions of Clean Water Act.
Natural Light	Ambient light conditions.
Neap Tide	Tide of decreased range occurring semimonthly as the result of the moon being in quadrature.
Nearshore	Wave and current dominated zone extending from where wave shoaling begins to the landward limit of storm-wave influence. The seafloor between the closure depth (typically near -30 feet MLLW) and Mean Lower Low Water (MLLW).
Nearshore Placement (Beach Nourishment)	Addition of sand to the submerged portion of the beach.
Nekton	Free-swimming aquatic animals, independent of wave and current action.
Nematode	Elongated cylindrical worms (round worms) of the phylum Nematoda parasitic in animals or plants or free-living in soil sediments or water.
Nephelometer	Instrument used to provide a relative measure of turbidity based on measurement of side scattering of light at angles centered on 900 to the incident light beam and calibrated to a standard (formazin).

Neritic	Relating to the region of shallow water (over the Continental Shelf) adjoining the seacoast.
Nitrate	Ion containing nitrogen and oxygen; its excess in water will stimulate the growth of algae.
Non-Degradation	An environmental policy that does not allow any lowering of naturally occurring water quality regardless of pre-established health standards.
Non-point Sources	Diffuse pollution sources that are not subject to NPDES permitting. The pollutants are generally carried off the land by runoff. Common non-point sources are agriculture, forestry, mining, dams, channels, and saltwater intrusion.
Northern California	Area of coastline between California/Oregon border and San Mateo County.
Nourishment	The process of replenishing a beach.
Nuisance	Defined by RWQCBs as anything that meets all of the following requirements: (1) Is injurious to health, or is indecent or offensive to the senses, or an obstruction to the free use of property, so as to interfere with the comfortable enjoyment of life or property; (2) Affects at the same time an entire community or neighborhood, or any considerable number of persons, although the extent of the annoyance or damage inflicted upon individuals may be unequal; and (3) Occurs during or as a result of the treatment or disposal of waste.
Nutrient	Any substance assimilated by living things that promotes growth. The term generally applies to nitrogen and phosphorus, but also applies to other essential and trace elements. Excess nutrients in surface waters stimulate plant and algae growth.
Oceanography	The science of the oceans, their forms, physical features and phenomena.
Ocean Plan	The water quality control plan for California's near-coastal waters, first adopted by the State Water Resources Control Board in 1972 (see Water Quality Control Plan).
Ocean Waters	California ocean waters are defined by law as territorial marine waters outside of enclosed bays, estuaries, and coastal lagoons. Discharges may be regulated to assure no violation of the Ocean Plan will occur in ocean waters.
Offshore	That part of the ocean bottom below the depth of closure.
Oil spill	An accidental or intentional discharge of oil that reaches bodies of water.

Omnivore	A consumer that eats many types of foods, including both plants and animals.
Opportunistic sand	Surplus sand from various source materials, including inland construction and development projects in the region, dredging of harbors or wetlands, etc.
Optimal Beach Fill Material	Material compatible with the dry beach portion of the beach profile. This was defined for the SCOUP program as having a fines fraction within 10% of that of the existing dry beach sediments. For example, if the dry beach fine content ranges from 0% to 5% fines, the Optimum Beach -Fill Material may be defined as having up to 15% fines.
Organism	Any form of animal or plant life.
Parameter	Values or physical properties that describe the characteristics or behavior of a set of variables.
Partnership	An informal or formal effort by two or more partners to achieve a shared objective or complete a project.
Pelagic	Of, in, or pertaining to the water column as opposed to the bottom of the ocean.
Permit	Permits enable the public to engage in legitimate activities that would otherwise be prohibited by law.
Perturbation	Any disturbance or departure from an assumed steady state of a system.
pH	A measure of the intensity of the basic or acidic condition of a liquid. It may range from 0 to 14, where 0 is the most acidic and 7 is neutral. Natural waters usually have a pH between 6.5 and 8.5.
Photic Zone	Area of water column that receives sufficient sunlight to support photosynthesis.
Phytoplankton	Microscopic plants, including blue-green algae, dinoflagellates, and diatoms, that are part of the plankton community.
Pinnipeds	A seal or sea lion.
Plankton	Small (microscopic) plants and animals that occur in the water column and are unable to maintain their distribution against the movement of water masses.
Plankton Bloom	A relatively high concentration of phytoplankton in a body of water resulting from rapid proliferation during a time of favorable

growing conditions generated by nutrient and sunlight availability; may result in toxic red-tides.

Plume — Patch of turbid water caused by the suspension of fine particles.

Pocket beach — Small, narrow beach between rocky headlands where sand sources are the surrounding cliffs and occasionally leakage around the adjacent shoreline.

Point source — A discharge point subject to the Clean Water Act's NPDES program; a point source is any discernible, confined, and discrete conveyance of discharge, including but not limited to, any pipe, ditch, channel, tunnel, conduit, and well.

Poleward — Northerly current and/or wind direction, towards the north pole.

Pollutant — Some substance present in an environment at unnatural concentrations or levels. Any agent that may cause or contribute to the degradation of beneficial uses of waters (also see contaminant).

Polychaete — An annelid worm of the class Polychaeta; these are found only in the ocean.

Primary Consumer — Animals that eat plants.

Primary Productivity — Amount of organic matter synthesized by producer organisms (mainly plants, phytoplankton) from inorganic substances per unit time and volume of water.

Profile Placement (Beach Nourishment)
Addition of sand throughout the dry and submerged portion of the beach.

Protozoans — Mostly microscopic, single-celled animals which playa major role in recycling of nutrients and constitute one of the largest populations in the ocean.

Qualitative — Pertaining to the non-numerical assessment of a parameter.

Quantitative — Pertaining to the numerical measurement of a parameter.

Range — The geographic area a species is known to or believed to occupy.

Reasonable and Prudent Measure (RPM)
An action that USFWS or NMFS believes necessary or appropriate to minimize the impacts (the amount or extent) of incidental take caused by an action that was subject to consultation.

Receiver Site	The location of placement of sediment during beach nourishment.
Receiving Waters	A river, lake, ocean, stream or other watercourse that receives discharged materials and/or substances.
Recovery	The process by which the decline of an endangered or threatened species is stopped, reversed, or threats to its survival neutralized so that its long-term survival in the wild can be ensured, and it can be removed from the list of threatened and endangered species.
Recovery Plan	A document drafted by USFWS, NMFS, or other knowledgeable individual or group, that serves as a guide for activities to be undertaken by federal, state, or private entities in helping to recover and conserve endangered or threatened species.
Recruitment	Addition to a population of organisms by reproduction or immigration of new individuals.
Red Tide	(see plankton bloom)
Reef	A ridge of rock or other material lying below the surface of the sea.
Regional Water Quality Control Boards (RWQCBs)	The nine Regional Boards located throughout California are defined by watersheds, and are responsible for enforcing water quality standards within their boundaries. Coastal regions include: Region 1, North Coast Regional Water Quality Control Board, located in Santa Rosa; . Region 2, San Francisco Bay Regional Water Quality Control Board, located in Oakland; Region 3, Central Coast Regional Water Quality Control Board, located in San Luis Obispo; Region 4, Los Angeles Regional Water Quality Control Board, located in Los Angeles; Region 8, Santa Ana Regional Water Quality Control Board, located in Riverside; Region 9, San Diego Regional Water Quality Control Board, located in San Diego.
Respiration	The collective metabolic processes by which an organism converts stored chemical energy into physical energy; involves the use of oxygen and the production of carbon dioxide.
Return Flow	Surface water that returns to the natural environment after diversion.
Revetment	A facing of stone and/or concrete to protect an embankment or shore structure against erosion by wave action or currents.
Rip Current	Relatively narrow currents that flow seaward through the breaker zone; seaward return flow from longshore currents.
Riprap	Large rocks placed along the shore to prevent erosion of a structure, building, or embankment.

River	A natural stream of water larger than a creek.
Runoff	Water in excess of what can infiltrate the soil surface on land and that enters the ocean, rivers, streams, and/or lakes directly or indirectly from storm drains.
Runup	Maximum vertical height attained by uprush of the swash on the beach or structure.
Salinity	The standard measure of the "saltiness" of seawater; measured as the weight of salts (primarily sodium chloride) per unit of water and usually expressed as parts per thousand.
Saltation	Term use to describe movement of particle being transported by wind or water which is too heavy to remain in suspension.
Sand Bar	(See Bar)
Sand Backpassing	Transfer of sand from a wide stable beach to an upcoast sediment-starved beach.
Sand Bypassing	Transfer of sand along the shore around a barrier such as a jettied harbor entrance or inlet.
Sand Dune	(see Dune)
Sand Placement	Process of placing sand on the dry and/or aquatic portion of the beach (see beach nourishment, beach placement, nearshore placement, profile placement).
Sand Source	A resource of appropriate sand that can be economically used for beach nourishment. The sand must meet requirements for grain-size distribution and cleanliness, and its removal and transfer must not create unacceptable environmental effects. The source may be on land, offshore, estuary, navigational channel, shoal, or other area in which sand accumulates.
Scientific Name	A formal Latin or latinized name applied to a taxonomic group of animals or plants. A species' scientific name is a two-part combination consisting of the genus followed by the species. The printed name generally is italicized or underlined.
SCOUP Program	Sand Compatibility and Opportunistic Use Program (SCOUP). http:///dbw.ca.gov/CSMW/scoup.htm
Sea Cave	Cleft or cavity in a sea cliff, excavated where wave action has enlarged natural lines of weakness in weathered rock.
Sea Cliff	Cliff situated at the seaward edge of the coast.

Sea Cliff Notch	Cut or hollow along base of sea cliff formed by wave erosion undercutting.
Seawall	A structure built along a portion of ta coast primarily to prevent erosion and other damage by wave action.
Secchi Depth	Index of visual water clarity measured with a Secchi disc; i.e., depth of visual disappearance of a Secchi disc when lowered in water.
Secchi Disk (disc)	A white or black-and-white disk that is lowered into water on a scaled line until the image is judged to disappear from view; used to measure visual water clarity.
Secondary Consumer	Animals that eat other animals, particularly primary consumers.
Sedimentation	Direct or indirect addition of sediment to a habitat. Natural sources of sedimentation may result from watershed runoff, landslides, and/or settling of turbid water after high wave and/or storm conditions. Sedimentation from sediment management activities may result from sediment movement by currents and waves after placement and/or the settling of turbid plumes during and shortly after dredging and/or discharge.
Sediment Sink	A point or area at which beach material is lost from a coastal cell, such as an estuary, deep channel, and/or submarine canyon.
Sediment Source	A point or area on a coast from which beach material arises, such as an eroding cliff or river mouth.
Semidiurnal Tide	Tides occurring twice daily; two high and two lows per tidal day.
Sessile	Permanently attached; not free to move about.
Settleable Solids	Material heavy enough to sink to the bottom in a water body.
Shellfish	Mollusks (such as oysters, clams, and abalone) and crustaceans (such as crab and lobster) that have a hard outer shell or exoskeleton and are of sport or commercial interest.
Shoreface	Narrow zone seaward from the low tide shoreline permanently covered by water, over which the beach sands and gravels actively oscillate with changing wave conditions.
Shoreline Management	The development of a strategic, long-term and sustainable coastal defense and land-use policy within a sediment cell.
Shoreline Protection	Structures or sand placed at or on the shore to reduce or eliminate upland damage from wave action or flooding during storms.

Significant	Statistically, as defined by the SWRCB, is the significant difference in the means of two distributions of sampling results at the 95 percent confidence level.
Silt	Sediment particles with a grain size between 0.004 and 0.062 mm.
Slough	A tidal inlet and adjacent marshy area.
Slurry	A watery mixture of insoluble matter (e.g., sediment) that is produced to facilitate discharge.
Southern California	Area of coastline between Point Conception and the U.S./Mexico border.
Species	A group of morphologically similar organisms capable of interbreeding and producing fertile offspring.
Species of Concern	An informal term referring to a species that might be in need of conservation action. This may range from a need for periodic monitoring of populations and threats to the species and its habitat, to the necessity for listing as threatened or endangered. Such species receive no legal protection and use of the term does not necessarily imply that a species will eventually be proposed for listing.
Spit	A fingerlike extension of the beach.
Spring Tide	Perigean spring tide produced when the earth and moon are in close proximity and the moon is either new or full.
Stakeholder	Any person or organization who has an interest in the actions discussed or is affected by the resulting outcomes of a project or action.
Standing Stock	The abundance or biomass of living material per unit volume of water or area of sea-bottom.
Storm Surge	A rise or piling-up of water against shore, produced by strong winds blowing onshore.
Stormwater	Urban runoff consisting only of those discharges that originate from a precipitation event.
Strand	The shore or beach of the ocean.
Stratified	Occurring in distinct layers. In the ocean, where the layers are of different densities, the boundary is called a pycnocline. If the difference is in temperature, the sharp difference, the pycnocline, is also a thermocline; if in salinity, it is also a halocline.

Subaerial Beach	Area of beach exposed to air, which may be divided into two zones. The uppermost supralittoral (dry) beach lies landward of mean high water. The intertidal zone is located between mean high water and mean low water.
Subarerial Erosion	Natural processes of wearing down the land surface.
Submarine Canyon	Valley-like feature of the sea floor often heading near the coast and extending down the slopes.
Substrate	The base or material on which an organism lives or to which it is attached.
Subtidal Beach	The portion of the beach between mean low water and the depth of closure.
Subtidal Habitat	The area below mean lower low water (MLLW) which is covered by water most of the time.
Surf Zone	The nearshore zone along which the waves become breakers as they approach the shore.
Suspended Loads	Specific sediment particles maintained in the water column by turbulence and carried with the flow of water.
Suspended Sediments	Individual sediment particles that cause turbidity (also see suspended solids).
Suspended Solids	Small solid particles (sediments and other particulates) in water that cause turbidity. Settlement rates relate to particle size and density, although turbulent flow may counteract gravitational settling.
Suspension Feeder	Animal that feeds on plankton and particulate matter in the water column.
Swash	Area of wave run-up on the beach.
Talus	Rock fragments derived from and lying at the base of a cliff or very steep, rocky slope.
Take	To harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct; may include significant habitat modification or degradation if it kills or injures wildlife by significantly impairing essential behavioral patterns including breeding, feeding, or sheltering.
Terms and Conditions	Required actions described in an Incidental Take Permit under section 10 or Incidental Take Statement intended to implement the Reasonable and Prudent Measures under section 7 of the ESA.

Thermal Plan	Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California, last amended by the State Board in 1975.
Threatened Species	Under the state or federal Endangered Species Acts, animal and plant populations may be determined to be threatened, which are at risk of becoming endangered throughout all or a significant portion of its range. Populations listed as threatened are less severely depleted than populations classed as endangered.
Tidal Prism	The total volume of water passing in and out of a particular area, such as a lagoon or salt marsh during a tidal cycle.
Tide	Periodic rising and falling of the water that results from gravitational attraction of the moon and sun acting upon the rotating earth.
Tidepool	A pool of water remaining on a beach or reef after recession of the tide.
Trace Metal	Metallic elements such as cadmium, chromium, lead, nickel, silver, and zinc which occur naturally in "trace" amounts in ocean water.
Trophic Levels	Discrete steps in food chain in which energy is transferred from the primary producers (plants) to herbivores, carnivores and/or omnivores, and finally decomposers.
Transmissivity, Transmittance	Measurement of light transmission through water.
Transmissometer	See beam transmissometer.
Tsunami	A large, high velocity wave generated by displacement of the sea floor (such as sudden faulting, landsliding, or volcanic activity).
Turbidity	Cloudy appearance of water as a result of fine suspended sediments.
Updrift	Upstream waters; i.e., location in opposite direction of current flow.
Upstream	Waters upstream with respect to ocean or river currents.
Upwelling	Areas where cold, nutrient-rich deep water flows shoreward to the surface to replace surface water pushed seaward by seasonal winds. Generally, northern winds move nearshore waters offshore and deep, nutrient-rich water rises to replace the displaced water.
Urban Runoff	Storm water from city streets and adjacent domestic or

commercial properties that carries pollutants of various kinds into the sewer systems and receiving waters.

Waste Discharge Requirements (WDR)
The order adopted by the regional boards that regulates discharges of waste to surface water and discharges of waste to land. WDRs are often synonymous with regional board 401 certification conditions or "permits."

Water column — Area of water between the surface and bottom of a water body.

Watershed — The geographical area which drains to a specified point on a water course, usually a confluence of streams or rivers (also known as a drainage area).

Water Quality Control Plan (Basin Plan)
Each Regional Board establishes the beneficial uses of the waters within the region. The plan contains numeric and/or narrative water quality objectives and spells out a program by which the objectives can be achieved within their boundaries.

Water Quality Criteria — Numerical or narrative limits for constituents or characteristics of water designed to protect specific designated uses of the water. When criteria are met, water quality will generally protect the designated use [40 CFR Section 131(b)]. This term also is used to describe scientific information on the relationship that the effect of a constituent concentration has on human health, aquatic life, or other uses of water, such as the criteria in the USEPA "Gold Book". California's water quality criteria are called "water quality objectives."

Water Quality Objectives — Numerical or narrative limits on constituents or characteristics of water designed to protect designated beneficial uses of the water. California's water quality objectives are established by the State and Regional Water Boards in the Water Quality Control Plans.

Water Quality Standards — Provisions of state or federal law which consist of a designated use or uses for waters of the United States and water quality criteria for such waters based upon such uses. water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the Act [40 CFR Section 131.3(i)]. A water quality standard under the Federal Clean Water Act is equivalent to a beneficial use designation plus a water quality objective. In California, wataer quality standards are promulgated by the state and Regional Water Boards in Water Quality Control Plans. Water quality standards are enforceable limits for the bodies of surface or ground waters for which they are established.

Wave-cut Platform — Flat, gently sloping underwater erosional surface extending seaward from a sea cliff. The platform is part of the wave-

	cut terrace and is caused by abrasion in and near the surf zone.
Wave-cut Terrace	A platform formed just below sea level by the cutting by the waves.
Wave wash	The erosive action on shores or embankments caused by the lapping or breaking of waves.
Wetlands	An area that is saturated by surface or ground water with vegetation adapted for life under those soil conditions, as swamps, bogs, fens, marshes, and estuaries.
Zooplankton	Weakly swimming microscopic animals and larvae of invertebrates that are part of the plankton community.

Sources: Davis-Colley and Smith 2001, Keeton 1972, Kuhn and Shepard 1984, NRC 1995, Lincoln et al. 1988, Moffatt & Nichol 2005b, Nittrouer and Wright 1994, NOAA 2001a; Parsons and Takahashi 1975, Pennak 1964, Shaffer 2002, SWRCB 2001, USAGE 1988a, http://coastalchange.ucsd.edu/ur7_glossary/b.html, , http://www.swrcb.ca.gov/waterwords.html, http://www.csc.noaa.gov/text/glossary.html, http://www.nmfs.noaa.gov/habitat/habitatprotection/efh/index.htm

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1.0 INTRODUCTION

Section Topics

1.1 Purpose and Need
1.2 Study Questions
1.3 Goals and Objectives
1.4 Methodology
1.5 Report Organization

The California Resources Agency and U.S. Army Corps of Engineers (USACE) formed the California Coastal Sediment Management Workgroup (CSMW) to facilitate regional approaches to protecting, enhancing, and restoring California's coastal beaches and watersheds through federal, state, and local cooperative efforts. Other participants of the CSMW include the Department of Boating and Waterways (DBW), Department of Parks and Recreation (DPR), California Coastal Commission (CCC), State Lands Commission (SLC), State Coastal Conservancy (SCC), U.S. Geological Survey (USGS), Minerals Management Service (MMS), and CalCoast.

The CSMW is engaged in several related technical studies associated with the development of a Sediment Management Master Plan (SMP) for California. This report presents the results of the biological technical review undertaken in support of the development of the SMP.

1.1 Study Purpose

The CSMW conducted an initial assessment of issues and concerns associated with development of the SMMP and identified a need to better understand the actual effects of sediment management activities on coastal biota, particularly related to beach nourishment. Incomplete knowledge of impacts and a general lack of understanding about coastal ecosystems have led to a disparity in permit requirements regulating coastal sediment management projects in California. It was agreed by the CSMW that a more complete understanding and better scientific data are needed for policy-makers, the regulatory community, and project proponents to make informed decisions and recommendations. In response to this need, the purpose of this study is to:

- Summarize available information and prepare a balanced critical evaluation of potential and documented impacts to biological resources associated with sediment management activities,
- Summarize available information on California's coastal habitats and biological resources in a manner that contributes to an understanding of how sediment management activities may affect them (positively or negatively), and
- Develop science-based recommendations to address relevant concerns and facilitate sediment management activities without negatively impacting coastal biota, including consideration of ecosystem and/or species approaches to resource protection.

1.2 Study Questions

Gathered Information was reviewed and evaluated to answer several questions of interest to the CSMW. Questions cover a broad array of topics ranging from biological issue identification to the scientific basis of current environmental protection practices and concerns.

General study questions include:

- *What are the ways biological resources may be impacted by sediment management activities?*
- *What are the types of species, threatened and/or endangered species, and sensitive habitats/ecosystems that are potentially impacted by sediment management activities?*
- *What are the positive and negative effects of beach nourishment on species and/or ecosystems?*
- *Are documented concerns based on scientific data, uncertainty-based conservatism, or other information?*
- *What mitigation measures have been implemented and has the effectiveness of any of these mitigation measures ever been demonstrated?*
- *What is the appropriate level and type of pre- and post-project sampling needed to evaluate the project for significant changes?*
- *What are the areas where the information needed to make science-based decisions is sparse or unknown?*
- *How can potential impacts from sediment management activities to coastal biota and ecosystems be minimized in order to reduce concerns of the regulatory community and streamline permitting of sediment management activities?*

Evaluations associated with these general questions as well as other specific questions of interest to the CSMW are addressed in the following report sections. The compiled information is organized into technical sections, some of which summarize background information and others that provide more detailed review and evaluation of relevant impact topics. The review also identifies where information is sparse and/or lacking. Information gaps and how those gaps if filled could improve future sediment management planning decisions are discussed. In addition, recommendations are presented with respect to resource protection, environmental process related to impact evaluations, and activities to facilitate streamlining future sediment management activities with appropriate protection of California's coastal ecosystems and sensitive resources.

1.3 Study Goals and Objectives

The following goals and objectives guided the preparation of this document (Table 1.3-1). The goals focus on providing a document to meet multiple information uses. The objectives identify why and how information is reviewed and summarized to meet the study goals.

Table 1.3-1. Biological study goals and objectives.

Study Goals

- Serve as a reference document for future beach nourishment and related sediment management projects,
- Provide an educational tool for regulators, project proponents, and interested public,
- Provide a mechanism for dialog among stakeholders on potential impacts of sediment management activities on California's natural resources.

Study Objectives

- Organize relevant information for ease of reference.
- Accurately explain the basis of concern to biological resources from sediment management activities.
- Provide a balanced critical evaluation of concerns based on review of relevant available information.
- Identify information gaps that limit current understanding of impacts.
- Provide science-based recommendations to address critical information gaps.
- Provide recommendations for appropriate ways to protect California's resources during sediment management activities, based on current understanding of potential impacts.
- Provide recommendations to streamline permitting.

1.4 Methodology

The foundation of this study is a comprehensive review of available literature and reports associated with sediment management activities. Information was gathered from a variety of sources, including published literature, unpublished reports, regulatory permits, and coordination with resource and regulatory agency personnel.

Published literature was identified using key word searches of environmental databases at the libraries of the Scripps Institution of Oceanography and University of California, Irvine. Literature and reports also were identified from review of bibliographies in relevant acquired documents. Relevant unpublished documents and reports were identified from searches of the World Wide Web and downloaded, as available. Environmental Assessments (EAs), Environmental Impact Statements (EISs), and Environmental Impact Reports (EIRs) were obtained from lead and/or local sponsor agencies and/or environmental consulting firms.

Permits issued by the USACE, Regional Water Quality Control Board (RWQCB), and CCC for sediment management activities were obtained from agencies, applicants, and/or other sources. Monitoring reports and/or data also were obtained from coordination with the USACE, RWQCB, project applicants, and/or environmental consulting firms.

Several published and unpublished reviews of beach nourishment and dredging were consulted (Navqi and Pullen 1982, LaSalle et al. 1991, NRC 1985, NRC 1995, Newell et al. 1998, Greene 2002, Peterson and Bishop 2005, Speybroeck et al. 2006). In addition, topical reviews that address specific impact factors such as entrainment, sedimentation, and/or turbidity were important reference sources (e.g., O'Connor 1991, Hall 1994, Newell et al. 1998, Puckette 1998, Reine and Clarke 1998, Thackston and Palermo 2000, Wilber and Clarke 2001, Davies-Colley and Smitch 2001, Wilber and Clarke 2001, Airoldi 2003, Berry et al. 2003, Germano and Cary 2005, Wilber et al. 2005).

Numerous monitoring studies have been conducted with respect to sediment management activities, many of which have not been published. The scope of this effort was limited with respect to obtaining "grey" literature reports for studies conducted outside California; however, several documents were downloaded from internet websites and reviewed. Sometimes relevant information was identified in reviewed documents based on unpublished reports not obtained for this study. In that case, both the secondary and primary document sources are referenced using the following citation convention (e.g., Spadoni 1993 cited in NRC 1995). This method of citation was used to distinguish source information compiled by others from that directly reviewed.

Several documents and sources of information relevant to sediment management activities and California biological resources were accessed from the World Wide Web internet. Selected websites are listed for brevity in Table 1.4-1. Other useful website sources are identified by topic in text boxes throughout the document. In addition, literature citations at the end of the document identify additional internet sources.

Important local internet sources of information include the website of the CSMW, regional agencies involved with shoreline protection and beach nourishment issues (e.g., BEACON, SANDAG), and a variety of state and non-governmental agencies involved with resource management and/or education with respect to California biological resources.

Other state and federal agency websites provide a substantial source of information with respect to beach nourishment. Minerals Management Service (MMS) and the National Oceanographic and Atmospheric Association (NOAA) provide relevant information on shoreline erosion issues, sediment resources, monitoring, and/or coastal processes.

Local districts of the USACE (Los Angeles, Sacramento, San Francisco) provide several sources of relevant information for local sediment management projects. Technical reports and studies conducted by the USACE around the United States with respect to physical processes and environmental effects of dredging and disposal may be accessed according to the following programs: Dredging Operations and Environmental Research (DOER) program, Environmental Effects of Dredging Programs (EEDP), and Dredge Material Research Program (DMRP). Another source of information is the USACE Environmental Effects of Dredging & Disposal (E2-D2) literature database.

Table 1.4-1. List of useful information sources relevant to sediment management projects and California resources.

Selected Local Sources

- http://www.beacon.ca.gov/
- http://dbw.ca.gov/csmw/sedimentmasterplan.htm
- http://www.calcoast.org
- http://ceres.ca.gov
- http://cnps.web.aplus.net/cgi-bin/inv/inventory.cgi/
- http://www.coastal.ca.gov/
- http://coastalchange.ucsd.edu/
- http://www.dfg.ca.gov/mrd/nfmp/section2_chap3.html
- http://resources.ca.gov/copc/
- http://www.sandag.org/index.asp?subclassid=32&fuseaction=home.subclasshome
- http://www.spl.usace.army.mil/
- http://www.spn.usace.army.mil/
- http://www.swrcb.ca.gov/

Selected Other State Sources

- http://www.dep.state.fl.us/beaches/programs/bcherosn.htm
- http://www.dnr.state.md.us
- http://dcm2.enr.state.nc.us/sitemap.htm
- http://wdfw.wa.gov/hab/ahg/dredge.htm.

Selected National Sources

- http://el.erdc.usace.army.mil/dots/doer/ technote.html
- http://el.erdc.usace.army.mil/dots/eedptn. html
- http://el.erdc.usace.army.mil/elpubs/eedp. html
- http://el.erdc.usace.army.mil/e2d2/index.html
- http://www.csc.noaa.gov/beachnourishment/html/human/dialog/index.htm
- http://www.mms.gov/sandandgravelAggregatestudies.htm
- http://www.usgs.gov/state/coastal_offshore.asp

Selected International Sources

- http://www.beachmed.it/Home/tabid/52/Default.aspx
- http://www.cefas.co.uk/decode/ref.htm
- http://www.environment.sa.gov.au.
- http://www.eurosion.org/shoreline/index.html
- http://www.mwg.utvinternet.com/iss_mag_ extract.html
- http://www.snh.org.uk/publications/on-line/heritagemanagement/erosion/index.shtml
- http://www.ukmarinesac.org.uk/activities/ports/ph5_2.htm
- http://www.ukmarinesac.org.uk/publications.htm

A number of international websites were consulted from Australia, New Zealand, and Europe. Similar issues and challenges with respect to shoreline management and resource protection are being addressed in other areas of the world with relevance to California. Most of the reviewed information pertained to beach nourishment, dune restoration, and offshore aggregate mining issues.

1.5 Report Organization

Report organization, format, and habitats and species addressed in this document were coordinated with the CSMW technical advisory group consisting of resource and regulatory agency personnel and other resource managers. Two coordination meetings, including a workshop to discuss major study findings and recommendations were held with the advisory group.

The document is organized into ten sections starting with this introduction of the study purpose, goals, objectives, and general study questions evaluated in the document. Section 2 provides overviews of relevant background information to provide context for the detailed technical reviews that follow.

Sections 3 and 4 describe and summarize biological information for coastal habitats and special interest species, respectively. In addition, these sections review available literature and documents of reported responses of biological resources to sediment management activities and other relevant sources of disturbance. Those sections are organized in a systematic way to provide information that contributes to understanding of habitat and species vulnerabilities and/or tolerances to disturbance, reported responses to relevant impacts, known recovery rates, information gaps, and brief summaries of the scientific bases of concern relevant to sediment management activities conducted in association with beach nourishment.

Sections 5 through 7 provide integrated evaluations on topics of particular interest to the CSMW. Section 5 summarizes beneficial and adverse effects of beach nourishment on biological resources. Section 6 reviews impact significance criteria and mitigation measures associated with several California sediment management projects. Monitoring approaches are discussed in Section 7. Study recommendations are given in Section 8.

The preparers, agencies consulted during preparation of this document, and individuals that reviewed sections and/or the document in its entirety are listed in Section 9. References are given in Section 10.

Four appendices are included at the end of the document. Appendix A provides a list of consulted permits. Annotated summaries of reported impacts from sediment management activities are given in Appendix B. Water quality technical support information is presented in Appendix C, including summaries of water quality monitoring requirements in California, representative water quality monitoring data, and laboratory effects data associated with suspended solids. Appendix D includes summaries of impact significance criteria and mitigation measures, including monitoring, for several representative California sediment management projects.

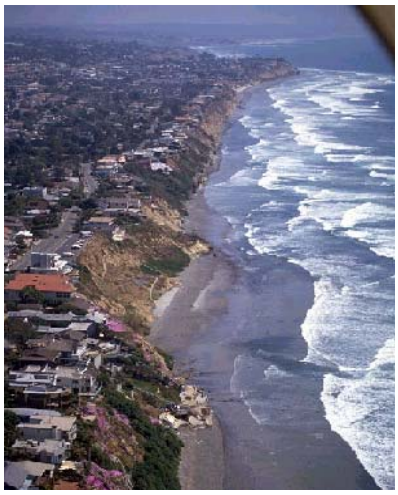
2.0 RELEVANT BACKGROUND INFORMATION

This section reviews several types of background information relevant to understanding issues and concerns on where and how biological resources may be influenced by sediment management activities in the coastal zone.

Section 2.1 provides an overview of coastal sediment management projects that are likely to occur in the future. Different activities associated with sediment management projects are identified in Section 2.2. Section 2.3 provides an overview of oceanographic characteristics, coastal processes, and water quality conditions that influence beach nourishment projects. Types of potential impacts to biological resources from sediment management activities are introduced in Section 2.4, which provides context for the detailed reviews and evaluations of impacts that are given in subsequent report sections. Section 2.5 briefly describes applicable federal and state regulations that protect California biological resources and/or that are evaluated for compliance during environmental review and permitting of sediment management projects.

Section Topics

2.1 Sediment Management Locations
2.2 Project Activities
2.3 Coastal Environment
2.4 Impact Issues
2.5 Applicable Regulations



2.1 Overview of Potential Future Locations of Sediment Management Activities

Sediment management is routinely conducted in coastal ports and harbors to maintain navigable channels. Smaller embayments such as lagoons and sloughs may require periodic removal of excess sedimentation to maintain open inlets for tidal flushing and/or adequate tidal exchange. Maintenance removal of sediment also is required in some rivers to maintain flood control channel capacity.

Excess sedimentation generally is removed using dredge equipment, although other mechanical equipment (e.g., bulldozers) may be used in smaller water bodies. Sediments from maintenance activities are routinely evaluated, and sandy materials determined by regulatory agencies to be suitable based on grain size, chemical, or hazardous characteristics (e.g., ordnance) may be placed on a nearby beach and in some cases in the nearshore. This type of activity may be referred to as "beneficial use", which is the use of dredged sediments as resource material in productive ways (http://el.erdc.usace.army.mil/dots/budm/glossary.cfm#b) disposal alternative. The relevant benefit to this study is the return of sands to the ocean, which is the natural receiving environment for coastal sediments. Damming of rivers, coastal urban development, and construction of protected safe harbors have all contributed to trapping of sediments and reduced flushing of sediments from coastal water bodies (CCC 1987).

Restoration of coastal wetlands is another type of project that may involve removal of sediment to improve tidal exchange and flushing. Placement of suitable sediments on the beach and/or nearshore often is a key element of such projects.

Projects also have been implemented specifically to nourish beaches to counteract coastal erosion and/or to provide shoreline protection, both of which have been identified as a major economic and public safety issues for the state. The importance of beach nourishment was recognized with the passage of Assembly Bill 64 (Public Beach Restoration Act) in 1999, which provided $10 million in grants to support local and regional beach nourishment projects and coastal research in 2000-2001. One of the funded projects was the California Beach Restoration Study, which identified candidate locations for future beach nourishment projects and/or studies (DBW and SCC 2002). Higgins et al. (2004) of the California Geological Survey (CGS) identified known beach nourishment needs based on review of records of erosion hot spots and compiled Information on past projects (modified from Coyne 2000) that involved sand placement on the beach and/or nearshore or beach nourishment.

Locations of potential future coastal sediment management activities are listed in Table 2.1-1 (at end of subsection). These locations were determined from review of information compiled by DBW and SCC (2002), Higgins et al. (2004), recent environmental documents for wetlands restoration projects, recent regional beach nourishment and/or opportunistic sand programs, and recent environmental documents and permits for port and harbor maintenance dredging.

A substantial number of the identified future sediment management projects are associated with periodic maintenance dredging of ports, harbors, and large bays (Table 2.1-1). Most major bays, ports, and harbors in California were included on the table based on ongoing or past sediment maintenance activities. Periodic maintenance dredging projects in northern California are required at Crescent City Harbor, Humboldt Bay, Noyo Harbor, Bodega Bay and Harbor, San Francisco Bay, and Pillar Point Harbor. Central California maintenance dredging occurs at Santa Cruz Harbor, Moss Landing Harbor, Morro Bay Harbor, and Port San Luis. Periodic maintenance dredging projects in southern California occur at Santa Barbara Harbor, Ventura Harbor, Channel Islands Harbor, Port Hueneme Harbor, Marina del Rey Harbor, King Harbor, Los Angeles Harbor, Long Beach Harbor, Anaheim Bay, Alamitos Bay, Newport Bay, Dana Point Harbor, Oceanside Harbor, and San Diego Bay.

Many of the port, harbor, and bay maintenance dredging activities involve sand placement at beach and/or nearshore locations (Table 2.1-1). Some conduct sand bypassing, which involves transport of sands from the upcoast side of a sediment-blocking structure (e.g., jetty) to the downdrift side. Sand bypassing occurs at Santa Cruz Harbor, Santa Barbara Harbor, Ventura Harbor, Channel Islands/Port Hueneme Harbors, Marina del Rey Harbor, and Oceanside Harbor (Wiegel 1994 cited in DBW and SCC 2002, NRC 1995). Sand backpassing from beaches in the lee of the Long Beach Harbor breakwater to downcoast beaches is conducted by the City of Long Beach. Continued sand bypassing and backpassing operations are anticipated in these areas. Beach nourishment from future port and/or harbor development was not assumed because sandy sediments often are re-handled to provide construction fill materials and unsuitable silty and/or contaminated sediments are subject to alternate disposal options (R. Appy, Port of Los Angeles, 2005 personal communication). However, historic locations where beach nourishment has been conducted from port maintenance dredging projects are listed on the table. Several bay and harbor maintenance dredging projects use designated ocean dredge material disposal sites

(e.g., Humboldt Bay, San Francisco Bay, Marina Del Rey, Los Angeles Harbor, Long Beach Harbor, Newport Bay) and/or designated in-bay disposal sites (San Francisco Bay). Deepwater ocean disposal sites were not listed on Table 2.1-1 since they are located outside the littoral zone.

Periodic maintenance with placement of sands in the coastal zone was assumed for shallow inlet embayments where historic records exist such as Bolinas Lagoon in northern California; San Lorenzo River in central California; and Goleta Slough, Santa Ana River, Agua Hedionda Lagoon, Batiquitos Lagoon, and San Elijo Lagoon in southern California. Planned lagoon and/or wetlands restoration projects where dredging will be required and placement of suitable sands on adjacent beaches has been identified include the Bolsa Chica Lowlands Restoration (Chambers Group 2000), San Elijo Lagoon Restoration (USACE 2005), and San Dieguito Wetlands Restoration projects (SDRP JPA and USFWS 2000).

Beach nourishment projects may occur at locations subject to ongoing and/or recently completed feasibility studies by the USACE based on results and/or recommendations of the Coast of California Storm and Tidal Waves Study (CCSTWS), which was authorized by Congress to develop coastal information to facilitate planning and actions in the coastal zone. CCSTWS studies have been completed by the USACE for the San Diego and Orange County regions. The Los Angeles Region CCSTWS is in progress. Future beach nourishment projects may occur in the following areas subject to feasibility study recommendations: Carpinteria City Beach, Peninsula Beach, Surfside-Sunset Beach, San Clemente, Oceanside, Encinitas/Solana Beach, and Imperial Beach (Table 2.1-1). Although the Corps feasibility study at Huntington Cliffs concluded there was no federal interest for beach nourishment, that finding does not preclude the potential for a local and/or joint state and local project (K. Sterrett, DBW, personal communication 2005).

Beach nourishment is anticipated at several locations in southern California based on regional and local planning documents. Surfside-Sunset Beach has been used as a “feeder beach” for the Orange County Beach Erosion Control Project since 1964 (DBW and SCC 2002). The Beach Erosion Authority for Clean Oceans and Nourishment (BEACON) developed the South Central Coast Beach Enhancement Program that calls for periodic nourishment of several receiver beaches in Santa Barbara and Ventura counties (Moffatt & Nichol 2005a). Opportunistic beach fill program criteria and concept designs have been developed for the City of San Clemente in Orange County (Moffatt & Nichol 2000a) and City of Carlsbad in San Diego County (Moffatt & Nichol 2000b). The Sand Compatibility and Opportunistic Use Program (SCOUP) was recently developed for SANDAG in San Diego County (Moffatt & Nichol 2005b). The San Diego Council of Governments (SANDAG) recently completed a monitoring program evaluating the effectiveness and impacts from the 2001 San Diego Regional Beach Sand Project, and is interested in pursuing regional sediment management planning.

Beach maintenance, enhancement, and/or nourishment are anticipated at several specific locations identified as candidate beach nourishment locations and/or as erosion hot spots (Table 2.1-1). Several locations have been identified in San Francisco Bay, central California, and in southern California. Higgins et al. (2004) compiled information on several identified erosion sites and indicated whether the sites had a need for beach nourishment based on review of Nobel Consultants (2000), DBW and SCC (2002), or information from USACE (Los Angeles and San Francisco Districts). Erosion sites with an identified need for beach nourishment are referenced as erosion hot spots on Table 2.1-1.

In some cases erosion sites identified by Higgins et al. (2004) as not having a need for nourishment were sites that were historically used in support of other sediment management activities (e.g., sand bypassing or beneficial use of maintenance dredge materials) and/or have been the subject of environmental documents evaluating their potential use as beach nourishment sites. In those situations, the site was listed in Table 2.1-1 in association with the relevant project, and was not identified as an erosion hot spot. Sites that were determined not to have a need for nourishment and had not been referenced in association with another sediment management project (historic or proposed) were not included in Table 2.1-1. These sites included El Granada and Sharp Park (San Mateo County), The Hook (Santa Cruz County), San Simeon State Park (San Luis Obispo), Ledbetter Beach (Santa Barbara County), Marina Park and San Buenaventura State Beach (Ventura County), and Seal Beach Mile 1 (Orange County).

Figures 2.1-1 through 2.1-3 show locations of potential future sediment management activities, including maintenance dredging and beach nourishment sites, which were visually estimated on the figures based on review of descriptions and/or illustrative maps. The figures demonstrate that most sediment management activities are localized to certain geographic regions and do not occur along the entire length of California. In-bay and offshore disposal sites were not shown on the maps, since the emphasis of this study was sediment management activities relative to beach nourishment.

Potential future sediment management activities in northern California are expected with maintenance dredging at Crescent City Harbor, Humboldt Bay, Noyo Harbor, Bodega Bay, and San Francisco Bay (Figure 2.1-1). Maintenance dredged materials may be placed at beach or nearshore beach nourishment sites, deepwater ocean dredge material disposal sites, in-bay disposal sites, and/or upland disposal sites depending on the embayment and environmental suitability of dredged material. Three erosion hot spots have been identified with a need for beach nourishment in and near San Francisco Bay (Figure 2.1-1).

Most central California sediment management activities are expected in association with maintenance dredging in Santa Cruz Harbor, Moss Landing Harbor, Morro Bay, and Port San Luis (Figure 2.1-2). Periodically maintenance of channels in San Lorenzo River may be required. Two locations (Cayucos Beach and Price Street Pocket Beach) have been identified as erosion hot spots in need of beach nourishment (Table 2.1-1).

The greatest variety of potential future sediment management activities have been identified for southern California (Figure 2.1-3, Table 2.1-1). These include maintenance dredging at several ports, harbors, bays, and small embayments; wetlands restoration; and regional as well as site specific beach nourishment to counteract coastal erosion. Over 20 locations have been identified as erosion hot spots, candidate beach nourishment sites, and/or have been the subject of shoreline protection feasibility studies with identified beach nourishment needs in southern California (Table 2.1-1)

Table 2.1-1. Types and locations of potential future sediment management projects in California.

County	Potential and/or Identified Project	Beach and/or Nearshore Placement Locations	Type of Project				
			Port/Harbor Maintenance	Bay/Lagoon/Flood Control Maintenance	Bay/Lagoon Restoration	Regional Beach Nourishment	Local Beach Nourishment and/or Shoreline Protection
Northern California							
Del Norte	Crescent City Harbor dredging	Crescent City Beach, Whaler Island	X				
Humboldt	Humboldt Bay dredging		X				
Mendocino	Noyo Harbor dredging		X				
Sonoma	Bodega Bay and Harbor dredging	Nearshore, Doran Regional Park Beach	X				
Marin	Bolinas Lagoon dredging	Stinson Beach		X	X		
Multiple	San Francisco Bay dredging		X				
San Francisco	DBW beach nourishment candidate site, erosion hot spot	Ocean Beach					X
Alameda	DBW beach nourishment candidate site	Crown Beach					X
San Mateo	DBW beach nourishment candidate site	Coyote Point					X
	Pillar Point Harbor dredging	Princeton Beach	X				
Central California							
Santa Cruz	Santa Cruz Harbor dredging, sand bypassing	Twin Lakes State Beach, Nearshore	X				
	San Lorenzo River channel maintenance	Twin Lakes State Beach		X			
Monterey	Moss Landing Harbor dredging	Moss Landing State Beach, South Sandspit, Aquatic SF-12, SF-14	X				
San Luis Obispo	Morro Bay Harbor dredging	Morro Strand State Beach, Morro Bay State Park sand spit, Montano de Oro State Beach	X		X		
	Port San Luis dredging	West Bluff Beach	X				
	Erosion hot spot	Cayucos Beach, Price Street Pocket Beach					X
Southern California							
Santa Barbara	Santa Barbara Harbor dredging, sand bypassing	East Beach	X				
	Goleta Slough dredging	Goleta Beach County Park		X			

Table 2.1-1 (Continued)

County	Potential and/or Identified Project	Beach and/or Nearshore Placement Locations	Type of Project				
			Port/Harbor Maintenance	Bay/Lagoon/Flood Control Maintenance	Bay/Lagoon Restoration	Regional Beach Nourishment	Local Beach Nourishment and/or Shoreline Protection
Santa Barbara	DBW beach nourishment candidate site, erosion hot spot	Regugio State Beach, El Capitan State Beach, Isla Vista, Goleta Beach County Park, Carpinteria State Beach					X
	Carpinteria City Beach Feasibility Study, erosion hot spot	Carpinteria City Beach					X
	South Central Coast Beach Enhancement Program	Goleta Beach County Park, Carpinteria Beach (Ash Avenue)				X	
	BEACON Beach Nourishment Demonstration	Goleta Beach, Padaro Lane				X	
Ventura	Ventura Harbor dredging, bypassing	McGrath State Beach, San Buenaventura State Beach	X				
	DBW beach nourishment candidate site, erosion hot spot	La Conchita, Hobson County Park, Emma Wood County Beach, Pierpoint Beach					X
	Channel Islands Harbor dredging, sand bypassing	Silver Strand Beach, Hueneme Beach	X				
	Port Hueneme Harbor dredging, bypassing	Hueneme Beach	X				
	South Central Coast Beach Enhancement Program	Oil Piers, Surfer's Point, Oxnard Shores, Hueneme Beach				X	
	Surfer's Point Managed Shoreline Retreat	Surfer's Point					X
	BEACON Regional Sand Management Plan	Pierpoint Bay Beach, Oxnard Shores				X	
Los Angeles	County of Los Angeles Sediment Placement Site Analysis	Dan Blocker Beach, Will Rogers Beach, Topanga State Beach, Las Tunas Beach					X
	DBW beach nourishment candidate site, erosion hot spot	Dan Blocker Beach					X
	Marina del Rey Harbor dredging, bypassing	Dockweiler Beach, Redondo Beach, Venice Beach	X				
	King Harbor dredging	Redondo Beach	X				
	Los Angeles River dredging			X			

Table 2.1-1 (Continued)

County	Potential and/or Identified Project	Beach and/or Nearshore Placement Locations	Type of Project				
			Port/Harbor Maintenance	Bay/Lagoon/Flood Control Maintenance	Bay/Lagoon Restoration	Regional Beach Nourishment	Local Beach Nourishment and/or Shoreline Protection
Los Angeles	Los Angeles Harbor dredging	Cabrillo Beach	X				
	Long Beach Harbor dredging	Long Beach,	X				
	Long Beach sand backpassing	Alamitos Peninsula Beach					X
	Peninsula Beach Feasibility Study	Alamitos Peninsula Beach					X
	Alamitos Bay dredging	Alamitos Peninsula		X			
Orange	Anaheim Bay dredging	Surfside-Sunset Beach		X			
	Orange County Beach Erosion Control Project	Surfside-Sunset Beach				X	
	Surfside-Sunset/Newport Beach Nourishment	Surfside-Sunset Beach				X	
	Seal Beach Feasibility Study	Surfside-Sunset Beach					X
	Bolsa Chica Lowlands Restoration	near Huntington Cliffs			X		
	Huntington Cliffs Feasibility Study*	Huntington Cliffs					X
	Santa Ana River dredging	Newport Beach, Huntington Beach		X			
	San Clemente Feasibility Study	San Clemente					X
	Newport Bay dredging		X				
	Dana Point Harbor dredging	Capistrano Beach, Baby Beach	X				
San Diego	Oceanside Harbor dredging, sand bypass	Oceanside	X				
	Sand Compatibility and Opportunistic Use Program (SCOUP) Pilot Study	Oceanside, Moonlight Beach, Solana Beach, Coronado Beaches, Imperial Beach					X
	Agua Hedionda Lagoon dredging	Carlsbad, beach north of inlet jetty, between inlet and discharge jetties, and south of discharge jetty.		X			
	Carlsbad Opportunistic Sand Program	South Carlsbad State Beach (Ponto Beach)					X

Table 2.1-1 (Continued)

County	Potential and/or Identified Project	Likely and/or Identified Placement Locations	Type of Project				
			Port/Harbor Maintenance	Bay/Lagoon/Flood Control Maintenance	Bay/Lagoon Restoration	Regional Beach Nourishment	Local Beach Nourishment and/or Shoreline Protection
San Diego	Batiquitos Lagoon dredging	Batiquitos Beach		X			
	DBW beach nourishment candidate site, erosion hot spot	Carlsbad State Beach					X
	Beach Maintenance	Moonlight State Beach					X
	San Elijo Lagoon inlet maintenance	Cardiff State Beach		X			
	San Elijo Lagoon Restoration	Cardiff State Beach			X		
	San Dieguito Wetlands Restoration	Del Mar			X		
	Los Penasquitos Lagoon inlet maintenance	Torrey Pines			X		
	Encinitas/Solana Beach Feasibility Study	Beaches within Cities of Encinitas and Solana Beach (multiple sites)					X
	DBW beach nourishment candidate sites, erosion hot spots	San Diego State Beaches (Batiquitos, Leucadia, Cardiff, Torrey Pines)					X
	SANDAG Regional Sand Management	Multiple beaches Cities of Oceanside, Carlsbad, Encinitas, Solana Beach, Del Mar, Mission Beach, Imperial Beach				X	
	DBW beach nourishment candidate site, erosion hot spot	Mission Beach					X
	Imperial Beach Feasibility Study	Imperial Beach					X
	San Diego Bay dredging	Imperial Beach, Silver Strand Beach, Coronado Beaches, Port landfills	X				

Sources: CRM 1997; Chambers Group 2000a; DBW and SCC 2002; Higgins et al. 2004; Moffatt & Nichol 2000a, 2000b, 2005a,b; SDRP JPA and USFWS 2000; USACE 2005a,b,c; USACE et al. 2001; permit review (see Appendix A).

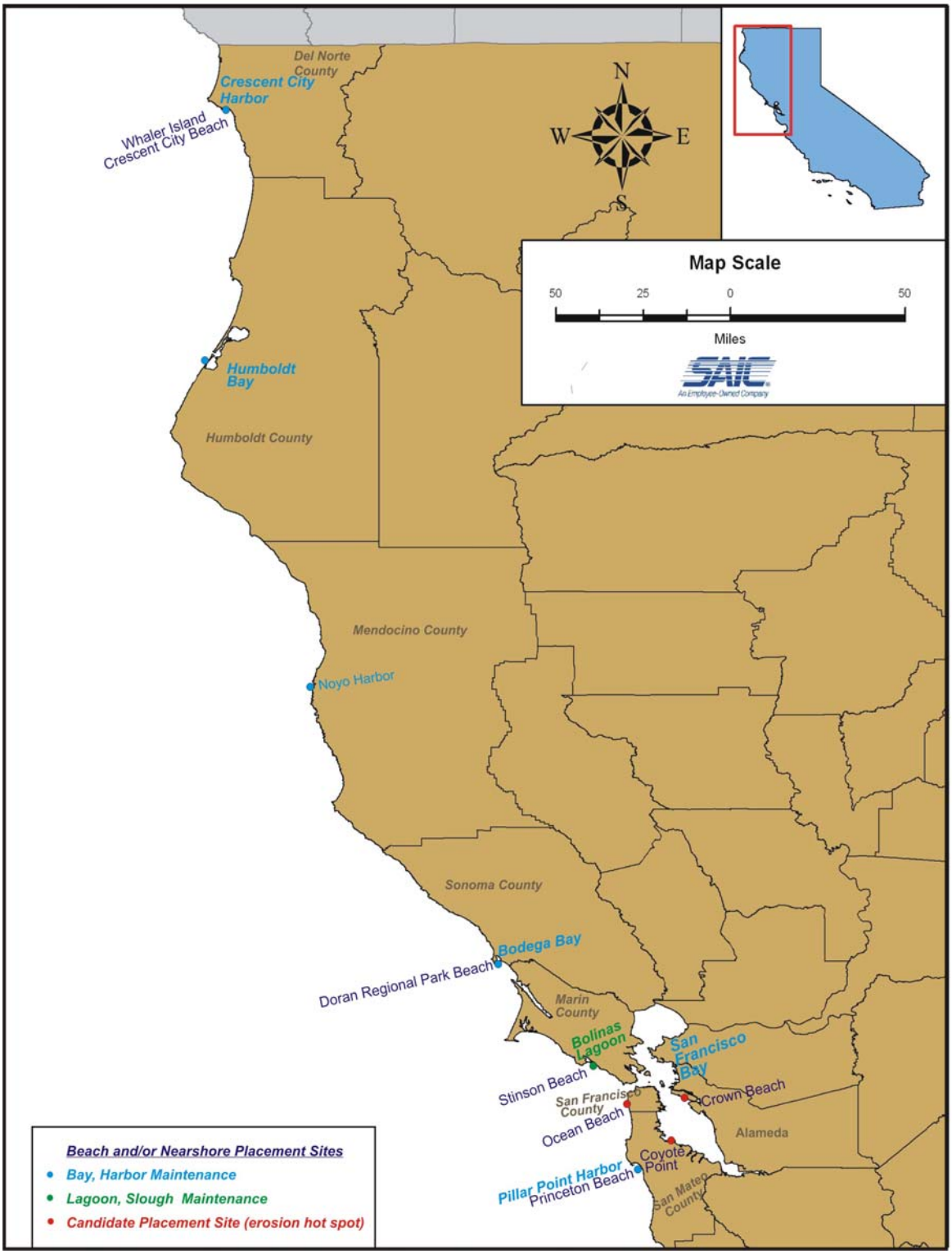


Figure 2.1-1. Locations of potential future sediment management activities in northern California.

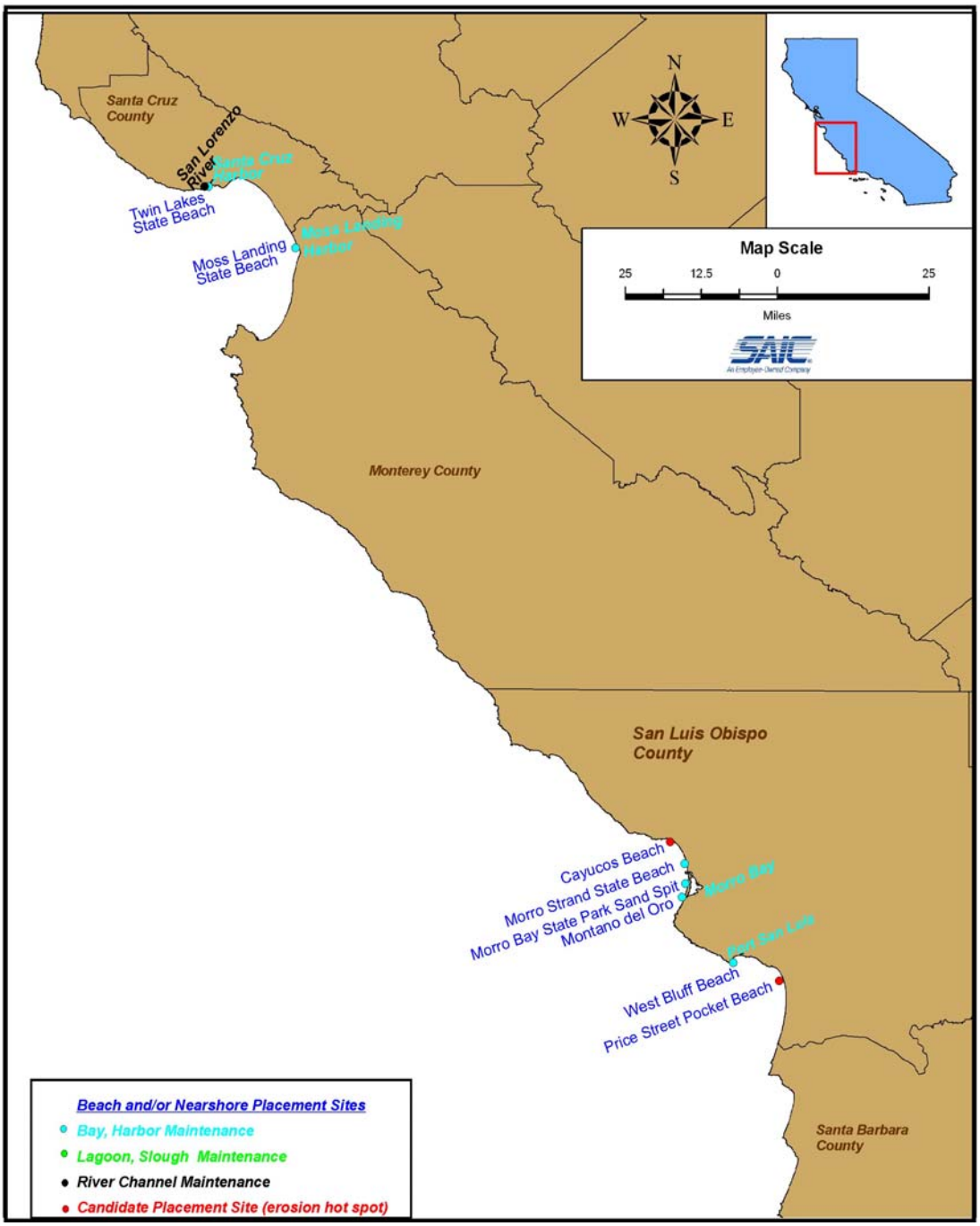


Figure 2.1-2. Locations of potential future sediment management activities in Central California.

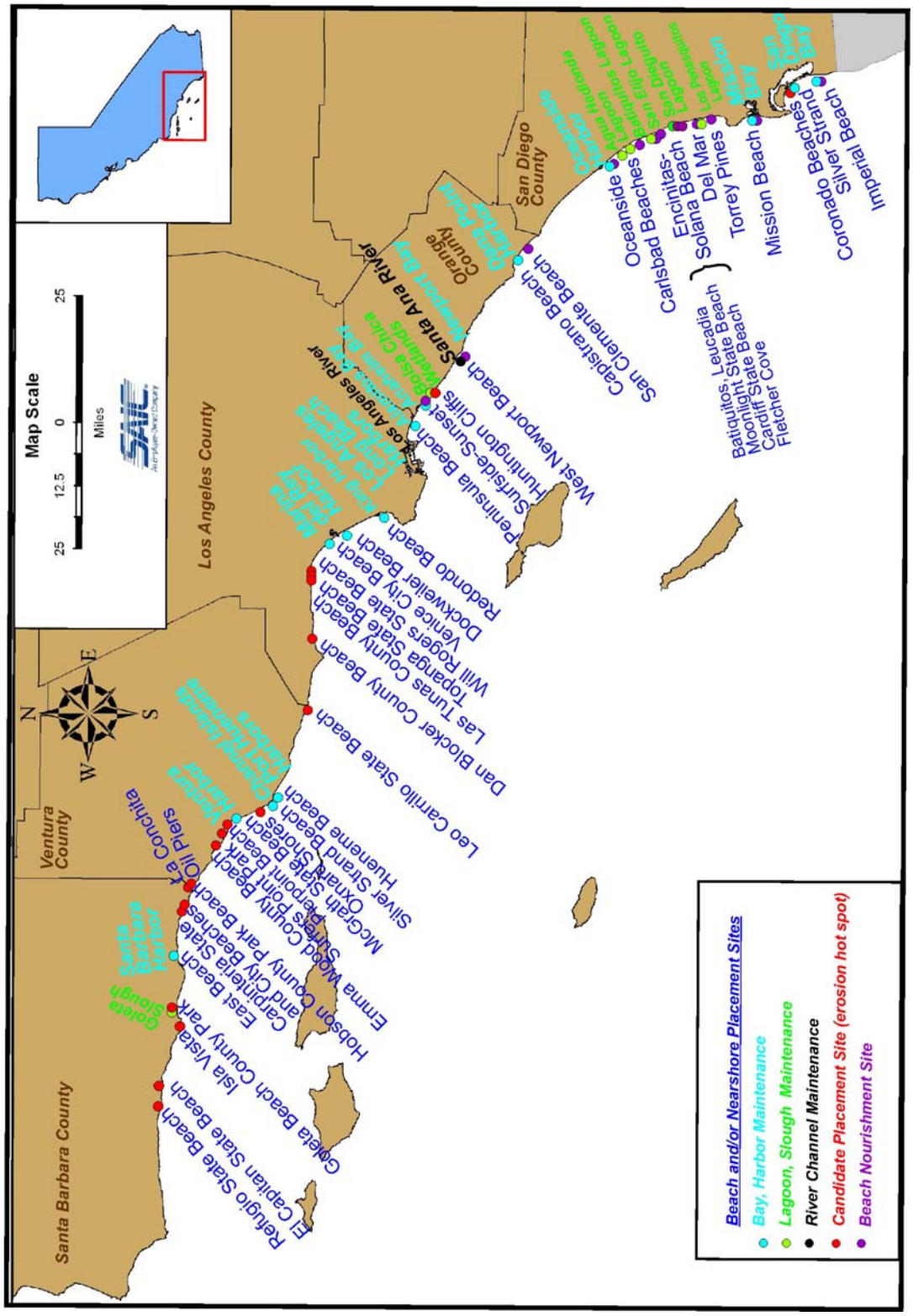


Figure 2.1-3. Locations of potential future sediment management activities in southern California.

2.2 Overview of Types of Sediment Management Activities and Methods

Several different types of sediment management activities may occur, including removal, disposal, and/or beneficial reuse of sediments. Project implementation involves activities associated with three project phases: pre-construction, construction, and post-construction. Activities and methods associated with each phase and their relevance to biological resources are briefly described below to provide overview background context for the more detailed reviews of impacts to biological resources and measures to avoid and/or minimize impacts, which are presented in Sections 3 through 6.

2.2.1 Pre-Construction Phase

The pre-construction phase is the most critical phase for ensuring adequate protection of biological resources during sediment management activities. It is during this phase that environmental constraints are identified, potential impacts are evaluated, environmental consequences are considered, and mitigation measures to avoid and/or minimize adverse impacts are recommended. Activities undertaken during the pre-construction phase generally include the following actions: project definition, technical and/or feasibility studies that guide project design and alternatives, preparation of environmental documentation, and application and obtaining of permits, approvals, and/or concurrences from local, state, and federal agencies to implement the project.

As part of the environmental review process, sediments to be dredged and/or excavated from waters of the United States require testing under 404(b)(1) guidelines to determine potential environmental impacts, need for additional chemical or biological testing, and suitable disposal options. Sediments (dredged or otherwise) proposed for placement (discharge) on the beach and/or in the nearshore environment also require evaluation to determine acceptability of this use. The USACE and U.S. Environmental Protection Agency (USEPA) share regulatory responsibility for all discharges of sediments to waters of the United States under Section 404 of the Clean Water Act (CWA) and Section 103 of the Marine Protection, Research, and Sanctuaries Act (MPRSA or “Ocean Dumping Act”). These agencies encourage the use of suitable dredged materials (which might otherwise be disposed of) for beneficial use projects (including beach nourishment).

Biological resources as well as other aspects of the environment to be affected by the sediment management project are described and evaluated for potential impacts. All aspects of the project including geographic area of influence e.g., construction and staging areas and transportation routes), equipment and methods to be used, project size, schedule, and duration are considered. Biological resources may be described based on documents, reports, and/or surveys of the project area. Potential impacts to biological resources and other environmental resources associated with different project alternatives are evaluated in an appropriate environmental document. Projects requiring state or local government approval, financing, or participation by the State of California must comply with the California Environmental Quality Act (CEQA). Projects undertaken by federal agencies must comply with the National Environmental Policy Act (NEPA). Several environmental laws and regulations guide the environmental document preparation, impact analysis, and review process (refer to Section 2.5).

Different environmental documents are required under CEQA and NEPA, although joint documents may be prepared when there is shared project responsibility between federal and local (state, municipal) agencies. CEQA documents prepared for sediment management activities may either be a negative declaration (ND), mitigated negative declaration (MND) or environmental impact report (EIR). An ND is appropriate when the project has no significant impacts under CEQA. An MND is appropriate for projects that have potentially significant impacts but which can be mitigated to be less than significant. An EIR is required for projects with a potentially significant effect that cannot be mitigated to be less than significant. EIRs also may be appropriate even if significant impacts can be mitigated to less than significance when the project is controversial and/or is under substantial public scrutiny. NEPA documents may include an environmental assessment (EA) followed by a finding of no significant impact (FONSI) or environmental impact statement (EIS). An EA and FONSI generally are prepared for most regulatory actions. An EIS normally is required for authorization and construction of major projects, proposed changes to projects that substantially increase project size or add additional purposes, and proposed major changes in operation and/or maintenance (USACE 1988).

The CEQA/NEPA statutes specify a specific process of impact analysis and public review. Several agencies may be involved in the regulatory review, concurrence, and/or permitting process for sediment management projects (Table 2.2-1). Coordination also may occur with additional agencies and organizations to avoid and/or minimize conflicts with land/water uses and protection and/or harvest of biological resources (e.g., California Department of Parks and Recreation, National Marine Sanctuaries, local commercial fishing organizations, and local aquaculture and/or mariculture enterprises). The environmental process requires public notification and a specified time period for public review and comment on CEQA/NEPA documents and permit applications.

Final environmental documents must address public comments (resource and regulatory agencies, local agencies and organization, and general public). Consequently, resource and regulatory agency review of final documents ensures consideration of public issues and concerns as well as agency mandates.

Required measures to avoid and/or minimize environmental impacts during construction are specified as terms and conditions in permits and certifications, conditions of approval in agency required consistency determinations and/or concurrences, and/or environmental commitments in NEPA documents and contractor specifications for federal projects. Permits also may specify monitoring to evaluate compliance with required conditions during construction, and/or monitoring to determine post-project impacts and the need for mitigation of significant impacts to biological resources.

2.2.2 Construction Phase

The construction phase involves all activities associated with implementation of the sediment management project. Some activities may be undertaken prior to construction to finalize project planning and logistics; however, most activities occur during project implementation. Construction activities associated with sediment management projects may include dredging, excavation, obtaining sand from other sources, and delivery of sediments to the receiver site. For beach receiver sites, construction activities may involve spreading sands and grading of beach fills to required dimensions with earth moving equipment.

Table 2.2.-1. Agencies involved with review and/or approval of sediment management projects.

Agency	Role
U.S. Army Corps of Engineers (USACE)	Regulatory authority for 404 (Clean Water Act, CWA) and Section 10 (Rivers and Harbors Act) permits for state and/or local projects, regulatory authority for all discharges of dredged materials in the ocean under Section 103 of the Marine Protection, Research, and Sanctuaries Act (MPRSA or "Ocean Dumping Act"); sponsor for federal navigation, flood control, and/or ecosystem restoration projects; feasibility studies and NEPA documentation for federal projects.
U.S. Environmental Protection Agency (USEPA)	Shared regulatory authority for all discharges of dredged material in waters of the United States under Section 404 of the CWA and Section 103 of the MPRSA.
U.S. Fish and Wildlife Service (USFWS)	Regulatory coordination (Fish and Wildlife Coordination Act), review of CEQA/NEPA documentation, federal biological opinion (BO) regarding actions that may affect federally listed endangered and/or threatened species and/or Critical Habitat, sponsor for federal restoration projects.
National Oceanic and Atmospheric Administration (NOAA)	Administers the Coastal Zone Management Program, which requires coastal states to have enforceable policies to protect ocean and coastal resources, including policies that affect sediment management.
National Marine Fisheries Service (NMFS)	Regulatory coordination (Fish and Wildlife Coordination Act), review of CEQA/NEPA documentation, federal biological 0pinion (BO), Essential Fish Habitat assessment review and approval.
California Coastal Commission (CCC)	Regulatory authority for Coastal Development Permit for state and/or local projects, Consistency Determination for federal projects, review of CEQA/NEPA documentation and obtained permits.
California Department of Fish and Game (CDFG)	Regulatory authority for Streambed Alteration Agreements (1600 et seq.), CEQA/NEPA review, concurrence with federal BO or issuance of separate BO for state listed endangered and/or threatened species.
State Water Resources Control Board (SWRCB) and regional offices (RWQCB)	Regulatory authority (Porter-Cologne Water Quality Control Act) for Section 401 (CWA) water quality certification required for dredging and/or disposal activities, review of CEQA/NEPA documentation and obtained permits.
State Lands Commission (SLC)	Statutory authority to approve uses of state lands under its jurisdiction and oversight responsibility for tide and submerged lands legislatively granted in trust to local jurisdictions (Public Resources Code § 6301), sponsor for state projects.
Local County	Regulatory authority for county permits, review for consistency with county policies and ordinances, sponsor of local projects, and certification of CEQA/NEPA documents for local projects.
Local City	Regulatory authority for local permits; review for consistency with Local Coastal Plan, policies, and ordinances; sponsor of local projects, and certification of CEQA/NEPA documents for local projects.

Pre-construction surveys may be required to finalize project implementation logistics, and to document recent environmental conditions to serve as a basis of comparison to post project conditions. Monitoring may be required during construction to verify compliance with permit requirements and to minimize the potential for adverse environmental effects.

Activities associated with the construction phase are briefly reviewed below. Detailed reviews of measures that have been used to avoid and minimize impacts to biological resources are reviewed in Section 6.

Dredging, Excavation

Sediment management activities may involve dredging and/or excavation of sediments to maintain navigable channels in bays, ports, and harbors, and to maintain adequate tidal exchange in coastal lagoons and sloughs. Dredging may be an element of coastal wetlands restoration projects. Dredging also may be conducted offshore to mine sand for use in beach nourishment projects.

Clamshell dredging in San Francisco Bay.

Sands dredged from coastal water bodies generally use cutterhead-suction dredge, clamshell dredge, and/or trailing-suction hopper dredge and may involve direct discharge of materials to the nearshore and/or hydraulically pumping the material to the beach through a pipeline (NRC 1995). The cutterhead-suction dredge is a continuous operation involving dredging and directly pumping to the receiver site. Typically, a cutterhead-hydraulic pipeline method is used in calm waters (e.g., lagoons, bays) where the receiver site is located close enough for efficient hydraulic pumping with or without booster pumps.

The clamshell dredge is a bucket type dredge that typically is used in confined areas such as around piers, docks, etc. and/or where the disposal area is too far for feasible use of a cutterhead dredge.

In contrast, a hopper dredge is used for offshore work in rougher sea conditions and/or where there is greater distance between the dredge and disposal location (NRC 1995). The hopper dredge operation occurs in two separate phases consisting of: (1) dredging and filling the hopper barge, and (2) transit of the hopper to the receiver site and offloading of the materials. Hopper vessels may either directly discharge sediments to nearshore locations by opening doors on the bottom of the hull or with a split hull arrangement. Sediments also may be delivered to the beach by connecting to a mooring buoy and pumping materials through a pipeline.

Hopper dredge with pipeline to shore, SANDAG 2001
Photo credit: SANDAG

Earth moving equipment (bulldozers, trucks) may be used during excavation of sedimentation accumulated in tidal inlets and/or river channels.

Obtaining Sources and Delivery of Materials for Beach Nourishment

The method for delivery of sand for placement on the beach and/or nearshore or beach nourishment generally depends on the method used to acquire the material. For example, dredged sands may be conveyed by vessels and/or pipelines to the receiver site. Material excavated using earth moving equipment (e.g., sand backpassing projects, river channel excavation) or obtained from upland sources generally use bulldozers and/or trucks for delivery of materials.

Several sources of materials have been used for beach and nearshore sand placement and/or beach nourishment projects in California (DBW and SCC 2002), as follows:

- Bays and Harbors (e.g., often associated with maintenance dredging of navigational channels and/or sand bypassing).
- Lagoon Inlets (may involve dredging and/or earth moving equipment to remove ebb or flood tide deltas).
- Littoral System
  - Bypassing (involves transfer of accumulated sand upcoast of a barrier such as a jetty to the downcoast side, the term bypassing also has been applied to the activity of dredging littoral transport derived sands from entrances of bays, lagoons , and harbors).
  - Backpassing (involves transfer of sand from a wide stable beach to an upcoast sediment-starved beach).
- Nearshore or Offshore (involves dredging of sands and discharge to nearshore or on the beach).
- Rivers (occasionally used in association with flood control construction projects).
- Upland (may include flood control debris basins, dam reservoir basins, and coastal development projects).

Generally, dredged materials with a silt/clay content (grains < 0.074 mm) within 10 percentage points of the finest beach sample, or sediments with less than 20 percent silt/clay have been considered suitable for placement on California beaches and/or in the nearshore to serve a beach nourishment need (Higgins et al. 2004). The USACE, Los Angeles District recently issued (2006) Regional General Permit 67, which is designed to streamline regulatory procedures for permitting beach nourishment activities subject to Corps' authority under Section 404 of the CWA and Section 10 of the Rivers and Harbors Act. Sediments comprised of at least 80 percent sand and the fines fraction is within 10 percent of that of the receiving beach may qualify under the permit provided they test clean per tiered requirements of the Inland Testing Manual or be categorically excluded from testing according to 40 CFR Section 230.60(a) exclusions. Exclusions may apply when material is composed primarily of sand, gravel and/or inert materials from a high energy environment, sediments are from locations far removed from contaminant sources, or sediments are from pre-industrial age deposits not exposed to modern pollution sources.

Sediments with a higher percentage of silt/clay are not specifically excluded from use for beach nourishment, but would require USACE and USEPA approval on a site specific basis and may require additional tiered chemical and/or biological testing to determine the degree

of contamination in the fine fraction, consideration of the natural resources that might be impacted by the discharge, or deposition of the fine-sediment fraction (Higgins et al. 2004).

Sediment Placement

Construction activities vary depending on where the sands are placed. Several locations across the beach profile, ranging from the backbeach to nearshore zone, have been used for beach nourishment (DBW and SCC 2002). Different placement methods are briefly described below.

Dune placement involves use of earth moving equipment to place sand above the waterline to serve as a stockpile and/or provide for a more gradual winnowing of sands for beach nourishment (Figure 2.2-1a). In some cases, dune building (also termed beach scraping) is done before the winter season to provide shoreline protection of recreational facilities and then redistributed to the beach after the storm season. Dune building does not represent a beach nourishment strategy since sand is not added to the beach.

Beach placement may involve hydraulic pipeline delivery from hopper or cutterhead dredges. A hopper dredge may moor to a buoy or barge and pump the material through a pipeline that is submerged through the surfzone to the beach. A cutterhead dredge pumps sediment slurry to the beach through a pipeline, which may include floating and submerged sections. Pipelines also may be run along the backbeach to convey sediments to different areas of the beach.

Goleta Beach Nourishment Demonstration, 2003

Photo credit: Moffatt & Nichol Engineers

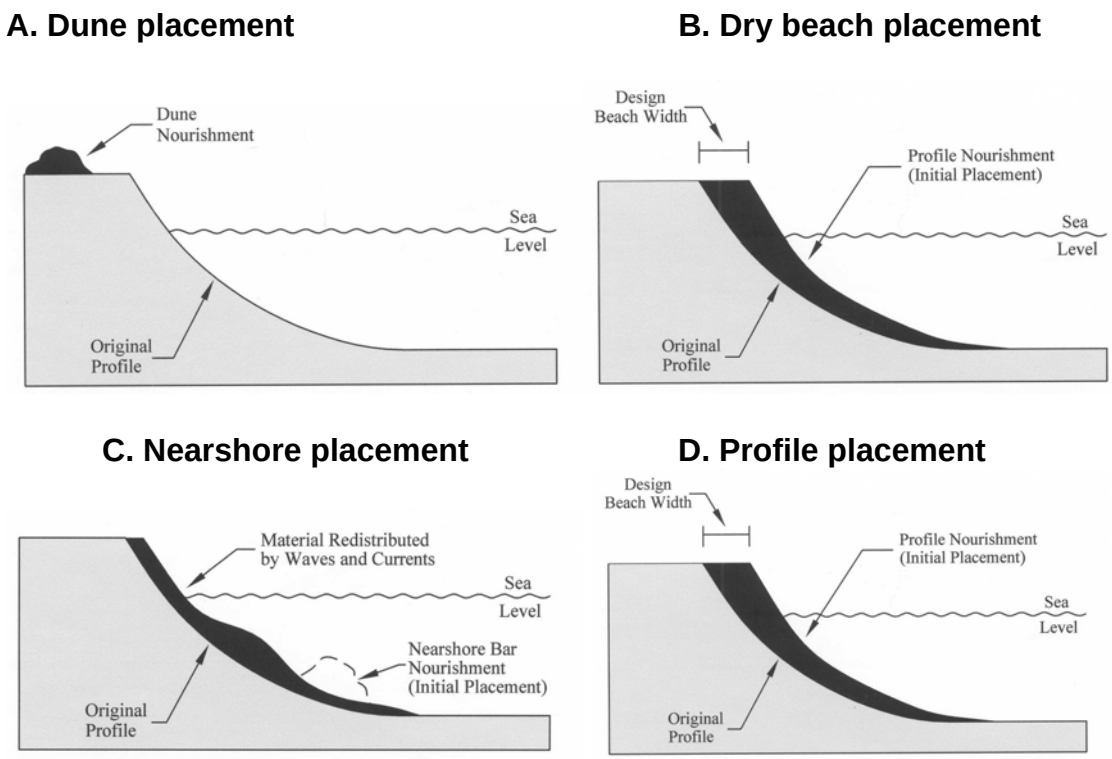
Trucks may be used to deliver sand to the beach. Sand may be placed on the dry portion of the beach within the tide range and/or near the waterline (Figure 2.2-1b). Earth moving equipment generally is used to redistribute and grade materials within the beach fill.

Temporary dikes and/or swales may be constructed from beach fill and native sediments near the onset of construction associated with pipeline delivery of sediment slurry as a means to control turbidity during sediment discharge.

Waves and coastal processes redistribute the sand offshore and along the submerged portion of the beach profile. Thus, beach width continues to narrow after placement as sand equilibrates along the offshore portion of the beach profile and moves up and/or downcoast with currents. This has been the most commonly used placement method for projects in California (refer to Table 2.1-1).

Nearshore placement involves hopper dredge or pipeline discharge of sands seaward of the surf zone (Figure 2.2-1c). Anchoring may be required with this method. The material is used to form a sand bar that will redistribute along the beach profile with waves and currents. Redistribution to the intertidal portion of the beach will vary according to wave and climatic conditions. This placement method is considered technically challenging, but may be the most cost effective (DBW and SCC 2002). Nearshore placement is the second most commonly used placement method for projects in California (refer to Table 2.1-1).

Beach profile placement involves a combination of nearshore and dry beach placement along the entire beach profile (Figure 2.2-1d). This placement attempts to build a stable beach so there is less change in beach width associated with sand redistribution. This method is considered the most difficult of the placement methods (DBW and SCC 2002).



Source: DBW and SCC 2002.

Figure 2.2-1. Examples of beach nourishment techniques.

Structures may or may not be associated with beach nourishment projects. Termed hybrid projects by the NRC (1995), projects may include some combination of beach nourishment and structures such as seawalls, revetments, groins, detached breakwaters, and submerged sills. Sand retention devices in conjunction with beach nourishment have not been used in California, but are being considered in some areas of the state to prolong the duration of beach nourishment benefits (Everts 2000 cited in DBW and SCC 2002, Moffatt & Nichol 2002). The USACE recently completed a design study for an offshore submerged structure for beach erosion control at Oil Piers, Ventura County (ASR Ltd. 2004).

Pre-Construction and Construction Monitoring

Biological surveys may be required to facilitate final project planning and/or to meet special permit conditions. Pre-construction surveys may be required for sensitive biological resources to ensure appropriate impact avoidance and minimization measures are implemented during construction. For example, pre-construction surveys were required for

the San Diego Regional Beach Sand Project to determine potential suitability of beach habitat for California grunion spawning, and those sites considered potentially suitable required monitors to be present during construction if activities were scheduled during the time of a predicted grunion run (AMEC 2002). Pre-construction surveys also were required to finalize vessel routes in the vicinity of kelp beds, corridors for pipelines submerged through the surf zone, and anchoring locations to ensure avoidance of sensitive resources during construction.

Pre-construction biological surveys also may be required as a permit condition to document environmental conditions for subsequent comparison to post-construction conditions to verify no significant environmental impacts result from project implementation (e.g., AMEC 2005, Moffatt and Nichol 2005c).

Monitoring during construction may be required to comply with permit conditions. The RWQCB may require monitoring of water quality to meet waste discharge requirements specified as a condition of the 401 water quality certification. Biological monitoring may be required by resource agencies to verify absence of sensitive species from the project area during construction, halt and/or redirect construction if sensitive resources enter the project area, and/or to confirm construction remains within designated work areas.

2.2.3 Post construction Phase

After sand placement, sediment transport redistributes sands within the beach profile. Sands seasonally move on- and offshore, and currents may carry sands up- and/or downcoast. Monitoring sometimes is performed to measure beach width and/or beach slope to document sand movement, project effectiveness, and/or duration of beach nourishment to facilitate future project planning decisions (e.g., Coastal Frontiers 2005).

Post-construction biological monitoring may or may not be a permit requirement. If required, the monitoring typically concerns sensitive habitat areas and includes pre- and post-construction monitoring to verify no significant impacts result from project implementation; mitigation requirements also are specified if significant impacts occur. For example, the 404 permit for maintenance dredging in Agua Hedionda Lagoon, San Diego County, requires pre- and post-construction mapping of eelgrass beds to verify that the dredging activity does not remove eelgrass outside agency approved dredge limits and specifies mitigation according to the Southern California Eelgrass Policy for any unauthorized eelgrass removal.

2.2.4 Maintenance

Sediment management activities often are a maintenance action. Periodic dredging and excavation are undertaken to maintain navigable channels, tidal exchange in lagoons, and/or flood control channel capacity. A number of factors may influence maintenance frequency including sedimentation rates, sediment characteristics, shoreline characteristics, local bathymetric and physical oceanographic conditions, proximity to man-made structures and local sand sources, and weather conditions. The time interval between maintenance activities may vary from one to several years depending on site conditions. Physical benefits from beach nourishment erode over time and require additional nourishment episodes to maintain benefits. Typical beach re-nourishment intervals range between two and ten years (NRC 1995, DBW and SCC 2002). .

Frequency of disturbance is an important consideration when evaluating the potential for impacts to biological resources. Biological resources need time to recover from disturbance impacts, the duration of which may vary from hours to years depending on recovery rates of affected resources and environmental conditions during the recovery phase. Recovery rates are reviewed for habitats and species in Sections 3 and 4, respectively.

Beach grooming is conducted at some beaches after nourishment to remove trash and debris to enhance public recreation. This is a maintenance activity generally undertaken by municipal and/or county parks and recreation departments. Beach grooming is not a sediment management activity; consequently it is not a featured topic in this study. However, information on beach grooming obtained during the course of this study that relates to response of biological resources to disturbance impacts was considered relevant and is included in the review (Section 3.3.2).

2.3 Overview of Oceanographic Conditions and Coastal Processes Affecting Beach and Nearshore Environments

Oceanographic conditions and coastal processes are primary factors influencing local differences in physical, chemical, and biological characteristics of the marine environment. These factors influence circulation and mixing of waters and transport of sediments. They also influence distribution and abundance of aquatic organisms, which in tern affect food resources for marine-associated species.

Brief overviews of oceanographic conditions, coastal processes, and water quality that are particularly relevant when evaluating the potential for impacts to biological resources from sediment management activities are presented in the following subsections.

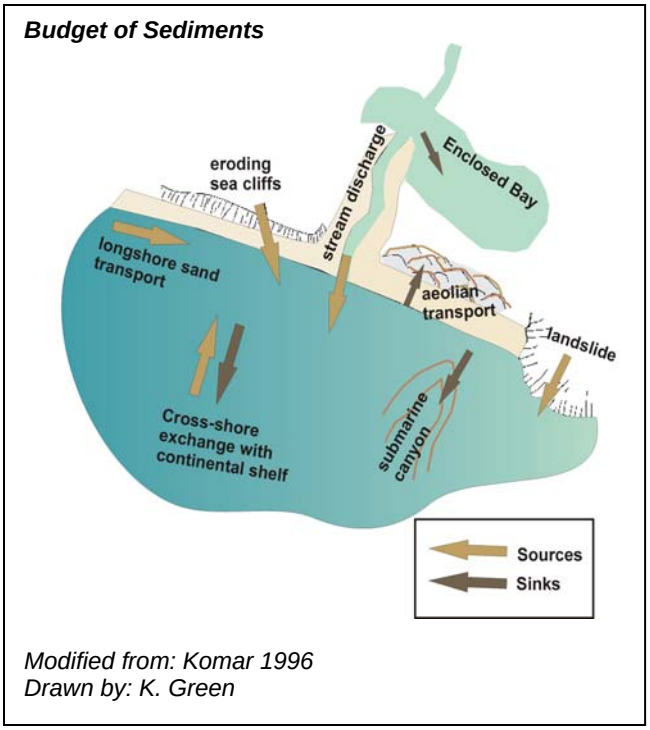
- Natural Sediment Supply and Sinks
- Currents, Tides, and Waves
- Upwelling and Downwelling
- El Niño Southern Oscillation
- Water Quality Objectives and Natural Water Characteristics

2.3.1 Natural Sediment Supply and Sinks

Sediment input to and movement within the coastal zone is dynamic and continuously affected by water, winds, and waves. Sediments washed from the land during winter storms are conveyed to the ocean by creeks, rivers and streams, which transport 70 to 90 percent (%) of the natural sand supply to California beaches (DBW and SCC 2002). Erosion of coastal bluffs and cliffs (including landslides) provide an important secondary source of sediment to the coast.

The relative contribution of sediment supply from river and stream discharges versus bluff erosion varies along the 1,100-mile (mi) (1,760 kilometer, km) coastline of California depending on local conditions, although river and stream supply remain dominant (CCC 1987). Heavier rainfall contributes to a greater number of perennial flows in northern California than in southern California, where most streams flow only part of the year. Human construction and development have substantially reduced natural sediment loads conveyed by rivers due to construction of dams, flood control channelization, urban development, and increased water diversion and draw down to meet agricultural and urban

demands. It has been estimated that damming of rivers alone has reduced half the natural sand supply to beaches between Santa Barbara and Mexico, resulting in serious sand supply and erosion problems for the southern part of the state.



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Human intervention also has reduced the relatively smaller, but still substantial contribution to sediment supply associated with eroding seacliffs. The majority of California's coast consists of eroding sea cliffs with only 13 percent considered largely non-erosive due to high relief, steep mountains (DBW and SCC 2002). Approximately 10% of the coast has been armored to protect lowlands, dunes, and eroding sea cliffs (CCC 1987).

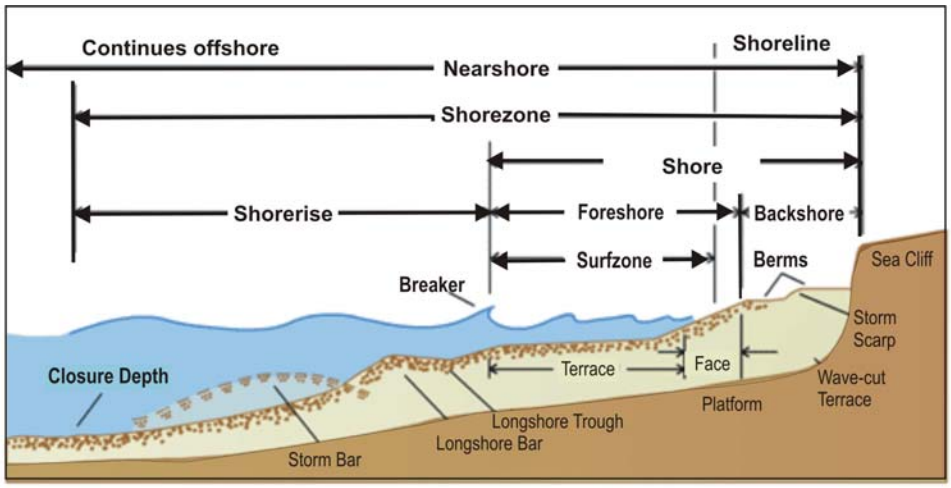
Sediment conveyed by rivers and streams to the coastal zone may empty into and become trapped within natural and/or man-made embayments (defined in this study as bays, esteros, lagoons, sloughs, harbors) resulting in sedimentation within these water bodies and the need for maintenance dredging and/or excavation. Embayments also may capture sediment moving alongshore. Thus, embayments represent natural (e.g., bays, lagoons, sloughs) and/or man-made (harbors, marinas, ports) sediment sinks.

Coastal dunes represent another type of sediment sink. Strong winds may blow beach sands landward with drifts accumulating around objects (e.g., logs, plants) with dunes developing over time from the combined action of steady winds and the drift acting as a barrier to sand movement (CCC 1987). Dune formation is a slow process and sands are subject to wind (aeolian) transport until stabilized by plants.

Sediments reaching the open ocean move both along and across the coastal shelf (also refer to Subsection 2.3.2). A specific transport area exists close to the beach, termed the littoral zone, within which sediments associated with the beach habitat move. The littoral zone is bounded by the backshore and offshore "depth of closure" of the beach, which is the depth at which sediment transport is not substantially affected by littoral processes (Figure 2.3-1). The depth of closure is variable along the coast depending on local bathymetry and other physical characteristics. For example, depth of closure ranges between approximately -13 and -30 ft (3.9 to 9 m) MLLW at several beaches in San Diego County (Coastal Frontiers 2005), -15 to -38 ft (4.5 to 11.6 m) MLLW off Santa Barbara (Moffatt & Nichol 2001), and -40 ft (12 m) MLLW or deeper in northern California (Moffatt & Nichol 2005b).

All coasts are divided into natural discrete nearshore compartments, termed littoral cells, which encompass a complete sedimentation cycle including sources, sinks, and transport paths associated with the beach (Figure 2.3-2). Rocky headlands and/or submarine canyons represent natural boundaries of littoral cells, with submarine canyons acting as

sediment sinks. Large storms can transport sediments offshore beyond the littoral zone where they become effectively lost to the beach.



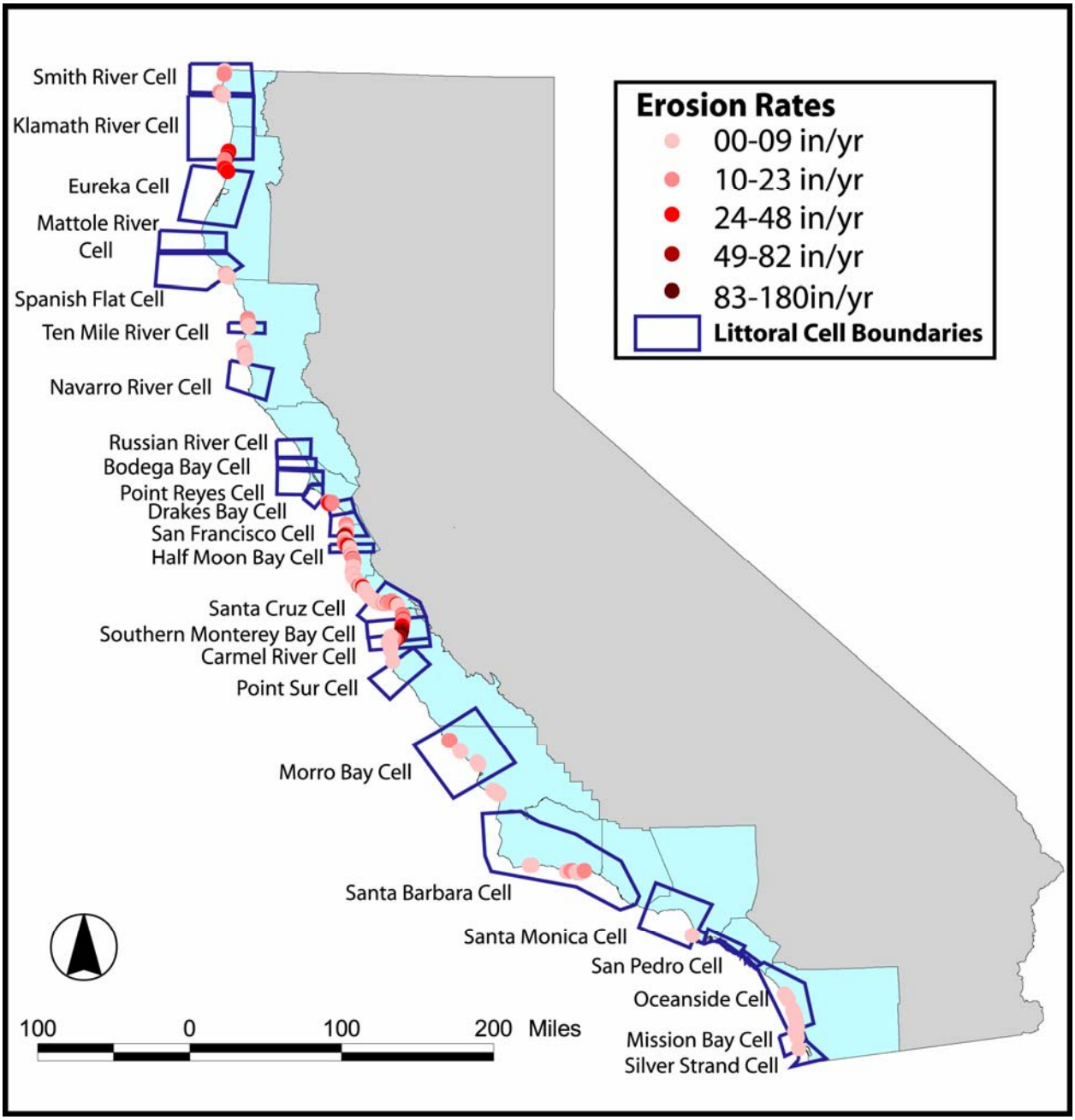
Source: Inman and Masters (eds), 2003. http://coastalchange.ucsd.edu, accessed September 2005. Reproduced with permission

Figure 2.3-1. Diagram of the beach shorezone and associated coastal features.

2.3.2 Currents, Tides, and Waves

The dynamic nature of sediment movement is important to consider when evaluating potential impacts to biological resources from sediment management activities. Nearshore aquatic habitats and species naturally experience a certain amount of sedimentation and sand movement associated with episodic storm runoff, persistent longshore sand movement, and reoccurring cross shelf transport. However, their degree of exposure to these effects vary on spatial (cross-shelf) and temporal (seasonal, episodic) scales that are not equivalent geographically along the coast or across surfzone, nearshore, and offshore environments.

The oceanographic circulation of waters offshore California is closely tied to the California Current, which is a broad (approximately 30-mile, 50-kilometer) band of relatively shallow equatorward (southward) flow that brings cold relatively less saline water offshore down the coast from the Gulf of Alaska and turns shoreward near the U.S.-Mexico Border (Hickey 1993). Outflows from large rivers (e.g., Columbia, Sacramento, San Joaguin) also contribute to lower salinity as the current proceeds down the coast (Broenkow 1996). South of Point Conception the land turns sharply eastward, forming the Southern California Bight, and the California Current flows a few hundred kilometers offshore although it may make seasonal incursions closer to shore (Hickey 1993, DiGiaComo and Holt 2003 cited in MSRP 2005). Velocities of the California Current range up to 1.0 foot per second (ft/s) (30 centimeters per second, cm/s), with measurements of 0.3 to 0.7 ft/s (10 to 20 cm/s) typical.



Source: Habel and Armstrong 1977 in DBW and SCC 2002.
Reproduced with permission from DBW 2005

Figure 2.3-2. Littoral cells and estimated erosion rates offshore California.

The California Current is characterized by localized eddies and jets (or "squirts"). In southern California, a portion of the shoreward flow of the California Current turns poleward (northward) along the shore and is termed the Southern California Countercurrent, which transports warmer water from southern California northward towards Point Conception and may form the "Southern California Eddy". Between the Santa Barbara coast and offshore Channel Islands, the countercurrent is known as the Santa Barbara Gyre. The Southern California Countercurrent is strongest in summer and fall, and may be absent during spring, which is consistent with the occurrence of the strongest nearshore equatorward flow during the spring (Hickey 1993). Surface currents near the coast may range from 0.17 to 1.5 ft/s (5 to 46 cm/s), with average speeds of approximately 0.33 ft/s (10 cm/s) (Hendrick 1976, CSDOC 1994).

The "San Francisco Eddy" has been described as a semi-permanent feature west of Monterey Bay (Hickey 1979). A jet may be found off Point Sur that transports cool upwelled waters over 60 mi (100 km) offshore. The importance of jets and/or "squirts" is that upwelled water may be transported offshore past the normal band of influence of the California Current

Over 800 ft (240 m) below the coastal surface flow is the poleward flowing California Undercurrent of relatively higher temperature and salinity (Hickey 1993). North of Point Conception, the poleward flow extends throughout the water column during late fall and winter, representing a reversal of the California Current and surfacing of the California Undercurrent (also referred to as the Davidson Current) (Broenkow 1996, UCSD 2003). The Davidson Current has velocities on the order of 0.5 to 1 ft/s (15 to 30 cm/s).

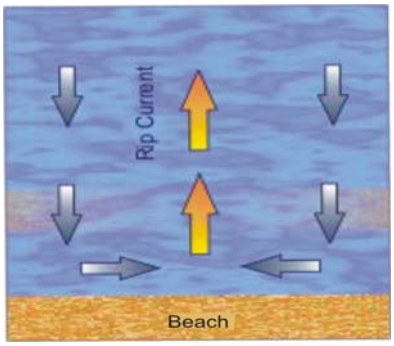
The warm and cold-water nearshore currents that meet at Point Conception create a transition that contributes to a change in marine species between the zoogeographical Oregonian Province to the north and California Province to the south. Some authors consider the area between Point Conception and Monterey as a Transition Zone where many species of the Oregonian and California Provinces have their northern or southern distribution limits (Abbott et al. 1980). Depending on season and location, currents transport pelagic larvae of marine species either northward or southward or by surface and/or subsurface currents.

Both near-surface and near-bottom current flow can be substantially altered by the effects of the bottom and influence sediment transport on the shelf and slope. Hickey (1993) generalized that flow in the bottom boundary layer is directed offshore for poleward flow and onshore for equatorward flow in southern California (Hickey 1993). Particulate transport is mainly poleward and offshore during storms in northern California (Nittrouer and Wright 1994).

Tides off California are a mixed, semidiurnal type with two unequal high tides and two unequal low tides. Tides generate shelf and coastal currents that are important to transport of finer sediments offshore; tides also are the primary sediment transport force inside enclosed bays and estuaries (Inman and Masters 2003).

Waves and the nearshore currents they generate are the predominant factors affecting nearshore coastal sediment transport and deposition (Nittrouer and Wright 1994). Waves break at an angle to the beach and generate a longshore current that flows parallel to shore either up or downcoast based on the propagation direction of the breaking wave. The water in the longshore current returns seaward as a cross-shelf rip current, with the spacing

between rip currents generally two to eight times the width of the surf zone (Inman and Masters 2003). Headlands, breakwaters, and other obstructions may alter the direction of longshore currents and spacing of rip currents. Obstructions also may accelerate erosion of downdrift beaches. Longshore currents may range from 0.17 to 8 ft/s (5 cm/s to 244 cm/s) and rip currents may exceed 5 ft/s (150 cm/s) (Shepard 1950, Beach and Sternberg 1988, Inman and Masters 2003).



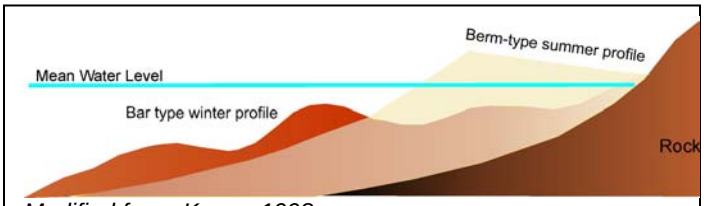
Rip Current through break in sand bar

Public domain: September 2005
www.ripcurrents.noaa.gov,

The wave climate is influenced by storm swells from extratropical storms during northern hemisphere winters (north or northwest swell), tropical storm swells and cyclones off the Mexican coast during northern hemisphere summers (southeast swell), and southern hemisphere swells generated by large South Pacific storms during southern hemisphere winters (south-southwest swell). Prefrontal winds and local winds also generate waves and when combined with storm swells can produce high wave conditions.

Wave energy in southern California is partially sheltered (shadowed) by offshore islands, shallow banks, and coastal submarine canyons depending on the direction of wave propagation. Wave energy is not shadowed along the central and northern California coasts, which also generally have more rugged and rocky coastlines. Wave heights tend to be higher during winter and spring due to storms from the North Pacific. Substantial wave heights also may be associated with El Niño Southern Oscillation events (see Subsection 2.3.4). Waves in California generally range from 3 to 10 ft (1 to 3 m) although heights > 19 ft (6 m) have been recorded during extreme storm conditions (Seymour et al. 1984, CCSTWS 1996). Extreme wave heights also have the potential to occur with tsunamis.

Seasonal variations in wave climate result in changes in sand volume on beaches with generally less sand (erosion) during winter and more sand (accretion) during summer (Shepard and Inman 1951). When sand supply within a littoral cell is at a deficit (i.e., more sediment lost to sinks than supplied from sources), sand may be seasonally stripped to the underlying rocky platform (Figure 2.2-3).



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Seasonal change in sand depth on a beach varies depending on local conditions such as bathymetry, protection by headlands and/or other structures, and wave energy. Flick (1992) reported that the sand layer on southern California beaches may vary from zero to several meters, depending on locations, season, and other factors. Seasonal sand depths varied by approximately 2 ft (60 cm) at Ellwood Beach west of Santa Barbara (Thompson et al. 1993). Season shifts in sand depths of > 2 ft (> 60 cm) were measured on the shoreface of several beaches in the Cities of Encinitas and Solana Beach, San Diego County, although seasonal variation was < 1ft (< 30 cm) at a beach with nearshore reefs, suggesting nearshore hard substrate may influence sand retention (SAIC 2006).

May 1999 – seasonal sand eroded condition prior to nourishment

July 1999 – seasonal sand accretion condition prior to nourishment

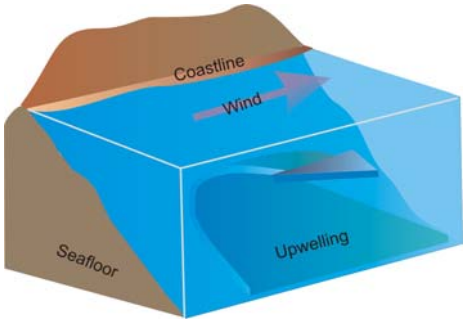
June 2002, view south toward beach in above photographs after nourishment
Photographs by: Karen Green

Figure 2.3-3. Example of seasonal beach change on Leucadia Beach prior to sand nourishment and condition of beach after nourishment

Because settling rates of particles are size dependent, waves and currents sort sediment as it moves offshore. Consequently, coarser sands tend to remain closer to shore and sediment grain size typically decreases with increased distance offshore. Littoral transport of sand also is important to the inlet dynamics of coastal lagoons with unstable inlets. While storm flows may serve to keep an inlet open, sand inflow from littoral drift may result in inlet closure. The inlet sand recharge rate is affected by the supply of littoral sand (Chang 1997).

2.3.3 Upwelling and Downwelling

Upwelling is an oceanographic process whereby northern winds move nearshore waters offshore and deep, nutrient-rich water rises to replace the displaced water (Hickey 1993). Upwelling is most intense off central and northern California and less so off southern California, although Point Conception is an area of intense upwelling. Upwelling generally occurs along the southern California coast near headlands and on the lee side of islands. Upwelling generally occurs in May-June in southern California and may occur between March through August-September in central and northern California when strong equatorward ("upwelling favorable") winds occur (Broenkow 1996).

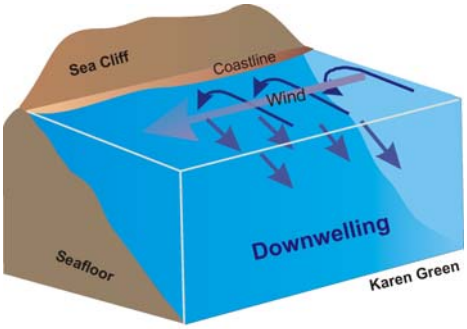


Strong winds towards south or offshore may produce upwelling.

Modified from: D. Reed
Redrawn by: K. Green

Upwelling is critical to primary production and has widespread influence on ocean productivity. It has been shown that while upwelling areas only cover approximately 1% of the ocean surface, they are directly responsible for 50% of the world's fisheries (NOAA 2005). Phytoplankton blooms, which may decrease water clarity, may result from upwelling and last on the order of one to three weeks. Relaxation of upwelling episodes may be important to shoreward transport and nearshore recruitment patterns of pelagic larvae of various marine organisms in northern California (Svejkovsky et al. 2002). Reduced upwelling in 2005, which has been linked with higher than normal ocean water temperature apparently unrelated to El Niño, represents a major ecosystem concern to fisheries in the Pacific Northwest (Martin 2005).

Downwelling is the opposite phenomenon, occurring when southern winds push offshore waters towards the shore, moving nearshore surface waters downward and causing offshore waters to be warmer and of lower salinity than is typical. Storm generated downwelling also may influence sand transport, and is considered a source of sediment to the inner shelf off northern California (Cacchione and Drake 1990 cited in Nittrouer and Wright 1994).



Strong winds towards north or onshore may produce downwelling.

2.3.4 Climate Oscillation Patterns

El Niño Southern oscillation (ENSO) events are global-scale climatic variations with a dominant period of 5 to 7 years (Hickey 1993). They are characterized by a decrease in atmospheric pressure in the eastern tropical Pacific Ocean, a decrease in the easterly trade winds, and an increase in sea level on the west coast of North and South America (Chelton et al. 1982). During an ENSO event, the California Current is weakened and the warmer Equatorial Countercurrent moves poleward. The atmospheric disturbances associated with these events may cause abnormally warm water temperatures, reversal of westerly trade winds, and increased sea levels (Flick 1998). Winter storms during El Niño conditions tend to be more vigorous with higher than average wave heights (Hickey 1993). There were six events with wave heights in excess of 19 ft (6 m) during the 1982-1984 El Niño; whereas, there were only 18 such events between 1900 and 1984 (Seymour et al. 1984). Although storms may result in increased sediment delivery to the coast, the high wave conditions may result in substantial beach erosion and, because of strong poleward to offshore current flow, loss of sediment offshore outside the littoral zone. The severe storms associated with the 1982-1983 and 1997-1998 ENSO events contributed to denuded beach conditions in southern and central California (Inman and Masters 2005, USACE 2005a).

Following El Niño conditions there may be a period of cold-water conditions, caused by stiffening trade winds, drought in the central and eastern Pacific, and rain in the western Pacific. These irregular events are termed La Niña (http://www.elnino.noaa.gov/lanina.html.).

El Niño and La Niña events may be thought of as lying on top of the larger scale temperature distribution determined by the Pacific Decadal Oscillation (PDO) (http://topex-www.jpl.nasa.gov/science/pdo.html). The PDO, which sometimes is described as a long-lived El Niño like climate pattern, occurs on the order of every 20 to 30 years (Mantua et al. 1997). Generally, PDO is detected as warm or cool surface waters, which have been termed “warm” or “cool” phases.

These climate patterns are relevant with respect to understanding existing marine ecosystem conditions at the time a sediment management project may be scheduled. This may be of particular interest with respect to evaluations of recovery rates after disturbance. Major changes in Pacific marine ecosystems have been correlated with phase changes in the PDO with warm eras characterized by inhibited coastal biological productivity off California and cool era having the opposite trend (www.elnino.noaa.gov; (http://www.atmos.washington.edu/~mantua/REPORTS/PDO/PDO_egec.htm). ENSO events may result in substantial effects on marine resources due to depressed upwelling, nutrient limitation, higher temperatures, wave energy disturbance, and influx of southern species farther up the coast than is typical (Chelton et al. 1982, Broenkow 1996).

Useful References on ENSO and PDO Climate and Marine Ecosystem Patterns

- www.elnino.noaa.gov
- jisao.washington.edu/pdo
- www.jpl.nasa.gov/science/el-nino.html
- http://darwin.bio.uci.edu/~sustain/ ENSO.html

2.4 Water Quality Objectives and Natural Water Characteristics

Marine water quality may be affected by several factors, including oceanographic processes, climate, storm water runoff, wastewater and commercial/industrial discharges, vessel discharges, and atmospheric fallout. Currents, waves, seasonal storms, as well as episodic events such as phytoplankton blooms and ENSO conditions also contribute to changes in marine water quality.

Section 401 of the CWA provides the SWRCB and RWQCBs with the regulatory authority to waive, certify, or deny projects that result in discharge to surface waters of the State. The RWQCB or SWRCB is required to submit Waste Discharge Requirements (WDRs) for a 401 Certification, unless waived pursuant to CWA section 13269. To waive or certify a project, these agencies must find that the proposed discharge will comply with State water quality standards (http://www.swrcb.ca.gov/CWA401/index.html).

Water quality standards address the following three factors:

- Beneficial Uses - uses of water for drinking, agriculture, navigation, recreation, and fish and wildlife habitat;
- Objectives - numeric and narrative limits on water characteristics or bans on substances, which affect water quality; and
- Anti-Degradation Policy- which requires that existing high-quality waters be protected and maintained.

Regional Water Quality Control Boards (Regional Boards) maintain Water Quality Control Plans (Basin Plans) for each major hydrologic basin in California. The Basin Plans list the water bodies in each region and describe the applicable water quality objectives. Water quality objectives are specified for ocean waters and other waters, which may be divided into categories such as enclosed bays and estuaries, inland surface waters, groundwater, and other specific water bodies depending on regional board.

Water quality objectives for ocean waters and/or enclosed bays and estuaries are relevant to sediment management activities involving dredging and/or discharge of sands with beach placement, nearshore placement, and/or beach nourishment, and are described below. Water quality objectives related to inland surface waters (unless bays and estuaries) and groundwater are not applicable to such sediment management activities and are not discussed further.

2.4.1 Water Quality Objectives for Ocean Waters

All coastal RWQCB Basin Plans specify ocean water quality objectives consistent with the California Ocean Plan (Water Quality Control Plan, Ocean Waters of California) and the Thermal Plan (Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California). The California Ocean Plan specifies water quality objectives for protection of marine water quality (Table 2.4-1). Some objectives are designed to protect public beneficial uses. Others are more specific to protection of biological resources living and/or coming in contact with the waters. Sediment management projects must comply with water quality objectives that protect both public and biological resource beneficial uses.

Table 2.4-1. California Ocean Plan water quality objectives.

B. Bacterial Characteristics

1. Water-Contact Standards

a. Within a zone bounded by the shoreline and a distance of 1,000 feet from the shoreline or the 30-foot depth contour, whichever is further from the shoreline, and in areas outside this zone used for water contact sports, as determined by the Regional Board, but including all kelp beds, the following bacterial objectives shall be maintained throughout the water column:

30-day Geometric Mean – The following standards are based on the geometric mean of the five most recent samples from each site:
i. Total coliform density shall not exceed 1,000 per 100 ml;
ii. Fecal coliform density shall not exceed 200 per 100 ml; and
iii. Enterococcus density shall not exceed 35 per 100ml.
Single Sample Maximum:
i. Total coliform density shall not exceed 10,000 per 100 ml;
ii. Fecal coliform density shall not exceed 400 per 100ml;
iii. Enterococcus density shall not exceed 104 per 100 ml; and

b. The "Initial Dilution Zone" of wastewater outfalls shall be excluded from designation as "kelp beds" for purposes of bacterial standards, and Regional Boards should recommend extension of such exclusion zone where warranted to the SWRCB (for consideration under Chapter III.H). Adventitious assemblages of kelp plants on waste discharge structures (e.g., outfall pipes and diffusers) do not constitute kelp beds for purposes of bacterial standards.

2. Shellfish Harvesting Standards

At all areas where shellfish may be harvested for human consumption, as determined by the Regional Board, the following bacterial objectives shall be maintained throughout the water column:

The median total coliform density shall not exceed 70 per 100 mL, and not more than 10 percent of the samples shall exceed 230 per 100 mL.

C. Physical Characteristics

1. Floating particulates and grease and oil shall not be visible.
2. The discharge of waste shall not cause aesthetically undesirable discoloration of the ocean surface.
3. Natural light shall not be significantly reduced at any point outside the initial dilution zone as the result of the discharge of waste.
4. The rate of deposition of inert solids and the characteristics of inert solids in ocean sediments shall not be changed such that benthic communities are degraded.

D. Chemical Characteristics

1. The dissolved oxygen concentration shall not at any time be depressed more than 10 percent from that which occurs naturally, as the result of the discharge of oxygen demanding waste materials.
2. The pH shall not be changed at any time more than 0.2 units from that which occurs naturally.
3. The dissolved sulfide concentration of waters in and near sediments shall not be significantly increased above that present under natural conditions.
4. The concentration of substances set forth in Chapter II, Table B in marine sediments shall not be increased to levels which would degrade indigenous biota.
5. The concentration of organic materials in marine sediments shall not be increased to levels which would degrade marine life.
6. Nutrient materials shall not cause objectionable aquatic growths or degrade indigenous biota.

E. Biological Characteristics

1. Marine communities, including vertebrate, invertebrate, and plant species, shall not be degraded.
2. The natural taste, odor, and color of fish, shellfish, or other marine resources used for human consumption shall not be altered.
3. The concentration of organic materials in fish, shellfish or other marine resources used for human consumption shall not be bioaccumulate to levels that are harmful to human health.

F. Radioactivity
Discharge of radioactive waste shall not degrade marine life.

Source: SWRCB 2005

The water quality objectives include a combination of observations, numerical criteria, restriction against significant changes from natural (ambient) conditions, and non-degradation criteria. Significance is defined in the Ocean Plan as statistically different means at the 95% confidence level. Degraded is defined as statistically significant differences between waste field and reference areas in demersal fish, benthic invertebrates, and/or attached algae based on measures such as density, diversity, and/or growth.

Visual observations pertain to floating particulates, grease and oil, and discoloration. Compliance with Ocean Plan objectives requires that there be no visible floating particulates, grease, and oil, and no aesthetically undesirable discoloration of the ocean surface.

The natural light objective specifies no significant reduction outside the initial dilution zone, which is defined in the Ocean Plan for surface discharges or shallow water submerged discharges as being complete when the momentum induced velocity of the discharge ceases to produce significant mixing of the waste or the diluting plume reaches a fixed distance from the discharge as specified by the Regional Board. The Ocean Plan specifies that natural light may be determined by measurement of light transmissivity or total irradiance, or both, according to monitoring needs of the Regional Board.

Numerical water quality objectives in the Ocean Plan relate to bacteria, dissolved oxygen, pH, chemical constituents, and radioactivity. The Thermal Plan provides numerical objectives for temperature.

Compliance with dissolved oxygen and pH numerical objectives require that measurements of these constituents be within specified bounds relative to ambient conditions, which for dissolved oxygen is 10 percent and for pH is 0.2 units. The Central Coast Basin Plan also specifies additional numerical criteria for dissolved oxygen ($\geq$ 5 mg/L instantaneous, $\geq$ 7 mg/L annual mean) and pH ($\geq$ 7 or $\leq$ 8.5). The San Diego Basin Plan considers pH ranges of 6.5 to 9.0 as harmless. The Thermal Plan specifies that increases in temperature from new discharges to coastal waters shall not exceed 4°F (2.2^{o}C).

Compliance objectives for bacteria pertain to water contact recreation and areas of shellfish harvesting. Assembly Bill 411 (AB-411) was passed in 1997 that establishes bacteriological standards for water contact recreation at beaches. The AB-411 standard is similar to the California Ocean Plan water quality objectives for total and fecal coliform bacteria (Table 2.4-2).

Table 2.4-2. Comparison of Ocean Plan and AB-411 bacteriological standards.

	Ocean Plan (2001)		**AB-411**	
Parameter	**30-day (density/100 ml)**	**Single Sample (density/100 ml)**	**30-day (MPN/100 ml)**	**Single Sample (MPN/100 ml)**
Total Coliform	1,000	10,000	1,000	10,000 or 1,000 if fecal > 10% of total coliform
Fecal Coliform	200	400 ($\leq$ 10 % of samples in 60-day period)	200	400
Enterococcus			35	104

Note: MPN = most probable number of bacteria colonies per 100 milliliters
MPN standards also apply to measurements based on colony forming units (CFU)

The Ocean Plan also specifies that no more than 10 percent of the total samples analyzed in a 60-day period may exceed a fecal coliform density of 400 per 100 mL. AB-411 also includes a standard for enterococcus bacteria. Beach health risk postings are regulated according to AB-411 standards. Compliance criteria for bacteria In areas where shellfish are harvested require median total coliform density of ≤ 70/100 mL with not more than 10 percent of samples > 230/100 mL.

Objectives regarding chemical characteristics such as dissolved sulfides, nutrients, organics, and chemical constituents specified in Table B of the Ocean Plan (metals, ammonia, pollutants, radioactivity) relate to compliance with numerical water quality objectives and/or objectives that specify that chemical constituents shall not concentrate in sediments to levels that would degrade biota, cause objectionable aquatic growths, or bioaccumulate in marine organisms to levels that pose human health risk. Demonstration of compliance with these objectives involves testing of "waste" prior to discharge and may involve testing of ocean waters and marine organisms depending on type of discharge.

Sediment management activities involving dredging and/or discharge of sediments in waters of the United States are required to have the sediments tested prior to such activities to provide factual data upon which determinations by USACE and USEPA are made regarding permitted disposal and/or beneficial use options (e.g., beach nourishment). Generally, a tiered approach to analysis is used (USACE and USEPA 2004) consistent with guidelines in the Inland Testing Manual (USEPA and USACE 1998) and/or Ocean Testing Manual (USEPA and USACE 1991). First-tier analysis evaluates compatibility of the physical characteristics of sediments between dredge and/or discharge materials and the receiver site and the likelihood for contamination based on physical characteristics, previous and still appropriate chemical testing of sediments from the same vicinity, and/or whether the location of dredge/discharge materials is far removed from contaminant sources or from pre-industrial age deposits not exposed to modern pollution (40 CFR Sec. 230.60(a), U.S. Code of Federal Regulations 2003). Second-tier chemical analysis may or may not be required for beach compatible sands depending on whether additional data are required to determine the potential for chemical contamination. Third-tier biological toxicity testing is only required when contamination is detected and additional analysis is necessary to determine potential for biological impacts and suitable disposal options.

USACE and USEPA (2004) specify guidelines for acceptability of dredge material for beneficial use as beach nourishment, as follows: it should closely match the sediment composition of the eroding beach and be low in fine sediments, organic material, and pollutants. Because sands placed on the beach or in the nearshore are required by environmental regulations to be "clean" and free from substantial contamination, the appropriate testing data used to demonstrate compatibility of materials for beach nourishment by default will satisfy most Ocean Plan numerical chemical objectives. Similarly, beach compatible "clean" sands would be expected to satisfy physical, chemical, and biological characteristics and radioactive non-degradation objectives and biological objectives related to alteration of natural taste, odor, and color of fish and shellfish used for human consumption. Therefore, numerical criteria for chemical contaminants and radioactivity are not discussed further in this report.

The Ocean Plan specifies effluent limitations for industrial discharges and public owned treatment works that lack specific guidelines (Table 2.4-3). Effluent limitations may be applied to dredge/disposal projects (e.g., Crescent City maintenance dredging; USACE 1998c).

Table 2.4-3. California Ocean Plan effluent limitations.

Parameter	Unit	Monthly 30-day Average	Weekly 7-day Average	Instantaneous Maximum
Grease and Oil	mg/L	25	40	75
Suspended Solids	mg/L	(75% removal from influent stream before discharge)	60	
Settleable Solids	ml/L	1	1.5	3
Turbidity	NTU	75	100	225
pH	units	6-9	6 to 9	6-9

Note: suspended solid limitation may be adjusted to suit environmental and effluent characteristics of discharge based on RWQCB recommendation and concurrence from the USEPA.

2.4.2 Water Quality Objectives for Enclosed Bays and Estuaries

Water quality objectives for enclosed bays and estuaries also include a combination of visual observations, numerical criteria, restriction against significant changes from natural (ambient) conditions, and non-degradation criteria. All RWQCBs have visual observation water quality objectives for floatables, oil and grease, color (discoloration), suspended and settleable solids, suspended sediments, and biostimulatory growths (algae). In addition, observation-based objectives concern taste and odor of fish and shellfish used for human consumption. These water quality objectives specify they not cause nuisance or adversely affect beneficial uses. Several numerical objectives have been established for enclosed bays and estuaries, with some variability among regional boards (Table 2.4-4).

Generally, turbidity values must be within 10 to 20 percent of ambient measurements depending on background concentration. Some RWQCBs specify that turbidity measurements not exceed 10 Nephelometric Turbidity Units (NTU) or 10 Jackson Turbidity Units (JTU) above ambient values when turbidity is naturally high.

In addition, the San Diego RWQCB specifies that water transparency Secchi disk depths not be reduced by greater than 50% of ambient unless caused by rainfall runoff or dredging projects conducted in conformance with waste discharge requirements in San Diego Bay, Secchi depths must be > 8 ft in 20% of the readings in waters of any depth or ≥ 80% of ambient in waters < 10 ft (3 m) for not less than 20 percent of the readings.

Dissolved oxygen concentrations must be above 5 mg/L and must range between 5 and 9 mg/L depending on beneficial uses and the RWQCB. In addition, objectives for annual or median dissolved concentrations are specified by some RWQCBs, as follows: three-month median shall not be less than 80% in San Francisco Bay (SFBRWQCB 2004); median values should not fall below 85% saturation as result of controllable water quality condition for Central Coast enclosed bays and estuaries (SWRCB and CCRWQCB 1988); annual mean dissolved oxygen concentrations of not less than 6 mg/L are specified for Los Angeles-Long Beach Harbors (LARWQCB 1994); and an annual mean of not less than 7 mg/L more than 10% of the time is specified for enclosed bays and estuaries in San Diego (SDRWQCB 1994).

Table 2.4-4. Numeric water quality objectives for enclosed bays and estuaries.

Parameter	North Coast	San Francisco Bay	Central Coast	Los Angeles	Santa Ana	San Diego
Turbidity where ambient is 0 to 50 NTU	≤ 20% above ambient	Not specified	≤ 20% above ambient	≤ 20% above ambient	≤ 20% above ambient	≤ 20% above ambient
Turbidity where ambient is 50 to 100 NTU	same	≤ 10% above ambient	Not > 10 JTU	≤ 10% above ambient	Not > 10 NTU	Not > 10 NTU
Turbidity where > 100 NTU	same	≤ 10% above ambient	≤ 10% above ambient	≤ 10% above ambient	≤ 10% above ambient	≤ 10% above ambient
pH	≥ 6.5 or ≤ 8.5, ≤ 0.2 units from ambient MAR	≥ 6.5 or ≤ 8.5, ≤ 0.5 units from ambient	≥ 7 or ≤ 8.5, ≤ 0.2 units from ambient MAR	≥ 6.5 or ≤ 8.5, ≤ 0.2 units from ambient	≥ 7 or ≤ 8.6, ≤ 0.2 units from ambient	≥ 7 or ≤ 9, ≤ 0.2 units from ambient
Dissolved oxygen (mg/L)	≥ 7-9 SPWN ≥ 6 COLD, ≥ 5 WARM, MAR	≥ 7 COLD, ≥ 5 WARM, 3-month median 80% saturation	≥ 7 COLD, MAR, SPWN, ≥ 5 WARM, median values ≥ 85% saturation	≥ 5 MAR, WARM, ≥ 6 COLD, mean ≥ 6 LA-LB Harbors	No adverse effect to beneficial uses	≥ 6 COLD, ≥ 5 WARM or MAR, mean ≥ 7
Temperature *	≤ 5°F above ambient WARM; ≤ 4°F bays, estuaries	≤ 5°F above ambient WARM, COLD; ≤ 4°F bays, estuaries	≤ 5°F above ambient WARM, COLD; ≤ 4°F bays, estuaries	≤ 5°F above ambient WARM, COLD; ≤ 4°F bays, estuaries	≤ 4°F bays, estuaries	≤ 5°F above ambient COLD; ≤ 4°F bays, estuaries

Sources: LARWQCB 1994, NCRWQCB 2005, SARWQCB 1995, SDRWQCB 1994, SFBRWQCB 2004, SWRCB and CCRWQCB 1988.

*Note: COLD = cold freshwater habitat , WARM = warm freshwater habitat, MAR = marine habitat, SPWN = Fish spawning beneficial use.

Criteria for pH range between 6.5 and 9 with an allowable deviation from ambient of 0.2 to 0.5 pH units depending on the RWQCB.

All RWQCBs follow guidance in the Thermal Plan for temperature water quality objectives for bays and estuaries (should not exceed 4°F), and inland surface waters with WARM or COLD beneficial use designations (should not exceed 5°F).

Several numerical chemical (ammonia, toxic pollutants) and radioactivity objectives also apply to enclosed bays and estuaries. Similar to the above discussion under Ocean Plan water quality objectives, these objectives are not discussed further in this report because sands placed on the beach or in the nearshore for beach nourishment are required by environmental regulations to be “clean” and free from substantial contamination.;

Consequently, toxic effects, bioaccumulation, and/or impairments due to chemical contamination are not expected.

Bacteria numerical criteria for enclosed bays and estuaries may cover water contact recreation (REC-1), non-contact water recreation (REC-2), and/or shellfish harvesting (SHELL) beneficial uses (Table 2.4-5). Criteria mainly apply to fecal coliform bacteria. However, criteria for *Escherichia coli* and enterococci bacteria also are specified for San Diego Bay, as follow: (1) in areas where bay waters are used for whole fish handling, density of *E. coli* shall not exceed 7/100 mL in more than 20 percent of any 20 daily consecutive samples of bay water;(2) in REC-1 areas, *E. coli* density of ≤ 126 under steady state conditions and maximums of 235-576/100 mL depending on use; and (3) in REC-1 areas, enterococci density of 35/100 mL under steady state conditions and maximums of 104-500/100 mL depending on use.

Table 2.4-5. Comparison of fecal coliform bacteria objectives for enclosed bays and estuaries.

Fecal Coliform Objective	North Coast	San Francisco Bay	Central Coast	Los Angeles	Santa Ana	San Diego
Water Contact (REC-1) ≥ 5 samples for 30 day (value/ 100 mL)	≤ 50, ≤ 10% of samples ≤ 400		log mean of 200, ≤ 10% of samples ≤ 400	log mean of 200, ≤ 10% of samples ≤ 400	log mean of 200, ≤ 10% of samples ≤ 400	log mean of 200, ≤ 10% of samples ≤ 400
Non Water Contact (REC-2) (value/ 100 mL)	NS		2,000, ≤ 10% of samples ≤ 4,000	2,000, ≤ 10% of samples ≤ 4,000	NS	2,000, ≤ 10% of samples ≤ 4,000
Shellfish Harvesting (SHELL) (value/ 100 mL)	≤ 43 (5-tube test) or ≤ 49 (3-tube test)		30-day median ≤ 70, ≤ 230 (5-tube test) or ≤ 330 (3-tube test)	30-day median ≤ 70, ≤ 230 (5-tube test) or ≤ 330 (3-tube test)	30-day median ≤ 14 MPN, ≤ 10% of samples ≤ 43	30-day median ≤ 70, ≤ 230 (5-tube test) or ≤ 330 (3-tube test)

NS = not specified.
Note: MPN = most probable number

Physical, chemical, and biological water quality standards relevant to sediment management activities, the biological resources and/or functions they are intended to protect, and natural water characteristics are briefly reviewed below.

Floating Particulates

Floating materials are of concern because they may be an aesthetic nuisance as well as provide substrate for undesirable bacterial and algal growth and insect vectors (LARWQCB 1994, SDRWQCB 1994). Floating materials also are of concern if they interfere with foraging activities of marine associated species. Water quality objectives in the Ocean Plan

and regional Basin Plans specify floating materials (solids, liquids, foams, scum) shall not be visible (ocean) or in concentrations that cause a nuisance or adversely affect beneficial uses (bays, estuaries). Floatables are anthropogenic contaminants that may be present in water as a result of runoff and/or discharges, but otherwise do not naturally occur.

Oil and Grease

Oils and related materials are not soluble in water and may form a film on the water's surface. Consequently, oil and grease are of concern because the film may result in nuisance conditions of offensive odors and visual impacts, and oil and grease may coat birds and other aquatic organisms, resulting in adverse effects to respiration and/or thermoregulation (LARWQCB 1994, SDRWQCB 1994). Water quality objectives in the Ocean Plan and regional Basin Plans specify oil, grease, waxes, and/or other petroleum materials shall not be visible (ocean) or in concentrations which cause nuisance or adversely affect beneficial uses (bays, estuaries).

Generally, oil and grease result from anthropogenic inputs accidental spills, leaks from vessels and marine equipment, runoff, and/or discharges. Sheens of petroleum materials also may occur in areas of natural oil seeps.

Color (Water Discoloration)

Water color may be altered by plant matter, plankton, suspended sediment, and/or discharges. Color is primarily a concern for aesthetic reasons, although extremely dark colored water can limit light penetration and cause additional water quality problems (LARWQCB 1994). Water quality objectives in the Ocean Plan and regional Basin Plans specify discoloration shall not be aesthetically undesirable (ocean) or cause nuisance or adversely affect beneficial uses (bays, estuaries).

The natural color of coastal waters generally is greenish. However, color may have a brown cast during storm and/or high wave conditions due to suspended particulates and sediments. During phytoplankton blooms, water color may be altered to red, yellow, green, or brown (Hardy 1993). Phytoplankton blooms may last from a few days to 6 weeks (*ibid.).*

Suspended and Settleable solids, Suspended Sediment

Suspended and settleable solids and suspended sediment are of concern because of the potential to result in anaerobic benthic conditions, abrasion of surface membranes, covering of benthic organisms, clogging of fish gills, interference with respiration and/or sensory perception in aquatic organisms, and/or screening out light and hindering photosynthesis (LARWQCB 1994, SDRWQCB 1994). The Ocean Plan water quality objective addresses the rate of deposition and composition of inert solids (e.g., sediments) in the discharge, requiring that these not degrade the resident benthic communities living on the bottom. The bays and estuaries water quality objective specifies that suspended sediment load, discharge rate, and/or concentration shall not cause a nuisance or adversely affect beneficial uses.

Suspended and settleable sediment and/or solid concentrations may be naturally elevated in ocean waters from runoff, wave energy, and storm conditions. Concentrations in bays, lagoons, and harbors may range higher than in the open ocean due to creek, river, and/or

stream discharges within the water body, relatively shallow depths, and/or resuspension by vessel traffic.

During storms suspended sediment concentrations in rivers can be moderate to high. Total suspended sediment (TSS) concentrations after storm events ranged from 300 to 400 mg/L in the Los Angeles River and Ballona Creek in 1970-1971, and from 30 to >1,000 mg/L in the Los Angeles River in 1978 (Hickey 1993).

TSS concentrations in embayments may vary greatly depending on season and location (e.g., depth, proximity to river inflows). For example, TSS concentrations in San Francisco Bay ranged from 25 to 600 mg/L, with higher values associated with winter storms (Cloern et al. 2000, LFR 2004).

Moderate to high concentrations also may occur in nearshore and offshore waters due to stormwater runoff and high waves. Because stormwater plumes contain freshwater, they are buoyant (hypopycnal) and disperse under the influence of currents and winds. Hypopycnal plumes may spread several miles offshore and alongshore (Washburn et al. 2003), and during substantial storm discharges may carry finer silts up to 62 mi (100 km) offshore (Thornton 1981). Plume areas associated with river discharges from Los Angeles watersheds between 1997 and 2003 ranged from < 19.3 square miles (mi^2) (< 50 km^2) to a maximum of 386 mi^2 (1,000 km^2) during the 1998 El Nino period (Nezlin and DiGiacomo 2004).

On the other hand, sediments and fine particles (organic and inorganic) that form larger flocculated aggregates tend to settle quickly (e.g., > 0.2 cm/s to 0.5 cm/s) (Kineke and Sternberg 1989, Eisma 1993). TSS concentrations of 5 milligrams per liter (mg/L) were recorded in the Santa Barbara Channel after the 1969 storm (Drake et al. 1971 cited in Chambers Group 1992). Warrick et al. (2004) reported concentrations up to 60 mg/L near the river mouths of the Santa Clara and Ventura Rivers in southern California. Peak TSS of 56 to 100 mg/L were estimated offshore during storm runoff from the Russian River in northern California (Sherwood et al. 1994).

Sediment concentrations along the seabed also are greater during storm conditions. Sediments become mobilized, particularly under high wave conditions, and turbid bottom plumes may be transported many kilometers offshore at concentrations > 1,000 mg/L (Ogston and Sternberg 1999). Limited observations indicate that under very large river floods, excessively turbid (> 10,000 mg/L) near bottom (hyperpycnal) plumes may be produced, but likely are short-lived (i.e., hours) (Warrick and Milliman 2005).

Notwithstanding storm conditions, suspended sediments are a common phenomenon in nearshore waters due to the influence of waves. In shallow water, wave energy generates a circular motion within the water column that may induce resuspension and transport of bottom sediments. Rip currents transport higher turbidity water beyond the surf zone to nearshore waters. Generally, rip currents are more pronounced and nearshore waters more turbid during high wave conditions associated with higher tides, high winds, and/or storm swells

Generally, suspended sediment concentrations are higher inshore near the bottom and decrease with distance offshore and with height above the sea bed. Turbid near bottom (nepheloid) layers characterize sediment transport in the littoral zone. Mean TSS concentrations of 500 mg/L at 21 inches (in) (53.5 cm) above the bottom and 6,000 to

14,000 mg/L at the bottom, with short duration near-bottom peak concentrations of 20,000 to 40,000 mg/L were measured and/or estimated in the surf zone off Oregon (Beach and Sternberg 1988, Beach and Sternberg 1992, Ogston and Sternberg 1995). Near-surface ambient TSS concentrations of 17 to 26 mg/L were reported in the surf zone off San Diego, southern California (Sherman et al. 1998).

Nearshore surface TSS concentrations of < 1 to 47 mg/L were recorded over a 13-year period offshore Carlsbad, southern California (MEC 2000a). Near-bottom concentrations of 50 to 240 mg/L were measured at depths of approximately 39 ft (12 m) off central California (Storlazzi and Jaffe 2002).

Turbidity

Turbidity is of concern because it can result in a variety of water quality impairments, such as disturb water clearness, diminish penetration of light, adversely affect photosynthesis, and high concentrations can be directly lethal to aquatic life (LARWQCB 1994, SDRWQCB 1994).

Turbidity in rip current

Photo credit: Nick Steers, Life Guard Captain, http://www.ripcurrents.noaa.gov

Turbidity of marine waters varies considerably depending on factors such as proximity to river discharges, wave conditions, and occurrence of phytoplankton blooms. Thackston and Palermo (2000) refer to natural waters with 1-3 NTU as extremely clear, 10-15 NTU as having nominal turbidity, and 100-1,000 NTU as very turbid. Turbidity values of > 50 NTU have been measured in association with storms and/or high wave conditions (MEC 2000).

Natural Light Limitation

The Ocean Plan specifies natural light shall not be reduced at any point outside the initial dilution zone as the result of waste discharge (SWRCB 2001). The regional Basin Plans do not have a separate water quality objective for light, although light limitation concerns are mentioned in association with water quality objectives for color, suspended or settleable materials, sediment, and turbidity (LARWQCB 1994, SDRWQCB 1994). The regional Basin Plans objectives for color, suspended and settleable solids, and suspended sediments were described above, and basically specify they shall not cause nuisance or adversely affect beneficial uses. The water quality objectives for turbidity, which include numerical objectives for bays and estuaries, also are described above.

Several factors affect light transmission in water, including river discharges and storm water runoff, resuspension of sediments by waves and/or winds, upwelling of turbid waters, phytoplankton blooms, and discharges of wastewaters. Turbidity is the primary factor affecting light penetration and consequently the depth of the photic zone, where light is sufficient for photosynthesis.

Reduced light transmission also may be associated with biological processes, including plankton blooms. Generally, plankton blooms are associated with periods of upwelling and may last for a few days to several weeks (Hardy 1993). Dense blooms can deplete oxygen

and alter water color. Reduction in water clarity from plankton blooms and/or suspended sediments may limit light penetration, thereby reducing the compensation depth where photosynthesis equals respiration. Generally the compensation depth represents 1% of the surface radiation. Photosynthesis occurs at depths shallower, but not deeper than the compensation depth.

Light transmittance generally decreases closer to shore and with increasing depth. Transmissivity values ranging from 40 to 90% have been measured in surface waters off southern California (MEC 2000a). The annual mean transmissivity was 66% for inshore and 85% for offshore waters in Santa Monica Bay when averaged over the ten-year period from 1987 to 1997 (Nezlin et al. 2004).

Light transmittance in enclosed bays and estuaries may range lower than in the open ocean due to depths, currents, winds, and anthropogenic impacts such as vessel traffic. For example, annual mean transmissivity values ranged from 42 to 71% in surface waters and 20 to 64% in near bottom waters in Long Beach and Los Angeles Harbors in 2000 (MEC 2000b). Light transmittance ranged from 51 to 90% in Marina del Rey in 2001-2002 (ABC 2002).

Dissolved Oxygen

DO is of concern because adequate levels are required to support aquatic life, and depression can lead to anerobic conditions resulting in odors or, in extreme cases, fish kills (LARWQCB 1994, SDRWQCB 1994). Water quality objectives in the Ocean Plan and regional Basin Plans specify that dissolved oxygen concentrations must be within 10% of ambient (ocean) and/or must be 5 to 9 mg/L and not less than 5 mg/L depending on beneficial uses (enclosed bays and estuaries). Mean or median values of 6 to 7 mg/L or 80 to 85% are specified as objectives for some enclosed bays and estuaries.

Natural fluctuations in dissolved oxygen concentrations result from temperature and salinity changes, vertical water column mixing, phytoplankton blooms, upwelling/downwelling, El Niño, and movements of water masses. DO concentrations generally decrease with depth due to losses from biological respiration and decomposition.

DO concentrations in coastal waters typically range between approximately 5 and 11 mg/L (Thompson et al. 1987, Chambers Group 1992, MEC 2000). Dissolved oxygen concentrations < 5 mg/L may result in stress to marine species. Concentrations < 4 mg/L were found to reduce number of species of marine invertebrates in Los Angeles Harbor (Reish 1971 cited in Thompson et al. 1993).

Generally, nearshore waters are near saturation due to turbulent mixing and exchange at the air/water interface. DO above 100% saturation indicates that the biological source of oxygen (phytoplankton photosynthesis) exceeds the losses of oxygen to the atmosphere and to respiration by the biota. Values below 100% saturation indicate that the processes of biological and chemical oxygen consumption exceed the rate of primary production.

Enclosed bays and estuaries may have more variable dissolved oxygen content than the open ocean due to depth related temperature and salinity fluctuations, nutrient and phytoplankton and/or algae blooms, and/or muted and/or restricted tidal exchange. For example, DO values in San Francisco Bay ranged from 60 to 140% saturation between

1993 and 1998 (Cloern et al. 2000), and typical DO concentrations range between 6 and 10 mg/L (LFR 2004). Surface DO concentrations ranged from 6.7 to 8.1 mg/L, and differences up to 3.5 mg/L were noted between surface and bottom measurements in Long Beach and Los Angeles Harbors in 2000 (MEC 2000). DO concentrations in Marina del Rey ranged between 7 to 7.9 mg/L near the entrance and 1.2 to 13.5 mg/L in shallow back channel areas (ABC 2002).

pH

The hydrogen ion concentration of water, pH, is of concern because minor changes can harm aquatic biota, and changes alter the chemical form of certain constituents, thereby increasing their bioavailability and toxicity (LARWQCB 1994, SBRWQCB 1994). The pH scale ranges from 1 to 14, with 1 to 6.9 being acid, 7.1 to 14 being alkaline, and 7.0 being neutral. A change of one point on this scale represents a ten-fold increase in acidity or alkalinity (SDRWQCB 1994). Water quality objectives in the Ocean Plan and regional Basin Plans specify that values should range between 6.5 and 9 and not deviate by more than 0.2 to 0.5 units depending on habitat and beneficial use.

Ocean water pH values in nearshore and offshore waters of southern California typically range from 7 to 9 (MEC 2000a). Seawater is well buffered and only varies slightly geographically and with depth.

The pH of large embayments such as San Francisco Bay has been reported to be relatively constant, ranging from 7.8 to 8.2 (LFR 2004). Similarly, annual mean pH values ranged from approximately 7.8 to 8.1 in Long Beach and Los Angeles Harbors in 2000, although differences between surface and bottom waters often were greater than 0.2 units (MEC 2000b). Historically, pH concentrations in Marina del Rey have ranged between 6.8 and 8.7 (ABC 2002).

Temperature

Rapid temperature changes are of concern because they can adversely affect aquatic life (LARWQCB 1994, SDRWQCB). Water quality objectives in the Ocean Plan and regional Basin Plans specify that increases in temperature from discharges shall not exceed 4 degrees Fahrenheit (^{o}F) (2.2 ^{o}Centigrade, C) in the ocean and enclosed bays and estuaries, or 5°F (2.7^{o}C) for inland waters with COLD or WARM beneficial use designations.

Seasonal temperatures in nearshore marine waters range from approximately 54 to 75.2^{o}F (12 to 24°C) off San Diego County and 53 to 62°F (12 to 17°C) off Santa Barbara County in southern California (Chambers Group 1992, MEC 2000a). Water temperatures off central and northern California range cooler. Temperatures seasonally vary between 46 ^{o}F (8°C) during winter and 63 ^{o}F (17°C) during fall in Monterey Bay (Broenkow 1996). During El Nino conditions sea surface temperatures may range 2 to 4°F (1 to 2°C) above normal.

Temperature fluctuations in embayments may be similar to warmer than the ocean. For example, surface temperatures ranged from 55 to 75 ^{o}F (13 to 24°C) in Long Beach and Los Angeles Harbors in 2000 (MEC 2000b). Temperatures in shallower and/or more tidally restricted bays and estuaries may range warmer and/or colder than in the open ocean due to relatively shallow depths and/or restricted tidal exchange. Temperatures ranged from 52 to 73 ^{o}F (11.1 to 22.8 ^{o}C) in Marina del Rey in 2001-2002 (ABC 2002).

Biostimulatory Substances

Nutrient concentrations are of concern when they lead to excessive growth of algae and/or other aquatic plants. Algal blooms can be aesthetically unpleasant (causing taste, odor, color problems) and may depress the dissolved oxygen content of water and result in fish kills (LARWQCB 1994, SDRWQB 1994). Water quality objectives in the Ocean Plan and regional Basin Plans specify that chemical constituents shall not concentrate to levels that would cause objectionable aquatic growths (ocean), or promote growth to such an extent to cause nuisance or adversely affect beneficial uses (enclosed bays and estuaries). The SFBRWQCB (2004) indicates that irregular and extreme levels of chlorophyll a or phytoplankton blooms may indicate this objective has been exceeded and require investigation.

The Los Angeles Regional Board has defined as nuisance when more than 10% of samples exceed 30% cover for impairment listing purposes, and USEPA used 30% cover by floating algae and 60% cover by bottom algae in the Total Maximum Daily Load (TMDL) specified for Malibu Creek (USEPA 2002).

The SDRWQCB (1994) provides guidance threshold values of total phosphorous (P) to prevent plant nuisance of 0.05 mg/L in any stream at the point where it enters any standing body of water, 0.025 mg/L in any standing body of water, and 0.1 mg/L in streams and other flowing waters, with these values not to be exceeded more than 10 percent of the time unless approved by the Regional Board. In addition, natural ratios of nitrogen (N) and P are to be maintained or a ratio of 10N:1P, on a weight by weight basis, if data are lacking.

Although not considered a standard for other water bodies, similar thresholds are included in TMDL targets for N and P for Malibu Creek, at least for part of the year. The N and P TMDL numeric targets for Malibu Creek are 1.0 and 0.1 mg/L during summer and 8.0 mg/L nitrogen during winter (no winter threshold is given for phosphorus) (USEPA 2002).

Generally, eutrophication is more of a concern for enclosed bays and estuaries, particularly when tidal mixing is limited. Nitrogen and phosphorous are the primary nutrients of concern, with nitrogen considered the primary controlling factor of eutrophication in most coastal systems (NRC 2000). Kennison et al. (2004) found macroalgae proliferated over mudflat areas in several southern California estuaries, but were less abundant in areas with good tidal flushing. No clear relationship was found between water column N concentrations and macroalgae abundance, suggesting site specific physical characteristics and/or other nutrient sources were influential.

Nitrogen, phosphorous, and silica have been associated with phytoplankton production in southern California coastal waters and, similar to macroalgae, nitrogen has been suggested as the most common limiting factor (Hardy 1993). Sources of nitrogen to coastal waters include upwelling, rain, river discharges, and coastal wastewater discharges (*ibid*).

Coastal nitrate levels of 0.1 to > 8 mg/L and phosphate concentrations of 0.1 to 0.8 mg/L have been reported off northern California; the higher concentrations were associated with upwelling (BLM 1978 cited in MEC 2000). Nutrient concentrations measured over different seasons in the Santa Barbara Channel ranged from 0 to 0.74 mg/L nitrate, 0.02 to 0.12 mg/L phosphate, and 0.03 to 0.96 mg/L silicate (Kolpack 1971 cited in Chambers Group 1992); all those concentrations suggest lack of upwelling.

2.5 Overview of Potential Biological Impacts Associated with Sediment Management Activities

Sediment management activities may affect biological resources directly, indirectly, and cumulatively (see Section 5.2 for detailed review). Direct impacts are those that occur at the same time and within the same boundaries that are physically disturbed by the project. Indirect impacts are secondary responses to the direct impacts and may also occur at the same time as the project, but at adjacent locations influenced by the project or may occur at adjacent locations that are influenced by the project after it is completed. Cumulative impacts result from the incremental impact of a project when added to other past, present, or reasonably foreseeable future projects and can be the result of direct and/or indirect impacts.

Direct impacts during sediment management activities may involve loss and/or disturbance of habitat and associated species from construction equipment, machinery, and removal and/or placement of sediments. Indirect impacts during construction generally involve disturbances associated with runoff to water, noise, and/or lighting. Indirect impacts after construction may include migration of sediments from the project site, continued runoff, and/or changed noise and/or lighting conditions. Direct impacts generally are easier to quantify, but are not necessarily the most serious and/or long-lasting impacts (Greene 2002). Cumulative impacts associated with are of increasing concern due to multiple and increasing uses in the coastal zone, including beach nourishment (Peterson and Bishop 2005).

Depending on the type and magnitude of direct and indirect impacts and the habitats and species present within the area of potential effect, individual impacts may be beneficial, adverse, significant, and/or have no effect on biological resources. The CEQA/NEPA environmental review process requires consideration of avoidance and minimization measures to comply with environmental laws and regulations that provide protection to sensitive biological resources. Under CEQA (Section 15370), mitigation may include the following types of measures:

- Avoiding the impact by not taking a certain action or parts of an action.
- Minimizing impact by limiting the degree or magnitude of the action and its implementation.
- Rectifying the impact by repairing, rehabilitating, or restoring the impacted environment.
- Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.
- Compensating for the impact by replacing or providing substitute resources or environments.

Generally, mitigation measures are considered in sequence with avoidance considered first and compensation last (CCC 1995). If an avoidance measure is determined feasible and prudent then it should be selected. Minimizing, rectifying, or reducing impacts are measures designed to reduce the severity of impact. Compensation mitigation is undertaken to replace lost or adversely impacted sensitive habitat with habitat having similar functions of

equal or greater ecological value. Compensatory mitigation may involve in-kind replacement with the same type of habitat or out-of-kind replacement with a different habitat, but in each case the intent of the mitigation is to provide similar ecological functions of equal or greater value.

Considerable scientific research and experimentation has been conducted to develop methods that create, enhance, and/or restore ecologically valuable habitats. Considerable advancement has been made in the field of restoration biology. However, achieving adequate and successful mitigation is challenging due to the complexity of ecologically valuable habitats (CCC 1995).

Different types of direct and indirect impacts associated with sediment management activities are briefly described below. Detailed review of types of impacts and vulnerabilities of habitats and species to sediment management activities are presented in Sections 3 and 4, respectively. The types of beneficial and adverse impacts that have been reported for sediment management projects are summarized in Section 5. Types of impact avoidance and mitigation measures that have been implemented during sediment management projects are reviewed in Section 6.

2.5.1 Equipment and Disturbance

Sediment management activities may result in direct equipment disturbance impacts associated with dredging or excavation of source sands, transport of sediments to the receiver site (vessels, vehicles, and/or pipelines), and/or placing of sediments at the receiver site (earthmoving equipment, vehicles). Indirect equipment disturbance may be associated with the physical presence and/or use of equipment, including increased human activity, noise, and/or lights associated with construction.

Equipment used during sediment management activities may include dredges (clamshell, cutterhead suction, or trailing suction hopper dredges), vessels (hopper dredges, work boats), earth moving equipment (cranes, bulldozers, backhoes, graders, and trucks), pipelines, and construction lighting.

Dredging and/or excavation will remove sediment and associated benthic organisms. The cut depression will infill from slumping of adjacent sediment and sedimentation over time, the duration of which will be influenced by the initial cut depth and sedimentation rate in the water body. Generally, complete mortality is assumed for organisms removed by the dredge, although some small percentage may survive depending on discharge location (Naqvi and Pullen 1982, NRC 1995, Greene 2002). Examination of core samples from dredged sediments pumped to a beach verified no live organisms (Parr et al. 1978).

Hydraulic dredging also may entrain organisms as a result of near bottom water being withdrawn at the same time as the sediment. Studies examining dredge entrainment effects report that overall entrainment rates are low, but mortality rates range from 56 to 100% depending on species and their size (LaSalle et al. 1991, Reine and Clarke 1998).

Earthmoving equipment used to excavate sediment also will remove associated benthic organisms. Generally, excavated sediments are placed in piles either directly into trucks and/or the piles are rehandled on site to move sediment from excavated channel to the beach receiver site. Although no reports were found, mortality of benthic organisms from

this activity also would be expected to be high to complete due to desiccation and burial effects.

Propellers, anchors, and chains associated with vessels have the potential to directly dislodge and/or damage subtidal vegetation, marine animals, and associated habitats, if present. Pipelines used to deliver sands to receiver sites may involve anchoring and crossing of subtidal and/or intertidal habitats that may directly crush and/or damage invertebrates, and has the potential to damage vegetated reefs, if present. Pipeline placement near the back of the beach has the potential to impact dune and/or coastal strand habitats and/or bird nesting sites, if present.

Pipeline at Surfside-Sunset Beach

Photo credit: David Cannon, Everest International Corporation

Equipment generated noise, human activity, and construction lighting may disturb and temporarily displace wildlife (e.g., Courtenay et al. 1972, Worden et al. 2002, Worden and Smith 2004). Collisions with marine mammals are a potential hazard (Laist et al. 2001). In addition, use of dredge equipment, vessels, vehicles, and/or machinery has the potential to introduce contaminants into coastal environments if there are accidental spills.

2.5.2 Habitat Burial and Sedimentation

Sand placement will alter the appearance of the habitat within the receiver site. Beach placement generally results in a wider beach, steeper profile, and a distinct scarp or berm at the shoreface until the beach fill adjusts from wave action (NRC 1995). Discharge of sands in the nearshore portion of the beach profile will result in an elevated mound, which similar to a nearshore bar will erode and move within the beach profile according to seasonal erosion and accretion cycles associated with nearshore processes.

The primary direct impact to biological resources during sand placement projects is burial, crushing, and smothering of invertebrates within the receiver site footprint (NRC 1985, Greene 2002). Sands placed above the typical high water line may bury coastal strand plants living on supratidal beach, if not avoided. Placement has the potential to bury fish eggs (e.g., California grunion) and rocky substrate habitats, if not avoided. Larger, motile animals generally are able to escape direct burial impacts (NRC 1985, Greene 2002).

Secondary indirect impacts may include alteration of the forage base for mobile animals (e.g., fish, shorebirds) that normally feed on the impacted resources. Beach nourishment also may indirectly enhance habitat for invertebrates, fish, and birds in erosive areas where sandy beach habitat is seasonally limited.

Recovery from direct burial effects may range from months to years depending on the habitat and affected biological resources. Recovery rates generally are fastest for benthic invertebrates and slowest for vegetated habitats. Recovery rates are influenced by natural adaptations and resiliencies of organisms, seasonal timing of project, as well as the similarity between source and native sediments. Most monitoring studies have demonstrated sandy beach invertebrate recovery rates on the order of months after beach nourishment (e.g., Parr et al. 1978, Jutte et al. 1999, Burlas et al. 2001, Versar 2004).

Most references emphasize the importance of sediment compatibility between source and native sediments to minimize adverse impacts and facilitate recovery (Naqvi and Pullen 1982, NRC 1995, Peterson et al. 2000b, Greene 2002, Speybroeck et al. 2006). This recommendation is precautionary and ecologically sound based on current understanding of animal-sediment relationships and studies that have shown changes in invertebrate communities after substantial alteration to siltier or coarser sediments (McLachlan 1996, Rakocinski et al. 1996). Limited relevant information is available with respect to how broad a deviation in sediment characteristics can be tolerated before there is a change in invertebrate community structure.

Sand placed at a receiver site will winnow and eventually erode from natural physical processes. Sands placed on the intertidal or nearshore portions of a beach will be mobilized by waves and transported by currents. Strong winds may result in transport of sands placed above the tide zone. Sand transport from the receiver site will result in indirect sedimentation of downcurrent and nearshore habitats.

Indirect sedimentation may affect biological resources by burial, partial burial, increased sediment scour and/or abrasion, and/or habitat enhancement. Downcurrent beaches may be enhanced by increased persistence of sandy beach habitat (NRC 1995, SAIC 2006). There also may be adverse impacts if the amount of sand that is transported by waves and currents overruns sensitive reef and/or vegetated habitats in the vicinity (e.g., Lindeman and Snyder 1999, Goreau 2001, Coastal Planning & Engineering 2004a, b). However, other beach nourishment projects have been successfully conducted in the vicinity of reefs and vegetated habitats without significant impacts (e.g., Chambers Group 2003, Coastal Planning & Engineering 2004c, AMEC 2005). Factors considered influential to these differences in impact level include project size (sand volume), proximity to sensitive habitats, reef heights, and depth at which sensitive habitats occur.

Indirect sedimentation also may result in accelerated infilling of inlets and entrance channels of embayments (NRC 1995, Coastal Environments 2005). Increased shoaling has the potential to degrade environmental quality within those habitats, particularly if it resulted in closure of shallow-water inlets and/or an increase in the frequency of maintenance dredging.

Indirect sedimentation also may occur during dredging projects as a result of sediment resuspension and deposition. Generally, these are relatively thin-layers unless shoals (mounds) result from deposition over the course of multiple dredging cycles (Newell et al. 1998, Wilber et al. 2005). Field and laboratory studies indicate a number of species are sensitive to effects of sedimentation (e.g., kelp, eggs of some species of fish, oysters, corals). However, effects of sedimentation from dredging and disposal are poorly understood (Germano and Cary 2005, Wilber et al. 2005).

Potential impacts associated with indirect sedimentation are challenging to assess because of the complexity of physical processes and high degree of variability associated with depth, duration, and spatial scale of sedimentation (Section 5.4). Various models have been developed to increase understanding and prediction of potential effects. However, limited information is available with respect to model performance using empirical data collected before and after sediment management projects.

2.5.3 Water Quality

Sediment management activities involving beneficial use for beach nourishment (beach and nearshore placement) are required by environmental regulations to be “clean” and free from substantial contamination; consequently, contamination and toxicity are not an issue with beach nourishment and related sediment management activities.

Sediment management activities involving beach nourishment and/or dredging primarily affect water clarity or turbidity. Beach nourishment may result in elevated suspended sediment concentrations in nearshore waters. Nearshore and/or profile placement involves discharge of sands through the water column and resuspension of sediments when the discharge plume hits the bottom.

Dredging resuspends sediments in the vicinity of the dredge (NRC 1995, Newell et al. 1998). Water quality at offshore borrow sites may be affected by short-term turbidity associated with dredging; however, there also are cases where persistent lowered dissolved oxygen (anoxia) resulted from very deep excavations that altered local hydrodynamics and resulted in accumulation of particulates (NRC 1995, Newell et al. 1998, Brynes et al. 2004b). Dredging projects that remove excess sedimentation that improves tidal flushing hydrodynamics result in changed hydrodynamics may result in long-term improvements in water quality (e.g., wetland restoration projects).

Suspended particulate plumes often comprise both inorganic sediment and organic matter. While organic particulates may constitute an important food source for suspension and detritus feeding animals, suspended and settling inorganic particles generally are a stress disturbance for aquatic vegetation and animals (LaSalle et al. 1991, Wilber and Clarke 2001, Berry et al. 2003).

Organisms living in nearshore and/or estuarine environments generally are exposed to variable turbid conditions associated with wave and/or wind re-suspension and periodic storm runoff, and species display a variety of behavioral and/or physiological adaptations and varying tolerance levels to suspended sediment (Sections 3, 4). However, prolonged exposure and/or excessive suspended sediment concentrations may exceed defensive mechanisms and/or tolerance levels. Substantial reductions in water clarity may affect photosynthesis, growth, and/or reproduction of aquatic plants (e.g., Onuf 1994, Sabol et al. 2005. Elevated concentrations of suspended sediments may result in reduced foraging, growth, and/or respiration, and at very high concentrations may be lethal to aquatic animals (LaSalle et al. 1991, Newcombe and MacDonald 1991, Newcombe and Jensen 1996, Clarke and Wilber 2000, Wilber and Clarke 2001, Berry et al. 2003).

Placed sediments may be more easily resuspended than native sediments; therefore, turbidity levels may be higher in the nearshore during resuspension events at beach nourishment sites and/or at in-bay discharge sites (Onuf 1994, Wilber et al. 2005, Wilber and Clarke 2006). Concern that high turbidity pulses may occur over the long-term have been expressed in response to some projects on the East Coast that placed sands with lenses of mud (Reilly and Bellis 1983, Peterson and Bishop 2005).

2.6 Overview of Applicable Laws and Regulations

Federal and state environmental requirements relevant to sediment management activities are briefly reviewed below. These regulations form the basis for environmental impact evaluations pursuant to the CEQA and NEPA and permitting of sediment management projects.

2.6.1 Federal Environmental Regulations

Clean Water Act of 1972 (CWA)

The CWA was established to restore and maintain the chemical, physical, and biological integrity of the nation's waters. Specific sections concern different aspects of protecting waters and water quality. Section 401 applies to dredging and disposal activities, and requires certification by the RWQCB or equivalent that the permitted project complies with State Water Quality Standards, and would not cause concentrations of chemicals in the water column to exceed these standards. Section 401 of the CWA requires a water quality certification for issuance of a 404 permit (33 United States Code [U.S.C.] 1344).

Section 404(b)(1) guidelines require that dredging and disposal activities should have no unacceptable adverse impacts. The USACE issues 404 permits for the dredging and disposal of materials within the waters of the United States. A permit application must include an evaluation of the impacts on the affected resources, including, but not limited to: physical and chemical characteristics of the aquatic ecosystem, biological characteristics of the aquatic ecosystem, specific designated sites, where applicable and human use characteristics. The USACE prepares 404(b)(1) evaluations for federal projects, including evaluation of alternatives and identification of the less damaging practical alternative.

Coastal Zone Management Act of 1972 (CZMA) and 1976 California Coastal Act

The CZMA requires activities to be consistent with the enforceable policies of the approved state coastal program to the maximum extent practicable. The California Coastal Act authorizes the CCC to implement the CZMA. The implementing regulations for the CZMA are described in 15 C.F.R. 930, and the policies pertinent to coastal consistency determinations are included in California Public Resources Code (Cal. Pub. Res. Code) (Sections 30200-30365.5). These regulations require that the CCC prepare a consistency determination for all federal projects that could affect the coastal zone. A coastal development permit is required for non federal projects.

Fish and Wildlife Coordination Act of 1958

The Fish and Wildlife Coordination Act requires any federal agency proposing any action that may affect wildlife to first consult with the U.S. Fish and Wildlife Service (USFWS) and/or National Marine Fisheries Service (NMFS).

Federal Endangered Species Act of 1973 (FESA)

The FESA protects endangered and threatened species by prohibiting federal actions that would jeopardize the continued existence of such species or result in the destruction or adverse modification of habitat of such species. Under Section 7(a)(2) of the FESA, federal agencies must consult with federal resource agencies (USFWS and NMFS) and prepare a Biological Assessment (BA) if listed species and/or critical habitat is present in an area to be impacted by project activity. The USFWS and/or NMFS then will prepare a Biological Opinion (BO) on how the action would affect the species and/or its Critical Habitat, and will

suggest reasonable and prudent measures that it believes would avoid jeopardizing the continued existence of the species or adversely modifying its critical habitat.

Magnunson-Stevens Fishery Management and Conservation Act, as amended 1996 (Public Law 104-267)

Federal agencies and permit applicants must consult with the NMFS on actions that may adversely affect Essential Fish Habitat (EFH). EFH is defined as those "waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The NMFS encourages streamlining the consultation process using review procedures under NEPA, Fish and Wildlife Coordination Act, Clean Water Act, and/or FESA provided that documents meet requirements for EFH assessments under Section 600.920(g). EFH assessments must include (1) a description of the proposed action, (2) an analysis of effects, including cumulative effects, (3) the federal agency's views regarding the effects of the action on EFH, and (4) proposed mitigation, if applicable.

Marine Mammal Protection Act of 1972

This Act protects marine mammals and establishes a marine mammal commission to regulate such protection.

Marine, Protection, Research, and Sanctuaries Act (MPRSA)

MPRSA is divided into three parts: Title 1 – Ocean Dumping, Title 2 – Comprehensive Research on Ocean Dumping, and Title 3 – Marine Sanctuaries. Title 1 establishes the permit program for the disposal of dredged and non-dredged materials, mandates determination of impacts and alternative disposal methods, and provides for enforcement of permit conditions. The purpose of Title 1 is to prevent or strictly limit the dumping of materials that would unreasonably affect human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities. Several agencies participate in the implementation of MPRSA requirements. USEPA is the lead agency responsible for overall ocean disposal program management including site selection and management, establishes criteria for regulating waste disposal, and issues waste disposal permits other than for dredged material. The USACE issues dredge disposal permits and provide recommendations regarding disposal site locations.

Migratory Bird Treaty Act of 1972

This Act (16 U.S.C. § 703, amended 1994) between the United States and Canada, and subsequent amendments to the Act, provide legal protection for most breeding birds occurring in the U.S. The Act restricts the killing, taking, collecting, selling, or purchasing of native bird species or their parts, nests, or eggs. The Convention for the Protection of Migratory Birds and Animals (1936) between the United States and Mexico offers similar protection to birds.

National Environmental Policy Act of 1969 (NEPA)

The NEPA requires federal agencies to consider environmental consequences and project alternatives before a decision is made to implement a federal project. The law requires the government to consider the consequences of major federal actions on human and natural aspects of the environment in order to minimize, where possible, adverse impacts. Equally important, NEPA established a process of environmental review and public notification for federal planning and decision-making. The Council on Environmental Quality (CEQ) was established under NEPA, and in 1978 issued *Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act* (40 Code of Federal Regulations [C.F.R.] §§ 1500-1508).

Rivers and Harbors Act of 1899

Section 10 of the Rivers and Harbors Act prohibits the unauthorized obstruction or alteration of any navigable waters of the United States (U.S.), and authorizes the Corps to regulate all activities that affect the course, capacity, or coordination of waters of the U.S. Navigable waters of the U.S. are defined in 33 CFR Part 329 as those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce. The USACE processes Section 10 permits simultaneously with 404 permits because of their similar requirements.

2.6.2 State Environmental Regulations

California Endangered Species Act (CESA)

The CDFG (Fish and Game Code §§ 2050-2089) has regulatory authority over state-listed endangered and threatened species. The state legislature encourages cooperative and simultaneous findings between state and federal agencies. Participation by CDFG in federal consultation and adoption of a federal Biological Opinion (BO) is authorized by Fish and Game Code Section 2095. If the federal BO is found to be inconsistent with CESA, the CDFG will issue its own BO per Section 2090 of the Fish and Game Code and may issue a Section 2081 take permit with conditions of approval.

California Environmental Quality Act (CEQA)

CEQA requires that state and local agencies consider environmental consequences and project alternatives before a decision is made to implement a project requiring state or local government approval, financing, or participation by the State of California. In addition, CEQA requires the identification of ways to avoid or reduce environmental degradation or prevent environmental damage by requiring implementation of feasible alternatives or mitigation measures.

Marine Life Protection Act (MLPA)

The MLPA was adopted by the CDFG in 1999 (Chapter 10.5 of Fish and Game Code 2850 to 2863). The purpose of the MLPA is to design and manage a network of marine protected areas to improve protection of marine life and habitats, marine ecosystems, and marine natural heritage through the adoption of a Marine Life Protection Program and a comprehensive master plan.

Porter-Colonge Water Quality Control Act of 1969 (Porter Cologne Act)

This act represents anti-pollution legislation enacted by the California Legislature in 1970 (California Water Code §§ 13000-13999.10). It provides a framework for the regulation of waste discharges to both surface and ground waters of the state. It further provides for the adoption of water quality control plans and the implementation of these plans by adopting waste discharge requirements for individual dischargers or classes of dischargers. The Act mandates activities that may affect waters of the state shall be regulated to attain the highest quality. The RWQCB provides regulations for a non-degradation policy that are especially protective of waters with high quality.

3.0 REVIEW OF HABITATS POTENTIALLY AFFECTED BY SEDIMENT MANAGEMENT ACTIVITIES

Section Topics:

3.1 Habitats Where Sediment Management May Occur
3.2 Habitat Functions and Values
3.3 Review of Habitats and Impact Responses

Section 3.1 provides an overview of types of coastal habitats where sediment management activities may occur. Section 3.2 reviews differences in ecological functions and beneficial use values of the different habitats. Section 3.3 describes each habitat and provides relevant background information on natural resiliencies of habitats, potential and documented impacts from sediment management activities, and the scientific basis of concern relative to sediment management impacts.

3.1 Habitats Where Sediment Management May Occur

California supports a diverse array of coastal habitats, each with distinct physical conditions that support characteristic biological communities. Coastal habitats range from dunes and beaches to waters offshore. Biological resources differ between sandy and rocky habitats, and areas with substantial vegetation such as kelp forests, seagrass beds, and eelgrass meadows, all of which represent important spawning, nursery, and/or foraging areas for numerous invertebrates, fish, birds, and marine mammals. Tidally influenced bays and estuaries occur along the coast, and also represent important nursery areas for invertebrates and fish as well as important nesting and foraging habitats for resident and migratory birds. Creeks and rivers that flow into embayments or directly to the ocean connect the terrestrial watersheds to the sea, and in some areas of the state support emigration and spawning runs of anadronomous fish.

Different classification schemes have been applied to coastal habitats by the USFWS (Cowardin et al. 1992), NOAA (Aillee et al. 2000), and CDFG (Shaffer 2002, CDFG 2003a). The CDFG classification system, which considered consistency with the national systems, was the primary reference for this document. The CDFG hierarchical classification starts with separation of marine (offshore, nearshore, embayment) and estuarine (estuary, lagoon) systems. Marine offshore habitats, defined by the CDFG as seaward of the continental shelf-slope transition (Shaffer 2002), are outside areas of potential influence by sediment management activities associated with beach nourishment and are not discussed further in this document. Habitats associated with marine nearshore and estuarine environments with the potential to be influenced by beach nourishment and associated activities, including sand placement and dredging of potential source sands are addressed herein.

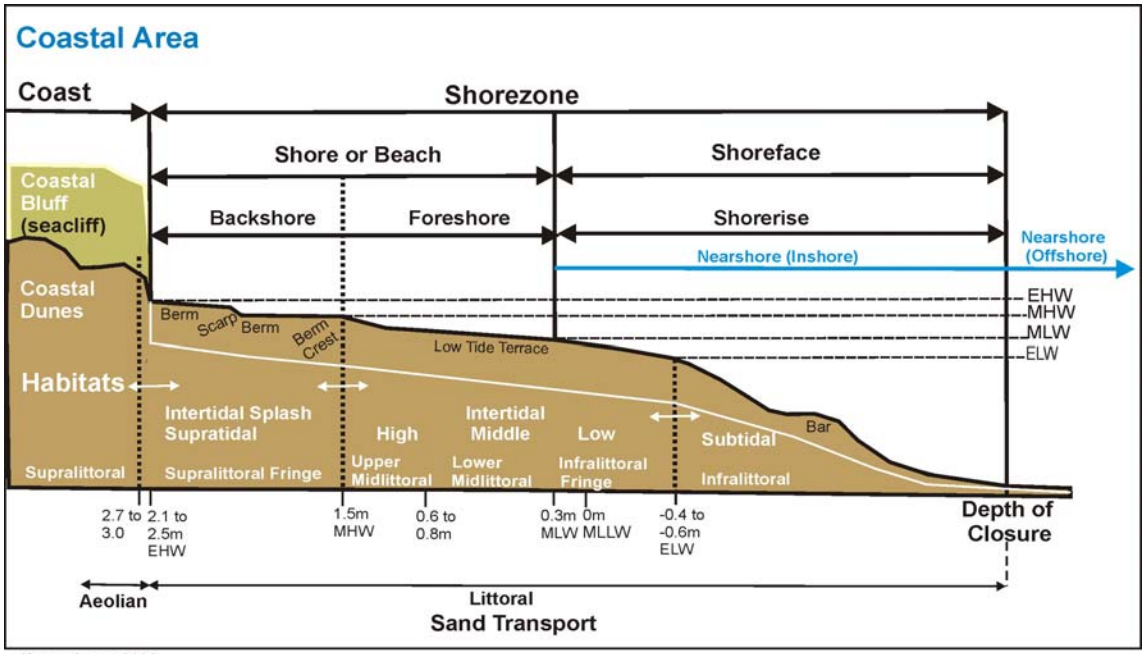
The CDFG classification distinguishes 40 habitats within the marine and estuarine environments based on considerations such as wave energy (protected, exposed), water depth, tidal influence, vegetation (kelp forest, surfgrass, eelgrass, tidal marsh), water column (pelagic) or sediment (benthic) association, substrate type, and physiography (e.g., bay estuary, canyon mouth estuary, river mouth estuary, dune system estuary) (Shaffer 2002). Some of this finer level of habitat discrimination is not followed in this document to minimize redundancy in presentation of reviewed information.

This document distinguishes coastal habitats based on tide inundation (terrestrial, intertidal, subtidal), substrate type (sandy, rocky), aquatic vegetation (kelp forest and/or bed, surfgrass bed, eelgrass meadow), and shallow versus deepwater inlet embayments. Both benthic and pelagic components of aquatic habitats are reviewed. Coastal dune is a terrestrial habitat subject to substantial marine or estuarine influence (Shaffer 2002) and source/sink for littoral sand (USACE 2003), and is therefore included in the review. Coastal strand vegetation associated with foredunes and/or beach backshore (CERES 2006) is reviewed together with coastal dune habitat. Differences between protected and exposed shores are addressed by habitat type. Inlet characteristics of embayments are distinguished because they may differ in vulnerability to sedimentation from beach nourishment and/or sediment management needs. Shallow inlet embayments are defined as estuarine systems associated with creeks, canyon mouths, esteros, lagoons, rivers, and sloughs. Deepwater inlet embayments include large, marine bays and bay-estuaries, many with harbors, ports, and marinas. The following ten marine-estuarine environments and/or types of habitats are reviewed in Section 3.3:

- Coastal Dune and/or Strand
- Sandy Beach
- Sandy Subtidal
- Rocky Intertidal
- Rocky Subtidal
- Kelp Forest and/or Bed
- Surfgrass Bed
- Eelgrass Meadow
- Shallow Inlet Embayment
- Deepwater Inlet Embayment

Figure 3-1 provides a cross reference between coastal shorezone terminology and biological habitats, which have some differences in boundaries. Coastal shorezone terminology defines the beach (also shore) as comprising a foreshore and backshore, collectively extending landward from the low water line, “mean low water unless otherwise specified”, to where there is marked change in material or physiographic form, or to the line of permanent vegetation (usually the effective limit of storm waves) (Voigt 1998, USACE 2003, CCC 2004). The foreshore is the area normally wetted by tides, and the backshore is the area above the normal reach of tides but acted upon by waves during storm tides (*ibid.*). The mean high water line is shown on Figure 3-1 as the backshore/foreshore boundary consistent with the USACE (2003) glossary illustration and the NOAA (Voigt 1998) glossary definition of backshore. The extreme high water line is used to show the landward boundary of the backshore based on definitions that this area only receives inundation during severe storms or storm tides (Voigt 1998, USACE 2003, CCC 2004).

Biological habitat classifications generally define boundaries based on extreme tide range and area influenced by wave splash. Thus, the intertidal habitat has broader boundaries than the foreshore and backshore boundaries (Figure 3-1). For example, the lower limit of intertidal habitat is defined as extreme low water (Thompson et al. 1993, Hill et al. 1998), which is seaward of foreshore definitions based on mean low water (NOAA 2001a, USACE 2003, CCC 2004). The intertidal landward limit includes the splash zone (Cowardin et al. 1992, Thompson et al. 1993, Hill et al. 1998), which extends slightly beyond the backshore definitions based on inundation by severe storms or storm tides.



Karen Green 2006

Source References
Coastal shorezone terminology- (Shepard 1963, NOAA 2001a, USACE 2003, CCC 2004)
Biological habitats - (CCC 1987, Thompson et al. 1993, Hill et al. 1998, Shaffer 2002)
Tide elevations – descriptive datums (NOAA 2001a, USACE 2003), numeric values (CCC 1987, Thompson et al. 1993, http://tbone.biol.sc.edu/tide/sites_uswest.htm - January 2006)
Nearshore zones – NOAA 2001a; Sand transport zones – NOAA 2001a, USACE 2003
Definitions: EHW = extreme high water spring tide, MHW = mean high water, MLW = mean low water, ELW = extreme low water spring tide

Figure 3.1-1. Cross reference between coastal terminology and biological habitat boundaries.

The intertidal habitat displays vertical zonation, the sequence of which is commonly referred to as splash (supralittoral fringe), high intertidal (upper midlittoral), middle intertidal (lower midlittoral), and low intertidal (infralittoral fringe) zones based on the early classification of Stephenson and Stephenson (1949) and modified by Ricketts et al. (1968) and Lewis (1964) (cited in Thompson et al. 1993 and Hill et al. 1998). The tide elevations corresponding to these zones vary depending on wave exposure (protected, exposed coasts) and type of tide (spring, neap tides). Approximate tide elevation boundaries for these zones in California are shown on Figure 3-1 based on reference to CCC (1987), Thompson et al. (1993), and review of 2006 extreme high and low tides for several recording stations along the coast of California from Crescent City to Point Loma (http://tbone.biol.sc.edu/tide/sites_uswest.html).

Coastal terminology definitions reference the nearshore area within the depth of closure as the inshore zone and the area further seaward to the edge of the continental shelf as offshore (Voigt 1998, USACE 2003). The USACE (2003) defines the inshore as a zone of variable width extending from the low water line through the breaker zone. The NOAA marine and estuarine habitat classification defines the nearshore area affected by surf as usually at depths < 30 ft (< 10 m) (Allee et al. 2000). Moffatt & Nichol (2005b) reported that

the depth of closure is approximately 30 ft (10 m) in southern California and up to 40 ft (12 m) in northern California.

The coastal area adjacent to the backshore may include transitional habitat between marine and fully terrestrial. The CDFG classification (Shaffer 2002) refers to this area as shoreline and beach, which may include various microhabitats (e.g., cliffs and bluffs, sand dunes, boulders, vegetation types, ponds). That terminology is not used in this document to avoid confusion with coastal terminology definitions used by other agencies for beach and shore (Voigt 1998, USACE 2003, CCC 2004). Instead the CDFG (2003a) terrestrial classification is followed for adjacent coastal habitat (e.g., coastal dune or coastal bluff).

Each of the ten coastal habitat types occur in northern, central, and southern California. However, the relative occurrences of these habitat types vary regionally (Table 3.1-1). Generally, sandy shores dominate the shoreline in southern California and rocky shores are more prevalent in central and northern California. In contrast, rocky subtidal habitat supporting kelp forests is more prevalent in the nearshore of southern California than in central and northern California combined. Similar numbers of shallow inlet embayments occur along central, northern, and southern California, but there are more deepwater embayments and ports in southern California. Eelgrass and surfgrass habitats occur throughout the state where suitable substrate and environmental conditions occur.

Table 3.1-1. Regional distribution of habitats in California.

Habitats	Southern California	Central California	Northern California
Coastal Dune and/or Strand	Few	Common	Common
Sandy Beach	80% of shoreline	39% of shoreline	46% of shoreline
Sandy Subtidal	Widespread	Common	Common
Rocky Intertidal	20% of shoreline	61% of shoreline	54% of shoreline
Rocky Subtidal	Localized	Common	Common
Kelp Forest and/or Bed	Present (giant kelp -75%)	Present (giant kelp - 20%)	Present (giant kelp - < 5%)
Surfgrass Bed	Rocky intertidal and subtidal	Rocky intertidal and subtidal	Rocky intertidal and subtidal
Eelgrass Meadow	Embayment and sandy subtidal	Embayment and sandy subtidal	Embayment and sandy subtidal
Shallow Inlet Embayment	25 or more	20 or more	30 or more
Deepwater Inlet Embayment	17	5	8

Sources: CCC 1987, Ambrose et al. 1989
Note 1: Percentage of kelp based on information provided in Ambrose et al. 1989; actual percentages may vary among years, but relative proportion among different regions of the state are considered representative.
Note 2: See Sections 3.2.9 and 3.2.10 for list of shallow and deepwater inlet embayments.

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3.2 Habitat Functions and Values

Coastal habitats provide a variety of ecological, recreational, educational, and commercial beneficial uses. Sediment management projects involve consideration of a range of potential impacts; therefore, the relative values of different habitats are an important consideration when conducting environmental evaluations. The following questions regarding habitat values are of interest to the CSMW:

- *Are there different ways to evaluate the relative value of different habitats?*
- *What are the relative biological, recreational, and commercial values of rocky vs. sandy vs. muddy bottom habitats?*

Table 3.2-1 summarizes different types of resources and beneficial uses supported by coastal habitats. Factors considered include the potential variety of supported species, occurrence of essential fish habitat, use by listed threatened and/or endangered species, use by commercial fishery species, use by state regulated or special interest species (e.g., California grunion, California spiny lobster, Dungeness crab, Pacific herring, Pismo clam, sea urchins, California Species of Concern), support of fisheries and/or mariculture, and types of recreational and educational beneficial uses. These factors represent different ways that the relative value of habitats may be examined depending on question of interest.

Potential ecological functions supported by rocky and soft sediment habitats are similar, including primary living space, resting, sheltering, foraging, reproduction, and trophic transfer. Vegetated hard or soft habitats generally support a greater variety of species than non vegetated habitats (Foster and Schiel 1985, Hoffman 1996, Ware 1993, Blackmon et al. 2006). Rocky habitats of variable relief heights with vegetation are some of the most productive of coastal habitats (Ambrose et al. 1989).

Actual use of habitats by biological resources may vary dramatically depending on size and quality of habitats. Generally, larger areas support a greater variety of resources and uses than smaller areas. Disturbance may affect ecological functions and values of habitats. Large-scale and/or frequent disturbance may eliminate and/or temporarily reduce species occurrence and/or biological resource use of habitats. For example, few if any biological resources are associated with low relief rocky substrate subject to natural sand scour in the littoral zone; whereas, higher relief reefs extending above the littoral sands can support a diverse variety of marine plants, invertebrates, and fish (Cross and Allen 1993, Ambrose et al. 1989, MEC 2000a). Coastal landslides can result in dramatic alterations of intertidal and nearshore communities due to sedimentation and chronic turbidity impacts (Stephens 1990, Pondella et al. 1996, Komar 1997). As previously mentioned (Section 2.3.4), El Niño events may result in widespread disturbance of habitats due to nutrient limitation, increased temperatures, and/or above average wave and storm disturbance.

Anthropogenic disturbances associated with urban runoff and discharges, vessel traffic, development, and public use may affect resource use and habitat quality depending on frequency and magnitude of impact. Beach nourishment and/or dredging may affect habitat quality during and after sediment management activities (Section 3.3).

Potential functional values and beneficial uses of coastal habitats are briefly summarized below. However, as noted above, the actual values and beneficial uses will vary depending

on site-specific environmental conditions. Differences in habitat quality should be considered when evaluating the potential for impacts associated with sediment management projects.

Coastal sand dunes may occur landward of the extreme high water line of some beaches. The beach backshore, which occurs landward of the mean high water, may transition to dune habitat. Coastal dune and/or strand habitat may support hundreds of species of plants, insects, reptiles, birds, and mammals (Section 3.3.1). Dunes provide shoreline protection from winter storms and contribute sand to the coastal zone. Quality of dune habitats may be degraded by human activities that damage plants and accelerate erosion and slumping. Several large dune complexes are part of the recreational park system of California and some are in preserves or ecological reserves. Different dunes areas may support education, hiking, recreational vehicles, and equestrian uses (CCC 1987).

Sandy beaches include both intertidal foreshore and backshore areas above the mean high tide line. As noted above, the backshore may transition to dunes or the backshore may be limited by coastal bluffs and/or development. Beaches with sufficient sand support a variety of resource uses and recreational values. Sandy beaches provide primary habitat for invertebrates; forage, resting, and nesting habitat for birds, including threatened western snowy plover; and spawning habitat for California grunion. Sandy beaches are preferred sunbathing, wading, surfing, and swimming areas and may support recreational clamming and fishing.

Species composition and diversity of marine resources associated with soft substrates differ with sediment type, which often varies according to depth and energy gradients. Generally, sediments are sandier near the open coast and muddier with increasing depth offshore. Fewer species of invertebrates live in sandy sediments in the shallow energetic nearshore zone than in sandy to mixed sediments offshore, probably due to greater sediment stability offshore (Oliver et al. 1980, Thompson et al. 1997). Consequently, relative ecological values of sandy versus muddy habitats are influenced less by grain size than by disturbance gradients. Important fisheries are associated with soft bottom habitats (e.g., Dungeness crab, halibut, Washington clam), but generally yield less overall commercial catch value than hard bottom or pelagic fisheries (CDFG 2001).

Rocky substrate habitats are capable of supporting hundreds of species of plants, invertebrates, and fish (Pequenat 1964, Abbott et al. 1980). Seals and sea lions also use exposed rocks and reefs as haul out sites (Orr and Helm 1989). The most productive reef habitats are characterized by a variety of substrate relief and vegetation, which provide important shelter and living space functions. In contrast, sand scoured low lying reef and/or cobble substrate support little marine life (Ambrose et al. 1989, MEC 2000a, SAIC 2006).

Well developed intertidal rocky habitats support public recreational and educational activities such as tidepooling and school field trips. Nearshore and offshore rocky reefs, including kelp beds, are favored destinations of recreational and commercial fishermen and divers. Collectively, hard bottom species (kelp, California lobster, rock crab, sea urchins, octopus, sea cucumber, sheephead) account for the highest value of commercial landings (CDFG 2001).

Table 3.2-1. Beneficial uses and relative values of coastal habitats.

Habitat	Supported Resources and Beneficial Uses					
	Variety of Resources Supported	**Essential Fish Habitat**	**Threatened and/or Endangered Species**	**Other Special Interest Species**	**Commercial Fisheries/ Mariculture**	**Education and Recreational Uses**
Coastal Dune and/or Strand	plants, insects, birds, reptiles, mammals		X	X		education, equestrian, hiking, recreational vehicles
Sandy Beach	invertebrates, fish (grunion), birds, pinnipeds	X	X	X		equestrian, sunbathing, swimming, recreational fishing
Sandy Subtidal	invertebrates, fish, marine mammals	X	X		X	commercial & recreational fishing
Rocky Intertidal*	plants, invertebrates, fish, birds, pinnipeds	X		X		tidepooling education, recreational fishing
Rocky Subtidal*	plants, invertebrates, fish, marine mammals	X	X	X	X	commercial & recreational diving, fishing
Kelp Forest and/or Bed	plants, invertebrates, fish, birds, marine mammals	X	X	X	X	commercial & recreational diving, fishing
Surfgrass Bed	invertebrates, fish, birds	X		X	X	commercial & recreational diving, fishing
Eelgrass Meadow	invertebrates, fish, birds	X		X	X	recreational diving, fishing
Shallow Inlet Embayment	plants, insects, invertebrates, fish, birds, amphibians, reptiles, mammals	X	X	X	X	bird watching, education, hiking, recreational fishing, mariculture, water craft
Deepwater Inlet Embayment	plants, invertebrates, fish, birds, marine mammals	X	X	X	X	bird watching, education, recreational fishing, mariculture, boating, commercial shipping and landings, military

* Diversity depends on substrate height, relief, and vegetation.

Three submerged aquatic vegetation (SAV) habitats of special interest in California coastal waters include: kelp forests and/or beds, surfgrass beds, and eelgrass meadows. SAV habitats provide important sources of organic matter, substrate, shelter, and nursery functions for many species. Often, hard bottom surfgrass and kelp bed habitats are located inshore and offshore of each other, respectively, on the same reef system. Surfgrass beds provide nursery habitat for commercially important California spiny lobster, shelter for a variety of invertebrates and fish, and forage habitat for birds (Stewart and Meyers 1980, DeMartini 1981). Kelp beds support hundreds of species of invertebrates and fish, many of which are prey for marine mammals (Foster and Schiel 1985). Eelgrass meadows occur on soft substrates in protected coastal areas, mainly embayments, but also may occur in the nearshore where suitable conditions exist. More species of invertebrates and fish are associated with SAV than non-vegetated habitats (Fonseca et al. 1991, Hoffman 1996, MEC 2000b).

Coastal embayments provide some of the most ecologically productive and heavily used recreational areas in the state. Bays, esteros, lagoons, and sloughs and associated wetlands provide a variety of habitats ranging from open water, mudflats, eelgrass beds, marshes, salt flats and/or pannes and may support thousands of species of plants, invertebrates, fish, amphibians, reptiles, birds, and mammals (CDFG 2001, Coastal Conservancy 2001). These habitats are considered important nurseries for marine fish, nesting and foraging areas for resident and migratory birds, and critical habitats for several threatened and/or endangered plants and birds. Embayments also support a variety of recreational (bird watching, educational activities, hiking, boating, fishing), commercial (commercial fishing landings, mariculture, shipping), and military (homeport) uses.

Mouths of creeks, esteros, lagoons, rivers, and sloughs provide ecologically important connections between watersheds and the coastal zone. They serve as inlets that bring tidal exchange to coastal wetlands and/or as outlets for storm water runoff, nutrients, and sediment supply to the coastline. Invertebrates inhabit inlet sediments, anadronomous and marine fish may transit inlets to reach estuarine and/or riverine spawning and foraging areas, and shorebirds and fish-eating birds forage within inlet areas. Dam construction, flood control channelization, water diversion, and/or development have reduced the size of many of California's rivers, which have transformed some inlets from perennial to intermittently open systems (CCC 1987). These factors also have affected shallow water inlets of lagoons and sloughs, which may experience sedimentation problems due to reduced tidal prisms and/or erosion and runoff from watersheds. Maintenance dredging and/or inlet excavation are conducted in several shallow inlet embayments in California (Section 2.1).

Coastal ports, harbors, and marinas have been constructed in portions of larger bays and/or along natural indentations of the coastline of California. These areas have a relatively deep water connection to the ocean and provide more protected habitats than the open ocean due to headlands, structural breakwaters, and/or distance from the open ocean. These protected embayments support hundreds of species, including a variety of invertebrates, fish, aquatic vegetation, fish-eating birds and waterfowl, and transient occurrence of marine mammals (e.g., CCC 1987, Allen 1999, MEC 2000b, Thompson et al. 2000). Recreational, commercial, and/or military uses are served in these habitats. Trapping of littoral sands and/or watershed runoff contributes to sedimentation problems and maintenance needs in most deepwater inlet embayments in California (see Section 2.1).

3.3 Review of Habitats and Impact Responses to Natural Disturbance and Sediment Management Activities

This section describes the ten types of coastal habitats in terms of regulatory status, distribution, ecological functions, and types of species supported. Each habitat is reviewed to address the following questions of interest to the CSMW:

- *What are the direct and indirect ways that habitats may be impacted by sediment management activities, particularly beach nourishment?*
- *Are documented concerns based on scientific data, uncertainty based conservatism, or other information?*

The reviews consider the range of sediment management activities involving dredging and/or placing beach compatible sands for beach nourishment. The activities may include maintenance dredging/excavation in embayments, offshore borrow site dredging, beach placement, nearshore placement, profile placement, and/or dune placement, as relevant to each habitat.

Types of impacts associated with these sediment management activities are briefly reviewed in Section 2.4, and relate to equipment, burial and sedimentation, and water quality (primarily turbidity) effects. Both direct (at same time and place) and indirect (same time but adjacent) impacts may occur during construction phases, and indirect impacts (later in time) may occur after construction. Cumulative impact considerations may include frequency of activity, multiple project considerations, and/or sediment management activities in combination with other multiple impact sources. Types of impacts are reviewed further in Section 5.

The following types of impact concerns associated with sediment management activities have been identified (NRC 1995, Greene 2002).

- Construction impacts from equipment may include direct damage and/or indirect disturbance (e.g., physical presence, noise, lights) from dredges, vessels, vehicles, and other equipment (e.g., pipelines) involved with removal, transport, and/or placement of sands in coastal habitats.
- Sand placement will result in direct burial of existing habitat within the receiver site during construction, and indirect sedimentation of adjacent habitat after construction as a result of natural winnowing and transport associated with coastal processes.
- Water quality of aquatic habitats may be impacted as a result of the resuspension and settling of dredged/excavated and/or placed sands.

These impacts potentially have adverse, beneficial, and/or no effect on habitats depending on the potential for impact, magnitude of effect, and vulnerability to impact. Most of these factors are interrelated. Potential for impact considers potential location of sediment management activity relative to the habitat of interest. The magnitude of effect relates to the duration and spatial scale of disturbances, which are influenced by project size and methods used during construction. Impact concern relates to the sensitivity and/or resiliency of the habitat to disturbance effects and recovery rates from disturbance. Recovery generally refers to reestablishment of the pre-project community structure and composition (e.g.,

similar number of species, abundance, biomass, and species composition) and/or habitat functions. When there is uncertainty regarding potential impacts, potential concern also may consider the ability to restore the functions and values of impacted habitats should mitigation be necessary.

The approach taken to answer the CSMW questions regarding types of impacts and the basis of concern involved literature review of a variety of topics, including ecological functions and values, natural adaptations to disturbance, recovery rates after disturbance, response to sediment management activities, critical impact thresholds, and restoration considerations, as available. Data gaps and information needs also are identified.

A standardized format is used for summarizing reviewed information, which is organized under headings by topic. Summary tables are provided for many of the topics, and when given, generally follow a text description. This format facilitates quick reference of summary table information by topic. The following topics are addressed:

- Regulatory Status – designations that may apply to habitats are identified, including CDFG managed (e.g., fisheries habitat and/or parks managed by the state), Essential Fish Habitat, or other special designation (e.g., Areas of Special Biological Significance, Critical Habitat, Ecological Reserves, Marine Life Refuges, Marine Sanctuaries, and/or Underwater Parks).
- Description and Distribution – habitats are defined based on key attributes. Habitat occurrence is described relative to geographic range, land versus aquatic habitat, depth range (intertidal, nearshore-inshore, nearshore-offshore), and type of coastline (exposed, protected). The inshore zone affected by surf is variable in California, but was considered as < 30 ft (< 10 m) in this document following marine habitat classification schemes (Allee et al. 2000) and the approximate depth of beach closure along much of the California coast (Moffatt & Nichol 2006a).
- Exposed and protected areas follow CDFG definitions (Shaffer 2002), with exposed coastlines being those directly influenced by wave action and protected coastlines being those protected from direct wave action by headlands, islands, and/or reefs. All embayments are considered protected coastlines in this document.
- Potential Functions Supported – habitat uses supporting primary living, foraging, reproductive, and/or fisheries (commercial and recreational) functions are described for associated species. In addition, the types of organisms representing forage and/or prey and supporting trophic transfer within habitats are identified.
- Life History Facts of Associated Species –behavior, reproductive strategies, and life span characteristics of dominant and/or representative species of habitats were briefly reviewed.
- Adaptations and/or Behaviors to Disturbance of Associated Species – tolerances, vulnerabilities, and responses of habitats and associated species to disturbance are reviewed.
- Potential Impacts from Sediment Management Activities – published and unpublished reports are reviewed of habitat responses to equipment, burial, sedimentation, and turbidity impacts associated with placement of sediment and/or dredging of source sands in support of beach nourishment. A distinction is made between direct burial and indirect sedimentation resulting from post-project sand transport. Potential impacts are identified for embayment and offshore borrow site

dredging, nearshore placement, profile placement, beach placement, and/or dune placement, as appropriate.

- Recovery from Disturbance – recovery processes and/or rates from impacts associated with sediment management activities (i.e., equipment, burial, sedimentation, turbidity) and/or other relevant disturbances are summarized, as available.
- Critical Impact Thresholds – concentrations and/or levels reported to result in habitat degradation and/or loss are identified, as available.
- Data Gaps – critical information gaps limiting the understanding of potential impacts and/or thresholds of concern are identified.
- Restoration – the potential need and/or feasibility considerations for restoring habitat functions and values are reviewed. In addition, examples of restoration required after impacts associated with sediment management activities are considered.
- Summary – the basis of concern for potential habitat impacts associated with sediment management activities is summarized based on integration of information from the above-listed topics.

The following standardized set of terms is used to summarize the basis of concern for different types of impacts based on consideration of available documents and literature, as follows:

- Documented – impact documented by science-based monitoring and/or experimental studies.
- Protective conservatism – impact not documented, but of potential concern based on perceived ecological sensitivity and/or vulnerability of habitat and/or a similar impact has been documented for other relevant project types with similar activities.
- Unnecessary – impact not documented, and concern unwarranted based on available information on habitat recovery and/or resilience.
- Not applicable – no supporting basis and not considered an impact concern.

The habitat reviews in this section consider representative species. Section 4 contains more detailed reviews of selected species groups and special interest species. Integrated summaries of beneficial and adverse impacts associated with sediment management activities on habitats and species are presented in Section 5.

3.3.1 Coastal Dune and/or Strand

Guadalupe Dunes
Photo: Ted Mullen, SAIC

Regulatory Status:

Endangered/Threatened (state and federal_	Plants, insects, birds, terrestrial animals
Essential Fish Habitat	NA
Other	Ecological Reserves, National Natural Landmark, State Parks, Wildlfie Refuge

Several dune complexes are managed by California State Parks (e.g., Oceano Dunes, Oso Flaco Lake), CDFG (e.g., Morro Dunes Ecological Reserve), and USFWS (e.g., Guadalupe-Nipomo Dunes Wildlife Refuge). Native coastal dune and/or strand vegetation series are considered rare in California (CDFG 2003). The Department of the Interior designated the Guadalupe-Nipomo dunes complex as a National Natural Landmark (http://www.dunescenter.org/dunes.htm).

Description and Distribution:

Coastal dunes are a terrestrial habitat dominated by sand and may be associated with marine, estuary, lagoon, and/or lake shores (Hesp 2002, Shaffer 2002). The definition of dunes relative to the beach backshore differs among references. For example, the USACE (2003) glossary of coastal terminology and USFWS habitat classification (Cowardin et al. 1992) illustrate dunes as occurring landward of the beach backshore. In contrast, NOAA (Voigt 1998) and Hesp (2002) define dunes or foredunes as developing on top of the backshore. The landward boundary of the backshore only receives inundation during severe storms or storm tides (Voigt 1998, USACE 2003, CCC 2004).

The term coastal strand is applied to vegetation associated with the beach backshore and foredune areas strongly affected by wind, waves, and salt spray (CCC 1987, Florida FWCC 2005, www.sms.si.edu/IRLField Guide/IRLHabitats.htm, CalFlora 2005, Jepson Flora Project http://ucjeps.berkeley.edu/cguide.html, CERES 2006). Coastal strand vegetation also may occur on bluffs because of salt spray (CCC 1987).

Coastal dune and/or strand habitat occurs along exposed and protected coasts throughout California; however, dunes are more developed in central and northern California than in southern California (CCC 1987).

	California			On Land	Inter-tidal	Inshore < 30 ft	Offshore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Coastal dune and/or strand habitat	X	X	X	X				E, P

Coastal dunes are formed from wind blowing sand (aeolian transport) landward from the beach and accumulating in drifts, which become stabilized by vegetation. Sand is supplied from the dry backshore and/or from the foreshore if sand dries out between tides (Brooks and Agate 2001, USACE 2002). Dunes usually are in the form of parallel hills or ridges, with the most recently formed foredunes nearest the beach and older established dunes further inland (CCC 1987, Hesp 2002).

A comprehensive review of initiation, development, geomorphology, and dynamics of foredunes is provided by Hesp (2002), who summarizes that there are two major dune types, termed incipient (developing) and established. Incipient foredunes (also termed embryo dunes) were described as forming from seed deposition in the wrackline (strandline) of the spring tide region of the backshore, rhizome growth onto the backshore, and/or from sand deposition within discrete or relatively discrete clumps of pioneer vegetation, individual plants, driftwood, or other debris at various locations ranging from the immediate backshore to back-barrier flats. Established foredunes were described as developing from incipient foredunes and being commonly distinguished by the growth of intermediate, often woody, plant species, and by their greater morphological complexity, height, width, age, and [more landward] geographical position.

Useful References for Coastal Dunes and/or Strand Habitat

- http://homepages.ihug.co.nz/ ~sissons/Coastalprocesses.html
- http://handbooks.btcv.org.uk/handbooks/ content/chapter/745
- http://www.epa.qld.gov.au/environmental_management/coast_and_oceans/beaches_and dunes/beach_conservation/
- http://montereybay.nos.noaa.gov/sitechar/ coast.html
- http://www.snh.org.uk/publications/on-line/heritagemanagement/erosion/2.1. shtml

The natural community classification by Holland (1986) recognized three elements of the coastal dune community: active dunes, foredunes (northern, central, southern), and dune scrub (northern, central, southern). The active coastal dunes element was defined as barren, mobile sand accumulations along beaches, and often overrunning adjacent foredune and backdune scrub communities. This definition apparently included non-vegetated berms on the backshore as well as blowouts, based on the reference to overrunning of adjacent foredunes and backdunes. Foredunes were defined as being similar to active dunes, but vegetated with perennial grasses and low, often succulent, perennial herbs and subshrubs to about 4 in (10 cm) tall. Foredune vegetation was referenced as potentially occurring on upper beaches as well. Dune scrub was defined as being restricted to stabilized backdune areas characterized by shrubs, subshrubs, and herbs generally less than 3 ft (1 m) tall.

The California Natural Diversity Data Base (CNDBB) defines coastal dune habitat as including active coastal dunes, foredunes (coastal, central, southern), and the following vegetation series: sand-verbena-beach bursage, beach bursage, and non-native iceplant (CDFG 2003). Grasslands (native dunegrass, non-native grasslands) and coastal scrub (yellow bush lupine scrub, dune lupine-goldenbush scrub) also are distinguished.

Non-native sea rocket (*Cakile maritima*) and European beach grass (*Ammophila arenaria*) are among the hardiest of the early colonizers of open sands in California (CERES 2006). Pink and yellow sand verbena (*Abronia* spp.) and beach bursage (*Ambrosia chammissonis*) also may occur at more exposed sites. Non-native iceplant, such as Hottentot fig (*Carpobrotus edulis*) and sea fig (*C. chilense*) may form monotypic stands on disturbed foredunes.

In more stabilized areas, a greater variety of plants generally occurs (Slattery 1996). Common species in California include beach pea (*Lathyrus* spp.), southern beach primrose *(Camissonia cheiranthifolia suffruticosa),* beach morning-glory (*Convolvulus soldanella*), native dunegrass (*Leymus mollis*), saltbush (*Atriplex* spp.), dune buckwheat (*Eriogonum latifolium*), northern bush lupine *(Lupinus arboreus),* yellow bush lupine (*Lupinus arboreus*), and sea lavender (*Limonium californicum*), and gray-green silver beachweed (*Ambrosia chamissonis*,) (Holland 1986, CCC 1987, Sawyer and Keeler-Wolf 1995, http://www.cruzcnps.org/localplants.html). The habitat of established dunes also may be complex with swales between parallel dunes. Seasonal ponds may form in swales as a result of winter storms and high water table (www.friendsofthedunes.org/fod.natural.history.shtml). The dune community may transition to coastal salt marsh along estuaries, coastal sage scrub further inland, or to urban development (e.g., buildings, roads, seawalls, sidewalks) depending on site conditions.

Various terms have been used to describe dunes based on appearance. Morphology depends on sediment supply, wind velocity and direction, plant community development (density, distribution, height and cover), waves (e.g., swash inundation, storm wave erosion, overwash incidence), and other disturbance (Hesp 2002). Foredune height and volume generally relate to beach-surfzone type, with large dunes associated with dissipative beaches and minimal dune development on reflective beaches (Short and Hesp 1982, Hesp 2002); see Section 3.3.2 for description of beach morphologies.

Blowouts are an important feature of dune dynamics and morphology. Blowouts, may form cup-, saucer-, or trough-shaped hollows, and contribute to dune shapes (Hesp 2002, USACE 2002). Blowouts may occur along seaward foredunes or within established backdune areas. Blowouts may occur from a variety of causes, including erosion (wave or wind) or where vegetation is weakened by human activities (e.g., vehicles, trampling) (Hesp 2002). Blowouts naturally range from large-scale, such as

Types of Dune Morphology

Incipient Foredunes

- Ramp – sand accumulation along foredune scarp or other obstacle and/or vegetation sand trapping along seaward sloping backshore.
- Ridge – sand accumulated in convex mound.
- Terrace – backshore stabilized by vegetation (plant growth is rapid, growth matches accretion, or little accretion occurs).

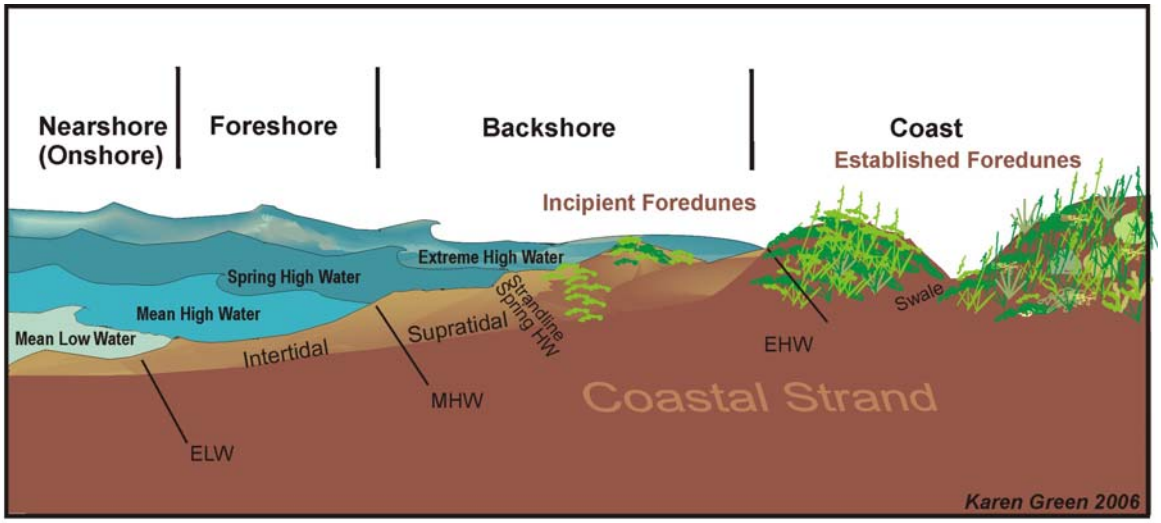
Established Foredunes

- Barchan – crescent shaped, extremities (horns) extend downwind.
- Longitudinal or parallel – ridges elongated parallel to wind direction (symmetrical in profile).
- Parabolic – arcuate ridges, concave portion faces beach.
- Transverse – ridges oriented perpendicular or oblique to dominant winds.

Sources: Smith 1954 (cited in USACE 2002a), Hesp 2002

associated with parabolic dune systems (high energy beach), to small-scale (low energy beaches) (Short and Hesp 1982).

Figure 3.3-1 illustrates relationships between the beach-dune system with incipient dune development shown on the backshore in the spring high water area and established foredunes are shown as landward of the backshore. The landward limit of the beach (or backshore) is defined as a region of marked change in material or physiographic form, or to the line of permanent vegetation (usually the effective limit of storm waves) (USACE 2003), which is shown on the figure as extreme high water.



Consulted references:
Nearshore, foreshore, and backshore boundaries (USACE 2003)
Coastal Strand = CalFlora 2005, Jepson Flora Project http://ucjeps.berkeley.edu/cguide.html)
Incipient and established dunes (Hesp 2002)

Figure 3.3-1. Beach-dune system relationships and terminology.

Coastal strand is shown on the Figure 3.3-1 as including the incipient foredunes on the beach and first foredune beyond the backshore, which are subject to wave and/or spray. The incipient foredunes are shown as a flat strandline terrace, convex ridge, and unvegetated ramp with vegetation at its toe.

Other dune classification schemes occur, but for simplicity are not shown on Figure 3.1-1. For example, in Europe, dunes may be referred to as foredunes (developing above swash limit, unstable and subject to wave erosion); yellow dunes (young dunes, unstable and wind blown, adjacent to backshore, where European beach grass also known as marram grass dominates); or grey (older dunes, stable, well vegetated, high humus content) (SNH 2000, http://en.wikipedia.org/wiki/Sand_dune).

Beaches in California vary considerably in the appearance and development of dunes and/or strand on the backshore and adjacent coast. Approximately twenty-seven relatively large coastal dune fields occur throughout the state (CCC 1987). The largest dunes occur along Monterey Bay and near the Santa Maria River (Guadalupe-Nipomo Dunes complex) in central California. Most of the other large dune areas occur in northern California. Few

relatively large sand dunes occur in southern California, the largest are at Coal Oil Point in Santa Barbara County and at the Tijuana River National Estuarine Reserve and Border State Park in San Diego County. The transverse dune type is most common in northern California, and parabolic dunes occur at Pismo Beach in the Guadalupe-Nipomo dune complex (CCC 1987).

Coastal dunes do not develop where the backshore ends at sea cliffs and/or bluffs; however, coastal strand vegetation may occur on bluffs in areas exposed to sea spray (CCC 1987). Small longitudinal dunes and/or relict dunes may occur on sand spits separating estuaries from the sea (e.g., Los Penasquitos Lagoon, San Dieguito Lagoon, San Elijo Lagoon) and/or adjacent to lagoon mouths (e.g., Batiquitos Lagoon) (http://www.sanelijo.org/plants/plants.htm, http://www.torreypine.org/parks/penasquitoslagoon.html). At popular recreational beaches, the backshore may be level and lack coastal strand vegetation due to frequent human disturbance (e.g., beach grooming, heavy public use).

Limited coastal strand, City of Encinitas
Photo credit: Chambers Group

Potential Functions Supported:

Dunes are naturally occurring coastal features that when present play an essential role in the stability of coastal communities (CCC 1987, Brooks and Agate 2001, Dahm et al. 2005). Dunes provide the first line of defense during storms and may protect sensitive vegetation and wildlife associated with foredune and more landward dune scrub habitats. Dune and/or coastal strand habitat may support primary living, foraging, reproductive, and/or resting functions for a variety of plant and animal species, including endangered and/or threatened species.

Associated Species	Primary Habitat	Forage Habitat	Reproductive Habitat	Resting Habitat	Forage /Prey
Vegetation	X		X		X
Invertebrates	X	X	X		X
Reptiles	X	X	X	X	X
Birds		X	X	X	
Mammals		X	X	X	
T&E Species	X	X	X	X	

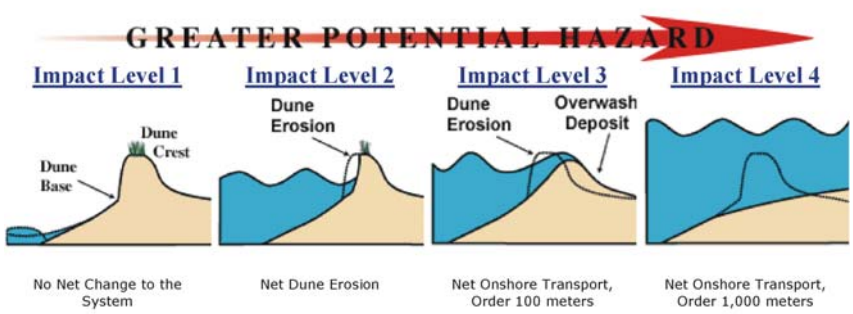
Sediment storage and exchange are key functions between the beach/foredune system (Hesp 2002, USACE 2003, Christiansen and Davidson-Arnott 2004). Dunes serve as a sediment sink and provide sand to intertidal habitat from erosion associated with blowouts and/or storm tide erosion. Foredunes may develop where there is sufficient width, suitable sediment supply (grain sizes within a range of 0.2 to 2.0 mm), and wind velocity (Hesp 2002, http://www.coastalguide.org/dune/ sandmob.html#foredune). Where dominant sand-moving

winds are oblique to the shore, a long narrow backshore may provide as much sand as a shorter broader backshore {Ranwell and Boar 1986 cited in Brooks and Agate 2001).

Sand transport from beach to foredune occurs from aeolian transport and from the dune to beach from storm tides eroding or washing over the primary foredune and/or from offshore winds (Brooks and Agate 2001, Hesp 2002, USACE 2002, Dahm et al. 2005). The beach/dune interaction and sand transport is influenced by the frequency of severe storms with large storm surges, height and width of the dunes, vegetation development, local sediment budget, and the rate at which aeolian sediment transport across the foredune take place (Hesp 2002, Christensen and Davidson-Arnoot 2004).

Waves may result in scarping of the seaward dune face, blowouts, and/or substantial dune erosion. The USGS coastal change hazard scale defines storm wave runup as Impact Level 1 (swash regime) if confined to the beach backshore; Impact Level 2 (collision regime) if runup exceeds and erodes the base of the vegetated dune or unvegetated berm; Impact Level 3 (overwash regime) if runup overtops the dune or berm; and Impact Level 4 (inundation regime) if storm surge overruns beaches and dunes and carries sand up to a kilometer inland.

A wind speed of 5 m/sec (about 10 mph) can mobilize sand grains, which move along by a process termed saltation (grains bounce downwind) and surface creep (force of descending saltating sand grains moves larger grains) (Brooks and Agate 2001) which, with sufficient wind velocity, may give the sand surface a cloudy appearance. Aeolian transport rates are affected by wind velocity and direction, foredune topography, surface roughness, and vegetation, with faster rates over hard substrates and deceleration and deposition where there is vegetation and other obstacles (Brooks and Agate 2001, Hesp 2002). Sand supply to back dune areas may be substantially limited from trapping within seaward foredunes.



Public domain credit: http://coastal.er.usgs.gov/hurricanes/ mappingchange/scale.html

Hesp (1999, 2002) reviewed the cycles of accretion and erosion of foredunes, recognizing five morpho-ecological stages that represents a combination of previous classifications (e.g., Short and Hesp 1982, Carter 1988, Arens 1994). The morpho-ecological types ranged from a scale of 1 (stable, fully developed) to 5 (substantial erosion). A wide variety of responses to dune erosion may occur over time, based on degree of wave scarping and overwash (mild to severe), sediment supply and other physical factors associated with dune formation, and degree of revegetation and reestablishment (Hesp 2002). A foredune may vary between

erosional and accretional forms within the same morpho-ecological stage or gradually build in place (stable coasts), slowly build or be replaced by new foredune development seawards (prograding coasts), or retreat landward or completely disappear (erosional coasts) (Hesp 2002).

Vegetation is a key element in dune formation and stabilization (Hesp 2002). Above ground canopy reduces wind velocity and contributes to deposition and trapping of wind blown sand. Below ground rhizomes bind and stabilize the dune surface. Loss of vegetation triggers dune erosion.

Ecological functions potentially supported by coastal dune and/or strand habitat relate to site-specific habitat characteristics. Large dune complexes with a mosaic of habitat types support a greater variety of species than smaller dune areas with a single foredune ridge. For example, the 18-mile coastline and 22,000 acres of preserve land associated with the Guadalupe-Nipomo dunes complex, which includes a mosaic of dune, swale, riparian, and scrub habitats supports more than 1,400 species of plants and animals (http://www.dunescenter.org/florfaun.htm).

The number of species also increases landward with relatively fewer species on the upper backshore and primary foredune than more established landward dunes. For example, dunes at the Monterey Bay National Marine Sanctuary include five or so plant species on any one beach and foredune face, but usually only one or two are dominant (Barbour and Johnson 1988 cited in Slattery 1996).

Non-native vegetation also can reduce habitat diversity. Coastal dune habitats have been substantially altered in many areas of the state by non native species. Non-native vegetation may form monotypic stands by out competing native species for available moisture and nutrients (CNPS 1996). Monotypic stands of exotics have limited habitat value to wildlife (Slatterly 1996, CNPS 1996). Most prominent has been the spread of European beachgrass (*Ammophila arenaria*) and several species of iceplant (*Carpobrotus chilenis, C.edulis*, *Mesembryantheum* spp.), which were initially used to stabilize sand dunes near railroads and highways (CNPS 2005). Other invasives of concern to dune habitats include sea-rocket (*Cakile edentula* and *C. maritima*), pampas grass (*Cortaderia selloana*), veldt grass (*Ehrharta calycina*), and ripgut brome (*Bromus diandrus*) (Cal EPPC 1999). . Although yellow bush lupine (*Lupinus arboreus*) is a native species, it is considered an “exotic” species north of Manchester Beach in Mendocino County (Sawyer and Keeler-Wolf 1995). European beachgrass, yellow bush lupine, and iceplant are being managed to restore native-dominated dune vegetation in several areas of the state (CNPS 2005).

The CalFlora database (2006) identifies over 200 native and non-native species with the potential to occur in the coastal strand community. Similar to other areas, a great variety of species is associated with dune habitats because of the mosaic of conditions represented across a geographic region associated with climate, substrate, water table, soil chemistry, and exposure (Brooks and Agate 2001), and also may relate in part to some species occurring in transition areas to coastal marsh and/or coastal scrub habitats.

Coastal dune and/or strand habitat supports nearly 20 federal and/or state-listed endangered and/or threatened plant species in California (CalFlora 2006) (Table 3.3-1). Over 50 CNPS rare plants are associated with coastal strand in the state. Many of the sensitive species

also are associated with coastal scrub and/or marsh habitats, emphasizing the potential value of transitional habitats with coastal strand.

CNPS List 1B rare plants (i.e., those that are rare, threatened, or endangered in California and elsewhere) associated with the coastal strand community include, but are not limited to: black-flowered figwort (*Scrophularia atrata),* Blasdale bentgrass (*Agrostis blasdalei*), Blochman's erigeron (*Erigeron blochmaniae*), Bolander's ragwort (*Senecio bolanderi var. bolanderi*), Brand's phacelia (*Phacelia stellaris*), coast wallflower (*Erysimum ammophilum*), coast woolly-heads (*Nemacaulis denudata var. denudata*), Coulter's saltbush (*Atriplex coulteri*), crisp monardella *(Monardella crispa),* Coulter's saltbush (*Atriplex coulteri*), crisp monardella *(Monardella crispa),* Mendocino Coast Indian paintbrush (*Castilleja mendocinensis*), manyleaf gilia (*Gilia millefoliata*), North Coast phacelia (*Phacelia insularis var. continentis*), Nuttall's lotus (*Lotus nuttallianus*), Point Reyes horkelia (*Horkelia marinensis*), round-headed chinese houses (*Collinsia corymbosa*), pink sand verbena (*Abronia umbellata ssp. breviflora***),** sand dune phacelia (*Phacelia argentea*), San Luis Obispo monardella (*Monardella frutescens*), and Wolf's evening-primrose (*Oenothera wolfii*) (CalFlora 2006).

Table 3.3-1. Federal and/or state-listed endangered and/or threatened species associated with coastal dune and/or strand habitat in California

Mainland Associated

Beach layia (*Layia carnosa*)
Beach spectacle-pod *(Dithyrea maritima*
Coastal dune milk vetch (*Astragalus tener* Gray var. *titi*)
Hoffman's gilia (*Gilia tenuiflora ssp. hoffmannii*)
Howell's spineflower (*Chorizanthe howellii*)
Humbolt, Menzies's, and Yadon's wallflower
(*Erysimum menziesii ssp. eurekense, ssp. menziesii, ssp yadonii*)
Monterey spineflower (*Chorizanthe. pungens* var. *pungens*)
Morro manzanita (*Arctostaphylos morroensis*)
Nipomo Mesa lupine (*Lupinus nipomensis*)
Robust spineflower *C. robusta robusta*)
Sand gilia (*Gilia tenuiflora ssp. arenaria*)
Seaside bird's beak (*Cordylanthus rigidus ssp. littoralis*)
Softleaf Indian paintbrush (*Castilleja mollis*)
Surf thistle *(Cirsium rhothophilium)*
Tidestrom's lupine (*Lupinus tidestromii)*

Wetland Associated

La Graciosa thistle (*Cirsium loncholepis*)
Saltmarsh bird's-beak (*Cordylanthus maritimus ssp. maritimus*)

Island Endemics

Northern Channel Islands phacelia (*Phacelia insularis var. insularis*)
Santa Cruz Island cliff-aster (*Malacothrix indecora*)

Coastal dunes and/or strand are home to hundreds of species of insects, including those species associated with wrack vegetation on the backshore, pollinators of endemic dune plants, and a wide variety of herbivores, detritus feeders, and predators (www.sbnature.org/collections/ invert/entom/COP/COPhabitats.php). Several sensitive

insect species are dependent on this habitat. Dune vegetation is used for feeding, egg laying, and caterpillar nursery habitat by the endangered Smith's blue butterfly (*Euphilotes enoptes smithi*), El Segundo blue butterfly (*Euphilotes battoides allyni*), Palos Verdes blue butterfly (Glaucopsyche lygdamus palosverdesensis), and sensitive Pheres blue butterfly (*Icaricia icarioides pheres*) and Morro blue butterfly *(Icaricia icarioides morroensis*). The globose dune beetle (*Coelus globosus*) (candidate for federal listing), is restricted to foredunes within 100 feet of the wave wash zone, and adult and larval stages of this flightless beetle burrow in sand to depths of approximately 5 to 10 cm beneath common dune plants such as sand verbena, beach bursage, and sea rocket (Slatterly 1996, Chambers Group 2001). Habitat suitability for globose dune beetles has been eliminated at most beaches due to human use activities and/or occurrence of non-native species such as European beach grass and/or iceplant (Slattery 1996). The endangered banded dune snail (Helminthoglypta walkeriana) may occur in sandy soils in central coastal dune scrub habitat.

Tadpoles of the pacific tree frog (*Pseudacaris regilla*) and threatened red-legged frog (*Rana aurora*) may be found in seasonal ponds that develop in swales and/or hollows between sets of dunes (www.friendsofthedunes.org/fod.natural.history.shtml). Black legless lizard (*Anniella pulchra nigra*) (proposed federal candidate 2) and silvery legless lizard (*A. p. pulchra*) (California species of special concern) may live under less disturbed sands (Bury 1981 cited in Slatterly 1996).

Coastal dunes provide habitat for many species of birds. For example, more than 200 species of birds live in, or migrate through, the Guadalupe-Nipomo Reserve (http://santalucia.sierraclub.org/osoflaco.html). Threatened western snowy plover (*Charadrius alexandrinus nivosus*) and endangered, California least tern (*Sterna antillarum browni*) may nest in foredune habitat (CCC 1987, USACE 2003).

The endangered Morro Bay kangaroo rat (*Dipodomus heermanni morroensis*), and a variety of other mammals (deer mice, California ground squirrels, California voles, gray fox, pocket gophers, striped skunk, mule deer) may live and/or forage in dune habitats (CCC 1987, Chambers Group 2001, USACE 1998b).

Life History Facts - Plant Community:

Most plants of coastal dunes and/or strand are perennial (sea rocket is a notable exception), which may be an adaptation related to the difficulty of establishing seedlings in loose sands (Slattery 1996). Plants may reproduce by flowers and seeds and/or vegetative spreading via rhizomes. Flowering and seed set primarily occur in spring through fall, and vegetative growth may be year round (http://www.cruzcnps.org/NFduneTxt.html). Dune habitat is used year round; seasonal use patterns may be associated with reproductive cycles and migratory species such as California least tern (see Section 4.4.2).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Flower/seed, Vegetative	Spring-Fall peak	Year round	NA	NA	Most species perennial, few annuals	Sedentary

Adaptations and/or Behaviors to Disturbance – Plant Community:

Coastal dune and/or strand vegetation are adapted to stress associated with winds, shifting sands, salt spray, and poor water-holding capacity and low fertility of the sandy sediment. Vegetation generally has low stature, deep and/or rhizomatous roots, and dense growth patterns that help anchor and protect individual plants from shifting sands and winds (CNPS 1996). Many of the plant species have morphological adaptations such as hairy or thick, leathery leaves that help capture water and/or minimize water loss. Plants also may have physiological adaptations to high-salt and low-nutrient soils; for example, saltbush (*Atriplex* spp.) has evolved special cells for salt excretion on its stems and leaves (CCC 1987). High reproductive effort and vegetative growth characterize many of the plant species. Rapid growth enables plants to keep from being buried by shifting sands (Slattery 1996).

Life Stage	Physical Adaptation			High Reproductive Output and/or Growth
	Low Stature	Protective Hairs or Sheath	Rhizomes	
Adult	X	X	X	X
Juvenile	X	X	X	X
Seed				X

Native dune species generally have an open growth spacing that permits co-occurrence of several species. In contrast, monotypic stands of non-native species may alter wind patterns and natural dune erosion and replenishment cycles (CNPS 1996). European beach grass changes the shape of dunes to be steeper, which can reduce dune width by blocking sand, and make them more vulnerable to storm waves (Slattery 1996).

Coastal dune and/or strand habitat is highly vulnerable to human impacts. Several factors have contributed to substantial changes and destruction of coastal dune and/or strand habitat in California (CCC 1987). Habitat loss has resulted from commercial and housing development, sand mining, and road construction. Increased vulnerability to wind erosion and blowouts has resulted from damage to vegetation from off-road vehicles, foot traffic, and equestrian use. Heavy recreational use has eliminated coastal strand vegetation above the highest high-tide line from many beaches, particularly in southern California.

Degraded coastal strand, San Diego
Photo Credit: K. Green, SAIC

Beach grooming is used to mechanically clean the backshore of high public use recreational beaches in some areas of the state. This practice may disturb development of incipient (embryo) dunes and colonization by pioneer coastal dune and/or strand vegetation by removing organic debris along the wrackline (www.ukbap.org.uk/UKPlans.aspx?ID=28). A field experiment at San Buenaventura State Beach, southern California, showed reduction in seedling survival of beach saltbush (*Atriplex leucophylla*) and increased sand transport rates at groomed relative to ungroomed stretches of beach (James et al. 2004).

Stephenson (1999) reviewed several studies of vehicle impacts to coastal dunes and summarized that vehicle traffic results in decreased height, biomass, total cover, and/or species composition of vegetation. The following examples cited by Stephenson (1999) provide quantitative estimates of damage and/or recovery to dune vegetation. Surveys at Cape Cod National Seashore, Massachusetts showed reductions in biomass of beach grass (*Ammophila breviligulata*) of 75 to 85% after 675 vehicles passes, with recovery of 39 to 59% of the original biomass within 12 months. In contrast, dunes dominated by beach heather (*Hudsonia tomentosa*) continued to show reductions in cover and number of plant species three years after impact (Brodhead and Godfrey 1977). Foredune vegetation cover was 45% less and number of species 13.3% lower at a site widely used by vehicles compared to an unimpacted site at Cape Fear, North Carolina (Hosier and Eaton 1980). Experimental studies of vehicle and pedestrian traffic showed greater impact (reduced height and cover) and slower recovery in climax (> 10 months) versus pioneer (≤ 10 months) dune vegetation, inhibition of recovery from repeated impacts destroying seedlings, and greater damage when vehicles drove on a curved path than along a straight path (Rickard et al. 1994).

Because of the high vulnerability of coastal dune and/or strand habitat to human impacts and substantial shoreline protection and ecological values, dune management planning and/or programs have been developed to conserve and restore dunes in many parts of the world (e.g., SNH 2000, Brooks and Agate 2001, Dahm et al. 2005, Government of South Australia 2005). Management plans generally address the following key actions: (1) dune stabilization, (2) dune revegetation, (3) access and vehicle control, (4) monitoring and maintenance, and (5) public education. Sensitive species protection also may be part of site specific plans based on resource occurrence.

Loss of sand from beaches and dunes is a shoreline protection concern in many parts of world. Loss of sand from aeolian transport onto parking lots, sidewalks, roads, and residential areas adjacent to recreational beaches not only results in sand loss but also results in high street sweeping and/or other maintenance costs (Brooks and Agate 2001, DBW and SCC 2002). Dune erosion by waves, although a part of the normal beach-dune interaction, is of concern in areas where sediment supply has become limited by river damming and/or other development activities (www.ukbap.org.uk/UKPLANS.ASPX?id=28). Sand mining from beaches and dunes was outlawed by 1991 from most areas of California, although legal mining still occurs in one area in Monterey County (Magoon and Lent 2005). Beach and dune mining it is discouraged because it may disrupt sand transport, remove vegetation, adversely affect shorebirds, and ultimately result in beach erosion (Brown and McLachlan 2002, Magoon and Lent 2005).

Dune stabilization techniques may include the use of sand retention walls, drift fencing, and/or revegetation to prevent loss of wind blown sand (Brooks and Agate 2001, Dahm et al. 2005). Sand retention walls and/or sand fencing are used along the backshore adjacent to urban development in some coastal cities in California (e.g., Mission Beach, Carlsbad, Redondo Beach, Hermosa Beach, Port Hueneme, Ocean Beach) (DBW and SCC 2002, K. Green personal observation). Dune revegetation also was used to control aeolian transport at Port Hueneme (DBW and SCC 2002).

The type of species selected for dune stabilization can have broader environmental consequence than erosion control. Historic use of non-native European beach grass and iceplant to control wind blown sand near coastal railroad tracks and highways displaced

native species, resulting in increased vulnerability to erosion over time and habitat degradation, which now represents a restoration challenge in many areas of the state (Slattery 1996, CNPS 2005). Dune revegetation and restoration are discussed further in a separate subsection below.

Adequate understanding of local sand transport processes also is important for avoiding potential impacts to downdrift habitats. Artificial stabilization techniques can result in undesirable interruption of sand transport in areas where wind-blown transport of sand from updrift beaches occurs overland to downdrift beaches (Brown and McLachlan 2002).

Combinations of formal pathways, fencing, and/or signage have been used to control trampling damage and erosion of coastal dune and/or strand vegetation. Simple board and chain (sand ladder) access ways are common in New Zealand and have advantages of being relatively easy and inexpensive to build (Dahm et al. 2005). Sand drift fencing sometimes is placed for the dual purpose of limiting pedestrian access and sand retention (Government of South Australia 2005).
Designated use areas are used to control off-road vehicles. For example, fencing and signage are used to control vehicle use in sensitive habitat areas at the Oceano Dunes (http://ohv.parks.ca.gov/default.asp?page_id=1207). Small fenced enclosures also are used at Oceano Dunes to protect California least tern nests and their offspring from surrounding recreational use during their breeding season.

Potential Impacts from Sediment Management Activities:

Potential impact concerns to coastal dune and/or strand habitat from sediment management activities relate to the rareness of native vegetation and the potential use of this habitat by endangered, threatened, or other sensitive species. More detailed reviews of potential impacts to California least terns and western snowy plover are given in Sections 4.4.2 and 4.4.3, respectively.

The physical appearance and ecological values of this habitat, when present, range from limited development along the backshore to large, dune field complexes with a mosaic of habitats. Erosive beaches backed by seacliffs and/or riprap generally lack coastal dune and/or strand habitat. The need for beach nourishment is tied to erosive beach conditions; therefore, sediment management activities generally would not be expected at beaches backed by large dune fields. Consequently, beaches with limited to moderate development of coastal dune and/or strand habitat represent the likely range of habitat conditions with the potential to be affected by sediment management activities involving beach nourishment.

Types of sediment management activities and potential impact factors to coastal dune and/or strand habitat and associated species include:

- Maintenance dredging of embayments – not applicable.
- Offshore borrow site dredging – not applicable.
- Nearshore placement – turbidity.
- Profile placement – equipment, turbidity.
- Beach placement – equipment, turbidity.
- Dune placement – equipment, burial, sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging		A	A	A	A	
Growth			P	P		
Habitat			P	P		P
Reproduction /Nesting	A	A	A, P	A, P		
Resting/ Roosting	A	A	A	A		A

A = associated animals, P = plants

Equipment

Equipment use associated with pipeline placement, equipment staging, and/or vehicle use in support of beach nourishment is of potential concern if coastal dune and/or strand habitat is present. Native habitat is rare and extremely vulnerable to damage from vehicles and trampling. Potential impacts also could be of concern in areas with non-native vegetation, if disturbance resulted in dune destabilization and erosion. Sand mining from dunes for placement on the beach may disrupt sand transport, remove vegetation, adversely affect shorebirds, and ultimately result in beach erosion (Brown and McLachlan 2002, McGoon and Lent 2005).

Pipeline placement used to convey maintenance dredge materials to South Beach, Ventura County resulted in minor damage to dune vegetation (USACE 1998b). A beach erosion control project involving revegetation on the dunes and beach was conducted in 1985 to stabilize the sand. The most successful seeded species observed one year later included sea fig, sea lavender, and to a lesser extent lupine; also established were non-native sea rocket and native beach ragweed, which were not seeded (USACE 1998b). During the 1986-1987 Ventura Harbor dredging project, erosive beach conditions required laying the beach discharge pipeline in the revegetated area causing minor damage from which the plants subsequently recovered.

Several protective measures have been used to minimize impacts when coastal dune and/or strand vegetation is present. At Morro Bay, protective measures have included restriction of pipeline alignment and transportation corridors outside vegetated areas, whenever possible, and restriction against use of all-terrain vehicles by contractors (USACE 2001). Restriction of pipeline placement to avoid traversing of sand dunes also was implemented during placement of maintenance dredged materials at McGrath State Beach near Ventura Harbor (USACE 1998b).

In general, avoidance and/or minimization measures used to protect coastal dune and/or strand vegetation from direct damage also protect wildlife that may use the habitat.

However, the potential for direct and/or indirect impacts is of particular concern for threatened western snowy plovers and/or endangered California least terns, which may nest on unvegetated and/or sparsely vegetated backshore and/or dunes areas. Eggs and chicks of these species are particularly vulnerable because they are small and difficult to see. Protective measures that have been developed in coordination with resource agencies in California have included schedule avoidance, use of monitors and no work zones to ensure no direct impacts, restriction of vehicle corridors, temporary fencing, and/or surf zone and/or diked beach discharge to avoid or minimize interference with western snowy plover foraging (see Sections 4.4.2 and 4.4.3).

Most sediment management projects in California have occurred at beaches without sensitive coastal dune and/or strand habitat (e.g., USACE 1995, 1998a, 1999, 2000, SANDAG and USDN 2000, Moffatt & Nichol 2003).

Reshaping of the landward backshore slope and revegetation with dune vegetation has been used as a shoreline stabilization method and to create a more natural shore in New Zealand (Dahm et al. 2005). The Scottish Natural Heritage guide for managing coastal erosion in beach/dune systems recommends combining nourishment with sand fencing, thatching, and/or revegetation to prolong shoreline protection benefits and to encourage development of new foredunes and an extended dune habitat and/or to create more natural shore (SNH 2000).

Burial/Sedimentation

Beach nourishment involving the dune placement method has the potential to directly impact coastal strand habitat, if present, and indirectly impact adjacent intertidal and dunes (if present). This method involves placement of sands in a temporary berm or dike along the backshore to serve as a sand reservoir for nourishing beaches during high water conditions. This alternative has been included as a potential placement alternative for California opportunistic beach nourishment programs (Moffatt & Nichol 2000a,b, 2005b) and dual purpose shoreline protection and beach nourishment projects such as the Goleta Winter Dike Project (Chambers Group 2002). Pre-construction surveys did not report the occurrence of coastal dune and/or strand habitat in the area of potential effect of those projects.

The dune placement technique provides a sand reservoir for adjacent dunes, if present, and has the potential to affect aeolian transport dynamics of the beach to foredunes. This can benefit coastal dune and/or strand habitat and associated species. For example, beach nourishment can protect sensitive plant species from erosion (Spadoni 1993 cited in NRC 1995). Beach nourishment was used for shoreline protection to reduce erosion of existing vegetated foredunes on degrading beaches in New Jersey (http://gannet.stockton.edu/test/2001/Cape%20May/photoplates/225.htm). Beach nourishment enhanced nesting habitat for piping plovers (Melvin et al. 1991). Dune restoration in association with beach nourishment also has been used to enhance shoreline protection in several areas along the east coast and internationally (see Restoration subsection below).

Van der Wal (2000) conducted an integrated field validation of the aeolian transport model SAFE and air flow model HILL based on comparison of cross-shore changes at two nourished beaches and adjacent dunes. Nourishment sediment was placed at the toe of 32 to 46 ft (10 to 14 m) high vegetated dunes. Findings from that study showed generally close agreement between model predictions and empirical measurements of erosion and

deposition and beach profile morphology, but rates of aeolian sediment transport were overestimated, suggesting a number of factors (e.g., sediment moisture, variable wind conditions) that may reduce aeolian transport were not well accounted for by the model. Model simulations indicated that grain size and adaptation length (distance over which sediment transport adapts to the new equilibrium condition) were more influential than beach nourishment topography on predicted aeolian sand transport rates and beach profile morphology.

Turbidity

The dune placement method on the backshore, does not generate turbidity during construction. This method was suggested as a placement alternative that would enable a more gradual introduction of sand to the sea and/or turbidity control for the San Clemente Beach Replenishment Program (Moffatt & Nichol 2000), Goleta Beach Five-Year Winter Dike Project (Chambers Group 2002), and SANDAG Sand Compatibility and Opportunistic Use Program (SCOUP) (Moffatt & Nichol 2005b).

Turbidity generated during beach nourishment projects, if conducted nearby, will not affect coastal dune and/or strand habitat and most wildlife species associated with this habitat. One notable exception is the California least tern, which may use coastal dune and/or strand habitat for resting and/or breeding habitat, but forage on small fish in nearshore and/or estuarine waters; therefore, turbidity generated during beach nourishment has the potential to affect foraging habitat for this migratory bird, if present (see Section 4.4.2).

Recovery from Disturbance:

Coastal strand vegetation on the beach backshore is periodically removed by storm waves as part of the natural, dynamic beach cycle. Recovery after disturbance is associated with sand accretion and recolonization by pioneer plant species. Colonization of the beach backshore occurs by seed deposition in the wrack line and/or vegetative growth from adjacent foredunes (Hesp 2002). Rates of recovery from backshore habitat loss would be expected to take one or more years depending on proximity to unaffected habitat; i.e., distance from potential seed and/or vegetative colonization sources.

Recovery from disturbance of dunes located adjacent and/or landward of the beach backshore would depend on the extent of damage. Minor damage resulting from pipeline placement in a revegetated dune area at South Beach, Ventura subsequently recovered within one year (USACE 1998b). Minor repairs to gaps in dune vegetation also may occur within a season (Dahm et al. 2005). More extensive damage associated with blowouts; substantial vegetation loss from vehicles, equipment, and/or trampling; and/or a higher than normal frequency of erosion events may take several years to recover if at all (Stephenson 1999, Dahm et al. 2005).

The following summary table identifies that recovery rates from impacts associated with sediment management activities have the potential to span one to several years depending on impact factor. Recovery from equipment impacts could span one to several years depending on extent of impact. Direct burial of coastal dune habitat would not occur from beach nourishment activities. If burial of coastal strand vegetation on the beach backshore occurred, recovery would be expected to take one to several years depending on proximity to unaffected habitat; i.e., distance from potential seed and/or vegetative colonization sources.

Indirect sedimentation generally represents a potential beneficial impact for coastal dune and/or strand habitat.

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment		X	X		
Burial		Backshore	Backshore		Dune
Sedimentation				X	
Turbidity	Bird foraging				Habitat

Critical Impact Thresholds

Native dune vegetation is extremely sensitive to trampling, vehicles, and other forms of disturbance.

Data Gaps

Few studies have examined the effects of beach nourishment (adverse or beneficial) on coastal dune and/or strand habitat and associated species.

Restoration

Several dune restoration projects have occurred in localized areas of northern, central, and southern California. Most of these projects have involved eradication of non-native species. A few examples are referenced below to provide an indication of range of project sizes and involved agencies. The Nature Conservancy implemented a 10-acre (4-hectare) restoration of European beachgrass at Lanphere Dunes, northern California (http://tncweeds.ucdavis.edu/success/ca002.html). The Bureau of Land Management (BLM) conducted a massive removal of European beachgrass, yellow bush lupine, and iceplant where sensitive native plants were being displaced (CNPS 2001). The U.S. Navy provided funding to the City of Monterrey to restore approximately 44 acres of dunes that became destabilized after a winter freeze killed existing non native iceplant (http://www.coastalamerica.gov/text/regions/sw/nps.html). Researchers and students at the University of California, Santa Barbara conducted a 2.5-acre (1-hectare) restoration to remove iceplant and revegetate with native species (James et al. 2004). The USFWS is conducting exotic species removal and restoration at the Guadalupe-Nipomo Dunes Wildlife Refuge (USFWS 2005a).

Dune restoration has been conducted in several areas around the country to enhance shoreline protection, address undesirable aeolian transport of sands from beaches to developed areas, and/or to improve ecological function of coastal dune and/or strand habitat. Two relevant examples from California include projects near Ventura Harbor and Port Hueneme. The Ventura Port District began a dune re-vegetation program in 1985 to stabilize sands at South Beach (USACE 1998b). The City of Port Hueneme received a state grant to conduct dune restoration to stabilize the back beach to reduce sand loss and local maintenance problems associated with wind-blown erosion (DBW and SCC 2002).

Beach nourishment involving the dune placement method and stabilizing the dune with vegetation and/or sand fencing has been used to provide a natural shoreline protection alternative and to prolong duration of benefit elsewhere in the United States. Dune shoreline

protection and/or management projects have been conducted on the east coast from New York to Florida (e.g., NYSDEC 1998, Maryland DNR 2003, Florida DEP 2005, Louisiana DNR 2005, Sciaudone et al. 2005, http://www.townofkurebeach.org/beach_renourishment.htm).

Dune conservation and restoration are important issues internationally. Guidance recently was prepared to foster more natural and cost-effective shoreline and beach protection from coastal erosion and flooding in New Zealand (Dahm et al. 2005); a guide to managing coastal erosion of beach/dune systems was prepared for Scotland (SNH 2000); and documentation on dune care is available for Australia (http://www.esmediaweb.com/sandybeachdunecare/coasthome.php). Most conservation work in the United Kingdom has focused on protecting the dunes that still remain, recreating denuded dunes by trapping wind-blown sand using fencing, brushwood and transplanted vegetation, and providing suitable access routes to the beach to reduce visitor pressure (Brooks and Agate 2001, www.ukbap.org.uk/UKPlans.aspx?ID=28). Coastal defense in Holland changed in 1990 from the prior practice of reforming foredunes with bulldozers and planting with European beachgrass to what is termed dynamic maintenance of the coast, which involves beach nourishment; keeping the primary foredune free of blowouts, rabbits, rats and moles; prohibiting digging or removing sand from the primary foredune; and prohibiting cattle grazing on the dunes (http://www.coastalguide.org/dune/meijen3.html).

The feasibility of dune restoration has been demonstrated by numerous studies. Several reports and documents provide relevant restoration guidance (e.g., CNPS 1996, Pickart and Sawyer 1998, Dahm et al. 2005). Full restoration is labor intensive and generally requires maintenance to prevent invasion by non-native species. A successful, 10-acre (4-hectare) restoration of European beachgrass at Lanphere Dunes, northern California, required approximately 2,951 person-hours/acre for the initial three years of control at the dune, with the majority of hours in the first year (http://tncweeds.ucdavis.edu/success/ca002.html). Roughly a third of the cost was due to transportation costs because of the remoteness of the area. Over a five-year period from 1992 and 1997, native plant cover from existing seed bank increased 47% without the assistance of active re-planting.

In areas where restoration involves replacement of monotypic stands of exotic species (e.g., European beachgrass, iceplant), a program of gradual replacement with native species is recommended to minimize the likelihood of blowouts, particularly on exposed foredunes (CNPS 1996).

Ongoing monitoring and maintenance of restored dunes also may be required in areas where public beach use may result in damage to plantings and dune vegetation. Signs and controlled beach access ways have been effective in protecting restored areas (Dahm et al. 2005). Natural storm erosion does not necessarily require intervention or maintenance. If a dune is well vegetated and human disruption is minimized, the vegetation will naturally recover.

Monitoring may simply consist of regular inspections of dune condition and photographic records of restored areas. Other techniques such as Light Detection And Ranging (LIDAR) have been suggested for larger-scale monitoring and evaluation of coastal dune shoreline condition (Dahm et al. 2005).

Summary:

Native coastal strand vegetation is designated as rare in California. Coastal dune and/or strand habitat has been substantially modified from development, human use, and historical practices involving use of invasive exotic species to stabilize dunes. Beaches with high public use and/or limited sand supply and erosive conditions often lack coastal strand vegetation on the backshore and/or lack adjacent coastal dunes. Consequently, functional coastal strand backshore and/or dune habitat only occurs in localized areas of the state.

The basis of concern for impacts to this habitat is largely protective conservatism supported by documentation of public use damage and/or degradation of habitat from trampling and vehicle use in dune habitats. Few references of impacts from sediment management activities were identified with the literature review. Adverse impacts from sediment management activities have been avoided and/or reduced by a process involving establishment of no work zones, restriction of vehicles and pipeline alignments in dune vegetated areas, and replacement mitigation to offset inadvertent and/or unavoidable habitat loss. Such measures are considered prudent given the sensitivity of the habitat and high degree of vulnerability to disturbance.

Construction impacts of concern include direct damage and/or removal of native coastal strand vegetation by equipment and/or human disturbance, and direct and/or indirect interference with foraging and/or reproductive functions of sensitive wildlife that may use this habitat. Post construction concerns include the potential for destabilization and erosion of dunes due to construction impacts and, if that occurred, secondary losses in local productivity of wildlife that use this habitat. Direct and indirect beach nourishment benefits include shoreline protection of sensitive coastal dune and/or strand habitat and species.

Turbidity generated from sediment management activities conducted elsewhere may have the potential to affect foraging of endangered California least tern, if adjacent to coastal dune and/or strand habitat used for nesting.

Dunes with monotypic stands of invasive non-native species such as iceplant and/or European beach grass provide little habitat value and are resilient to minor disturbance. However, substantial disturbance of these degraded dune areas could result in dune destabilization, accelerate sand transport rates, and/or result in habitat loss requiring the need for restoration.

Recovery of native dune vegetation from minor damage during sediment management activities may be possible within a growing season; however, substantial damage would be expected to be on the order of years. In addition, recovery of native vegetation could be compromised by non-native vegetation if present in the vicinity. Dune restoration is considered feasible, but labor intensive and requires maintenance to avoid establishment of non-native invasive plants.

Most dune restoration in California has been applied to reduce exotic invasive plant species. However, dune management including nourishment and stabilization with vegetation and/or sand fencing is being applied elsewhere in the United States and internationally to provide shoreline protection for coastal structures as well as protective benefits to sensitive vegetation and wildlife.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities to coastal dune and/or strand habitat.

Issue	Type of Impact				
	Beneficial	Adverse Equipment	Adverse Burial	Adverse Sedimentation	Adverse Turbidity
Basis of Concern	Documented	Documented	Protective conservatism	NA	Protective conservatism*
Critical Impact Thresholds	NA	Vegetation loss	Vegetation loss	NA	NA
Habitat Impacts	Shoreline and sensitive species protection	Vegetation damage, loss; Animal disturbance , mortality	Vegetation loss, Animal disturbance, mortality	NA	Habitat NA, Feeding Interference (birds*)
Duration of Habitat Impacts	Months-years	Days-Months	Months-years	Months-years	NA
Potential for Habitat Restoration	NA	Yes	Yes	NA	NA

NA = not applicable, *Potential concern to California least tern if present and beach nourishment conducted in vicinity of dune habitat during nesting season.

3.3.2 Sandy Beach

Photo by: K. Green, SAIC

Regulatory Status:

Essential Fish Habitat	X
Other	Critical Habitat in some areas

Sandy intertidal beach is Essential Fish Habitat for managed fishery species. Some sandy shores have special regulatory status as Critical Habitat for threatened western snowy plover (Section 4.4.3).

Description and Distribution:

Boundaries of this habitat range from extreme low water to the upper limit of the beach profile (Thompson et al. 1993), which includes but extends seaward of the foreshore and includes the entire backshore. The backshore may transition to coastal sand dune and/or strand (Section 3.2.1) or meet a sea cliff, seawall, or coastal development.

Sandy shores occur throughout California along exposed and protected coasts, although they are more prevalent along the southern part of the state (80 %) than in central (39 %) and northern (46 %) California (Ambrose et al. 1989).

Life Stage or Function	California			On Land	Inter-tidal	Near-shore < 30 ft	Off-shore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Primary Habitat	X	X	X	X	X			E, P

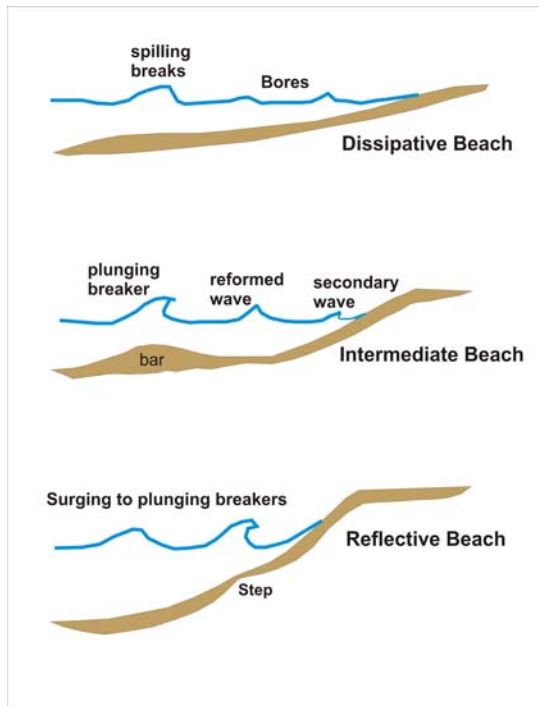
Potential Functions Supported:

The intertidal portion of sandy beaches may provide primary habitat for a variety of marcroinvertebrates (e.g., worms, sand crabs, isopods, amphipods, clams) and very small meiofauna (e.g., nematodes, platyhelmenthes, copepods, gastrotrichs) (Section 4.2.6). California grunion (*Leuresthes tenuis*) use sandy beach as spawning habitat, and invertebrates provide forage for fish in the surf zone (Sections 4.3.1, 4.3.4, 4.3.5). Sandy beaches may provide important foraging and resting habitats for a variety of shorebirds and seabirds (4.4.4 and 4.4.5). The endangered least tern and threatened snowy plover may nest on the beach backshore, and snowy plovers forage may above and below the high-tide line (Sections 4.4.2 and 4.4.3). Seals and sea lions may haul out (rest) on beaches, and breeding colonies use secluded beaches on the mainland and offshore islands; most rookeries occur on the Channel Islands (Section 4.5.2). Sandy beaches provide valuable recreational and scenic resources that substantially contribute to California's economy (DBW and SCC 2002). Some marine invertebrates (e.g., clams, crabs, sand crabs) are taken by recreational fishermen for bait and/or food, and grunion is recreational fished by hand during their spawning runs (CDFG 2005a).

Associated Species	Primary Habitat	Forage Habitat	Reproductive Habitat	Resting/ Roosting Habitat	Fisheries Habitat		Forage /Prey
					Commercial	Sport	
Invertebrates	X	X	X			X	X
Fish		X	X			X	X
Birds		X	X	X			
Marine Mammals			X	X			
T&E Species		X	X	X			

Beaches display considerable variability based on a combination of physical variables, including slope, width, and grain size characteristics. The interactions between tidal regime, wave climate, and sediment type produce a range of beach morphodynamic types spanning a continuum from wide and flat dissipative beaches to narrow and steep reflective beaches (Short and Hesp 1982, Defeo and McLachlan 2005).

Dissipative beaches are so named because they are fronted by a wide surf zone that dissipates wave energy. Dissipative beaches are formed under conditions of large tide range and high wave energy, but are characterized by gentle slopes and swash zone, limited sand mobility, and relatively high invertebrate diversity and biological resources (Hesp and Short 1982, Wright and Short 1984, McArdle and McLachlan 1992, Brown and McLachlan 2002). Reflective is the term applied to beaches where wave energy is reflected back to sea from waves breaking directly on a steep beach face. Reflective beaches form under small tides and waves and have a bar-less surf zone, but generally have a steep slope, coarse sand, limited sand mobility, and fewer biological resources. A variety of beach states fall between these two extremes. A bar-trough morphology in the surf zone and rip circulation generally characterize intermediate beaches (Short and Hesp 1982). The greatest degree of sand mobility is associated with intermediate but highly changeable wave conditions, medium grained sediment, and a modest or meager sediment supply (Wright and Short 1984).



After: Komar 1998
Redrawn by K. Green

Beaches may be classified according to beach morphodynamic type based on wave and sediment characteristics to compute a dimensionless index of sediment fall velocity,

commonly known as Dean's parameter (Ω), as follows: Ω = wave height/settling velocity x wave period (Wright and Short 1984). Values of Dean's parameter may range from 0 to 1 for reflective beaches, 2 to 6 for intermediate beaches, and 7 to 10 for dissipative beaches. Beach morphology may change towards dissipative or reflective according to environmental conditions, often seasonally, (Brown and McLachlan 2002).

Limited classification of California beaches according to morphodynamic type has been done to date. Straughan (1982) measured beach slope and sediment characteristics as part of biological surveys, providing useful information regarding relative morphologies among beaches in southern California. Dugan et al. (2000a) surveyed 36 beaches in southern California, between Los Angeles and Santa Barbara and on several Channel Islands, and classified the majority of them as intermediate (Dean's parameter of 1.5 to 6.6.) and a few as reflective (Dean's parameter of 0.2 to 0.6).

Beaches differ with regard to supported ecological functions depending on physical characteristics, biological interactions, and human disturbance. Beaches in California may undergo substantial volume change between seasons (Shepard and Inman 1951). This often is reflected in wider beach widths during summer accretion and narrower widths during winter erosion periods (Coastal Frontiers 2004). Sand depths across seasons may range from 0 to several feet (0 to > 1 m) depending on location, season, and other factors (Flick 1992, Thompson et al. 1993, MEC 2000a, Coastal Frontiers 2005, SAIC 2006). Straughan (1981) measured net movement of sand of up to 1 ft (0.3 m) between successive days at a beach during late summer and stated larger amounts are moved over shorter time frames during storms. Sediment profile measurements indicated winter to summer sand depth differences of ½ to 4 ft (0.15 to 1.2 m) for different beaches in southern California (Coastal Frontiers 2005). Hubbard and Dugan (2003) reported seasonal sand elevation changes by more than 4.9ft (1.5 m) at Isa Vista, Santa Barbara County.

On seasonally erosive beaches, invertebrate community development may fluctuate from moderately developed after seasonal sand accretion to limited (few species) after seasonal sand erosion if the sand layer thins and bedroack and/or cobbles become dominant (Brown and McLachlan 2002, SAIC 2006). Substantial seasonal erosion can limit habitat suitability across seasonal use periods for grunion spawning and foraging and resting habitat for shorebirds and seabirds (SAIC 2006).

Other factors affecting community development include macrophyte wrack, which imports organics to the upper beach. Several invertebrates (e.g., insects, crustaceans) depend on this resource, and provide secondary production for several bird species (e.g., gulls, plovers) (Brown and McLachlan 2002, reviewed in Dugan et al. 2003).

Human disturbance may modify sandy beach communities and functions. It has been estimated that over 45% of the coastline in southern California is subject to beach grooming with heavy equipment, which removes debris along the backshore (Dugan et al. 2003).

Mechanical removal of macrophyte wrack, if present, reduces nutritional input for invertebrates dependent on that resource, with potential secondary reduction of forage base for some birds (Brown and McLachlan 2002, Dugan et al. 2003). Beach grooming also may impact the success of grunion spawning (Martin 2002).

Dr. Karen Martin (Pepperdine University) and Dennis Simmons (Beach Manager for the City of San Diego) established the Ecologically Sensitive Beach Management Working Group in 2003 to conduct semi-annual workshops with resource and beach managers. Beach management best practices are discussed particularly as they concern sharing the shoreline with humans and wildlife. Among other topics, grooming practices are described and demonstrated that avoid grunion spawning habitat and minimize disturbance of the wrack line that provides foraging opportunities for shorebirds such as the threatened snowy plover. Beach grooming guidelines have been adopted by numerous agencies in the state.

Environmental beach grooming at Mission Beach, California

Note: Groomed area on backshore, high-tide and intertidal with kelp wrack ungroomed.

Photo: K. Martin, Pepperdine Univeristy

Other off-road vehicle use on California beaches is limited, primarily involving lifeguards, emergency response, and/or shoreline protection projects. Available studies indicate that vehicle impacts in the intertidal generally are minor during the day, particularly with low use (Wolcott & Wolcott 1984, Stephenson 1999). However, impacts have the potential to be substantial at night and/or with high use depending on resources with the potential to use the beach. For example, animals occupying burrows at the boundary of or on the backshore (e.g., talitrid amphipods, *Ocypode* ghost crabs), incubating grunion eggs, and turtle hatchlings have been reported as being vulnerable to vehicle impacts (van de Merwe and van de Merwe 1991 reviewed in Stephenson 1999, Brown and McLachlan 2002, Martin 2002); of these species, talitrid amphipods and grunion use California beaches.

Life History Facts – Associated Animals:

Sandy beaches may provide habitat functions year round, although biological resource use varies across season associated with reproductive and migratory patterns of fauna. For example, sand crabs migrate and recruit to California beaches in spring and may overwinter offshore (4.2.1). California grunion may spawn on beaches between March and September (Section 4.3.1). Generally, resource use is relatively high from spring through fall and lower during winter (Thompson et al. 1993). Sand limited or eroded beaches may exhibit shorter effective seasons for resident fauna. For example, seasonal erosion may limit duration of habitat suitability for grunion spawning (SAIC 2006).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Nest Egg/Spawn Planktonic Live birth	Spring-Fall peak	Year round	No	Depends on species	Depends on species	Depends on species

Reproductive methods and other aspects of life history are species specific. Invertebrates generally release eggs and/or larvae that undergo further development in the plankton, and then settle and metamorphose into their juvenile-adult morphology (see Section 4.2.1) California grunion spawning is tied to approximately two-week lunar cycles associated with

new and full moons (see Section 4.2.2.1). Few birds nest on beaches in California. The endangered California least tern and threatened snowy plover are seasonal migrants that breed and nest at some beaches, estuarine flats, and dredge spoil areas during spring and summer in California (Sections 4.4.2 and 4.4.3). Seals and sea lions establish breeding rookeries and/or give birth on secluded beaches on offshore islands and/or at a few locations on the mainland of California (Section 4.5.2).

Adaptations and/or Behaviors to Disturbance – Associated Animals:

Sandy beaches are harsh, physically controlled environments. All sandy beach environments are harsh due to shifting sands, alternating periods of tide and air exposure, and wave/storm disturbance. Beach morphodynamics, particularly wave exposure, influence the development of intertidal invertebrate communities with relatively fewer species able to survive on exposed reflective than protected dissipative beaches (Dexter 1982, McArdle and McLachlan 1992.). Thus, the degree of harshness varies among beaches along the coast.

Life Stage	Avoidance Behavior			High Reproductive Output and/or Growth
	Burrow	Fly	Swim Walk	
Adult	X	X	X	
Juvenile	X	X	X	
Egg/ Larvae				X

A variety of adaptations and behaviors to disturbance apply to invertebrates that live in sandy beach habitats, and species differ in the range of environmental conditions that they tolerate. Some species are habitat generalists with a wide tolerance (e.g., sand crabs) of beach morphodynamic type and sediment characteristics (Section 4.2.1). Animals primarily use their mobility as a means to escape disturbance. For example, invertebrates may burrow in sand (Section 4.2.6), birds may shift position or fly away (see Section 4.4.5), and seals and sea lions may episodically leave the beach and re-enter the sea (see Section 4.5.2). The majority of invertebrate species have high reproductive output with a planktonic larval phase.

Potential Impacts from Sediment Management Activities:

Sediment management activities involving beach nourishment are designed to result in local increases in sandy beach habitat. Consequently, documented impact concerns do not relate to habitat loss, but rather the environmental consequences of disturbing the habitat and associated biological resources. Documented concerns include disturbance of indigenous biota, which in turn may affect foraging patterns of the species that feed on those organisms; disruption to species that use beach habitats or adjacent areas for nesting, nursing, breeding, and/or resting; and disturbance of sensitive bird and plant species (Naqvi and Pullen 1982, Hurme and Pullen 1988, NRC 1995, Greene 2002). Another documented concern, which is applicable to the east coast but not California, is the potential for disturbance of sea turtle nesting (NRC 1995).

Types of sediment management activities and potential impacts to coastal sandy beach habitat include:

- Maintenance dredging of embayments – not applicable
- Offshore borrow site dredging – not applicable
- Nearshore placement – sedimentation, turbidity.

- Profile placement – equipment, burial, sedimentation, turbidity.
- Beach placement – equipment, burial, sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections. Comprehensive reviews of potential and documented impacts are included in reviews of key species and species groups that use sandy beach habitat in Section 4, as follows: invertebrates (4.2.6), California grunion (4.3.1), birds (4.4), and pinnipeds (4.5.2).

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Sand Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage,			
Foraging				X	X	
Habitat Use			X	X		X
Reproduction /Recruitment			X	X	X	
Resting/ Roosting		X		X		

<u>Equipment</u>

Equipment use may include some combination of earthmoving equipment, trucks, and placement of sand delivery pipelines. Equipment use on the beach has the potential to result in direct impacts (crush, bury) to sedentary invertebrates and California grunion eggs, if present. Equipment use also may result in indirect interference and disturbance of mobile animals (birds, marine mammals), if present.

Few studies have examined the effects of earthmoving equipment and vehicles on sandy beach fauna during sediment management activities. Peterson et al. (2000a) studied bulldozer impacts associated with creation of a berm for shore protection over a three month period in North Carolina and found reduction in habitat suitability for ghost crabs, reduced numbers of small but not large sand crabs, and increased numbers of *Donax* clams at bulldozed compared to non bulldozed sites.

Studies of impacts to invertebrates from vehicles during beach grooming and/or off road use indicate impacts vary depending on species. Studies of impacts from vehicle use on beach foreshores in North Carolina and South Africa showed mortality rates of < 10% for mole crabs (*Emerita talpoida)* and bivalves (*Donax serra, D. sordidus, D. variabilis*) (Wolcott & Wolcott 1984, van de Merwe and van de Merwe 1991 cited in Stephenson 1999). Ghost crabs (*Ocypode quadrata*) were completely protected by burrows as shallow as 2 inches (5 cm), and were not subject to injury during the day, but had the potential to be killed in large numbers by vehicles while feeding on the foreshore at night (Wolcott & Wolcott 1984); this nocturnal species does not occur on California beaches. Impacts to supralittoral isopods (*Tylos capensis*) on the backshore of a South Africa beach increased with intensity of vehicle use with approximately 10% of the animals damaged by 17 vehicle passes; this nocturnal

species was considered more susceptible to damage at night (van de Merwe and van de Merwe 1991 cited in Stephenson 1999). Comparisons of beaches with and without grooming practices showed substantial reductions in upper beach invertebrate fauna (e.g., talitrid amphipods, beetles), particularly associated with removal of macrophyte wrack on groomed beaches, which appeared to have secondary effects of reducing prey for some shorebirds (Dugan et al. 2003).

Beach nourishment activities have the potential to impact reproductive success of grunion. Limited information indicates grunion will spawn in the vicinity of beach discharges (USACE 1998a, Chambers Group 2001). Consequently, equipment use on the beach is of particular concern for grunion. Equipment used for beach grooming has been shown to directly impact California grunion eggs and significantly reduce egg viability from burial, excavation, and/or crushing (Martin 2002).

Equipment use also is of concern in areas where sensitive birds nest. The potential to crush eggs and chicks is a direct impact concern (Greene 2002). In a study at Cape Cod National Seashore, Massachusetts, least terns were found to habituate to vehicles passing close to their nests, but flushed when persons or dogs approached; however, vehicles passing through least tern colonies ran over camouflaged eggs and chicks (Blodget 1978 cited in Stephenson 1999). Some studies indicate reduced nesting success related to vehicle and other human-related disturbance. For example, endangered California least terns successfully nest on Venice Beach and Huntington State Beach, which experience high public use; however, nesting success was disturbed in colony areas closer to a maintenance building and where there was closer proximity to vehicles, pedestrians, and pets (Fancher et al. 1988, Obst and Johnson 1990).

People adversely impacted nesting success of snowy plovers (*Charadrius alexandrinus*) on the backshore of Pajaro Beach, Monterey County by driving over nests, stepping on eggs, and/or collecting eggs (Warriner et al. 1986). Stephenson (1999) reviewed that vehicle traffic on backshore areas reduced nesting success of white-fronted plover (*C. marginatus*) in South Africa (Watson 1992) and hooded plovers (*C. rubricollis*) in Australia (Buick and Paton 1989).

Birds are tolerant of disturbance within certain distances, but generally move away when threat is perceived. Shorebirds may be observed foraging in the swash zone below people sitting on the beach, but walk away or flush and settle further down the beach in response to perceived threats moving toward them (e.g., people walking, jogging, and/or exercising dogs, vehicles) (McCrary and Pierson 1999). These reactions tend to result in less foraging time by the disturbed birds (Burger 1991, 1994; Lafferty 2000, Lafferty 2001a,b). Similar behaviors have been seen in response to beach nourishment. Worden and Smith (2004) noted temporary disruption of foraging and roosting snowy plovers in the path of heavy equipment and vehicles during installation and removal of the dredge pipe associated with surf zone disposal off McGrath State Beach, Ventura. However, Chambers Group (2001) observed undisturbed snowy plover foraging in the vicinity of stationary beach discharge of dredged material from Santa Barbara Harbor. Vehicles also had minimal disturbance on foraging activities of shorebirds (plovers, sandpipers) at Cape Cod National Seashore, Massachusetts (Blodget 1978 cited in Stephenson 1999).

Pinnipeds on shore are sensitive to human activities. People walking near or in rookeries and/or haulout areas of California sea lion and northern fur seal can cause major short-term disturbance (Richardson et al 1995).

Published and unpublished photographs indicate that opportunistic gulls may be attracted to dredge slurry discharges associated with beach nourishment. Gulls were seen in the diked discharge area at receiver sites during the San Diego Regional Beach Sand Project (AMEC 2002) and during the 1997 Surfside-Sunset beach nourishment project (Green, personal observation). Gulls have been photographed in the immediate vicinity of the pumped sediment slurry during beach nourishment projects conducted elsewhere in the United States (Peterson et al. 2002, Melvin 2005).

Temporary berms (dikes) have been used as temporary shoreline protection of backshore areas during high water conditions. Such berms have been created by beach scraping and piling of sand above the high water line and/or trucking sand to the beach and placing it in a berm above the high tide line before the onset of winter storms (e.g., several beaches in San Diego County). Wrack line debris (including washed ashore kelp and surfgrass) may be moved to the backshore with this beach maintenance activity.

Avoidance and/or minimization measures have been used to reduce equipment impacts on sensitive wildlife during beach nourishment activities in California. Projects have been scheduled outside the grunion spawning and/or snowy plover breeding season (e.g., September to March) to avoid potential impacts (e.g., Chambers Group 1992, 2000, 2001; USACE 1993, 1994a, 1998a, 1998b, 2000, 2001, 2002). A number of the above-referenced projects specified protective measures to avoid significant impacts in the event actual construction schedule overlapped grunion and/or snowy plover season. Potential additional protective measures included halting and/or redirecting of construction activities, or restricting operations to diked single-point or surf zone discharges in consultation with resource agencies (USACE 1993, 1994a, 1998a,b, 2000, 2001). In other cases, construction during grunion season has been permitted when pre-construction surveys determined lack of suitable spawning habitat and/or monitors were present during monitoring with authority to halt and/or redirect work, if necessary. For example, pre-construction habitat suitability surveys and construction monitoring were conducted during the 2001 San Diego Regional Beach Sand Project (EDAW 2002 in AMEC 2002). Biological monitors redirected discharge activities during that project to avoid substantial grunion spawning runs, but redirection was not required when fewer fish were observed (EDAW 2002).

<u>Burial/Sedimentation</u>

The physical character of the beach is altered with beach placement, which generally results in a wider beach, steeper profile, and distinct scarp or berm until the beach fill adjusts through the profile from wave action. The height of the dune or scarp may initially vary from a few inches to several feet (centimeters to more than a meter) depending on placement technique (Parr et al. 1978, Reilly and Bellis 1983, NRC 1995).

The influence of beach nourishment on beach morphodynamic state is of increasing interest, but has received limited attention. Benedet et al. (2004) report that calculation of Dean's parameter Ω after beach nourishment may be biased if sediment samples are collected only from the beach face (towards reflective state) or the bar (towards dissipative state); they

recommended collection of composite sediment samples across the cross shore profile to avoid such bias.

Beach nourishment may have a beneficial impact on sandy beach habitat functions (SAIC 2006). Prior to the 2001 San Diego Regional Beach Sand Project, beaches were characterized by seasonal sand wash out and/or cobble with few biological resources. After beach nourishment, relatively deep sand depths persisted across seasons, there was less seasonal variability in invertebrate community development, and habitat suitability for grunion spawning spanned their reproductive season. In addition, beach use by shorebirds and gulls was found to be higher at beaches that changed from cobble to sandy beach after nourishment, and was generally higher across tide range at wider, nourished compared to unnourished beaches.

Sand placement on the beach will result in direct burial of sedentary invertebrates within the receiver site (Section 4.2.6). This is the primary direct impact to sandy beach habitat and results in unavoidable burial, crushing, and/or smothering of invertebrates (NRC 1985, Greene 2002). Most invertebrates within the receiver site footprint are not expected to survive this impact; however, some may escape mortality along the outer and/or leading edges of beach fills where overburden depths are less.

Experimental studies indicate that some intertidal invertebrate species are able to burrow through overburdens of > 1 to < 2 ft (40 to 50 cm), while other species have much lower tolerances (e.g., inches) (Kranz 1975, Nelson 1985, Maurer et al. 1986). Some invertebrates migrated through overburden depths of 23 to 35 in (60 to 90 cm) during beach nourishment at Folly Beach, South Carolina (Lynch 1994 cited in NRC 1995, Greene 2002). Maurer et al. (1986) concluded that vertical migration is one mechanism that may contribute to invertebrate recolonization when deposits are similar to native sediments, but did not expect this to be a viable mechanism for invertebrate recolonization when deposits exceed 35 in (90 cm).

Maurer et al. (1986) showed that burrowing ability substantially decreases over relatively short time frames (e.g., 3 days). Therefore, potential escape from burial is only expected during the early part of the construction period. Sediment compatibility between native and overburden sediments also may affect burrowing and survival. Experimental studies show that vertical migration rates slow and mortality increases when overburdens have silt/clay contents ranging from 17 to 99% depending on species (Turk and Risk 1981, Maurer et al. 1986).

Recovery of the invertebrate community begins almost immediately after cessation of construction activities, but the duration for complete recovery may vary depending on sediment characteristics and seasonal considerations (see Recovery below). Turbidity may delay the recruitment process during the construction period (Reilly and Bellis 1983).

Beach nourishment placement in the high tide zone has the potential to bury grunion eggs too deeply for them to hatch, if present. As mentioned above under equipment, impacts to grunion have been avoided and/or minimized by either restricting the construction schedule outside their spawning season or monitoring and implementing protective measures during construction. Impacts do not appear to extend much beyond the construction period. Grunion were observed to spawn within one month of beach nourishment at Imperial Beach (Parr et al. 1978).

Reduction in invertebrates from burial effects has the potential to affect foraging of secondary consumers such as shorebirds and fish (Peterson et al. 2000b, Peterson et al. 2002, Peterson and Bishop 2005). Generally, impacts from reduced forage base would be expected to be tied to the time period associated with recovery of invertebrate populations after beach nourishment. Source materials too high in silt or shell content may adversely affect shorebird foraging (Peterson et al. 2000b, Greene 2002, Peterson et al. 2002). Secondary consumer effects on fish are addressed in the next section on sandy subtidal habitat (Section 3.3.3).

Indirect sedimentation along the intertidal and subtidal profile of the beach will occur from any placement technique as fill material redistributes to a more stable profile, and may be expected to influence downcurrent beaches as reworked sands are transported with littoral drift. Thus, post-construction sedimentation will occur over longer time scales associated with natural beach erosion and accretion cycles.

Few studies have examined the influence of indirect sedimentation from beach nourishment. SAIC (2006) found enhancement of invertebrate populations and grunion habitat at two sites at distances 1,000 to 2,500 ft (300 to 760m) downcurrent from receiver sites that each received approximately 100,000 cy of sand from the 2001 San Diego Regional Beach Sand Project compared to erosive conditions prior to nourishment. Foraging and resting habitat for shorebirds and gulls was more seasonal at one of the indirectly nourished sites due to less sand habitat after winter erosion.

Movement of sediments away from a receiver site may result in beneficial effects by providing additional sand to downcurrent beaches (NRC 1995). Indirect sand nourishment of beach sites located approximately 1,000 to 3,000 ft (300 to 900 m) downcurrent of receiver sites in the City of Encinitas resulted in improved habitat conditions for invertebrates, California grunion, and birds after the San Diego Regional Beach Sand Project (SAIC 2006). Sand volumes placed at the receiver sites ranged from 101,000 to 132,000 cy. The amount of improvement at downcurrent sites appeared to relate to pre-project substrate, with more sand cover across seasons at sites that had a seasonal mix of sand/cobble than at sites with persistent cobble cover prior to indirect nourishment.

Beach nourishment resulting in increased beach width appeared to benefit gulls and terns after a beach nourishment project in North Carolina (CZR 2003). The benefit was not associated with abundance, but was considered related to improved energetics since birds were able to increase resting times as a result of increased available beach space. Beach nourishment also increased available nesting habitat of piping plovers on the east coast (Melvin et al. 1991, 2005).

Effects from sedimentation also relate to sediment compatibility issues and existing conditions adjacent and downcurrent from the receiver site. Similarity of sediment characteristics to the receiver site is considered a primary factor associated with rapid recovery of sandy beach fauna (see Recovery from Disturbance below). Slower recovery and/or degraded habitat functions have been associated with use of sediments that are substsantially coarser or finer than existing sediments.

Adverse impact concerns associated with sand transport sedimentation away from the beach receiver site generally focus on indirect burial of sensitive hard bottom and/or vegetated

habitats, sensitive nearshore spawning areas, and/or shoaling of inlets and/or navigational channels of downcurrent embayments. These impacts, some of which have been documented, are reviewed in greater detail in the following sections that address these habitats.

Turbidity

The extent of the turbidity plume and gradient of suspended sediment concentrations may vary considerably depending on placement method, grain size characteristics of placed material, project volume, and wave climate (Greene 2002). Turbidity has the potential to impact sandy beach habitat during beach, profile, and/or nearshore placement. Dune placement, which is above the high tide line, does not generate turbidity during placement.

Several dominant sandy beach fauna are suspension and/or filter feeders (e.g., sand crabs, clams) on microscopic plankton and other organic material. Filter-feeding organisms may be vulnerable to suspended sediment interfering with feeding behavior. For example, mole crabs (related to sand crab) suffer impaired feeding with increased turbidity (Turner 1990). Organisms living in the intertidal to nearshore zone often have morphological adaptations that provide protection from naturally turbid conditions, which occur during storm and/or high wave conditions. For example, Pismo clams have papillae in their inhalant siphon that excludes larger sand particles (CDFG 2001). Peterson et al. (2002) found little difference in growth or condition of *Donax variabilis* over a two week period when exposed to turbidity concentrations of 9 and 96 NTU, although growth was somewhat slower (statistically significant) for the 96 NTU treatment compared to the 9 NTU treatment.

Total suspended sediment (TSS) concentrations during beach nourishment appear to vary depending on sediment grain size characteristics, placement method, and hydrodynamic conditions during discharge. Sands with 18% fines that were pushed to the surf zone in Carlsbad, California resulted in TSS concentrations from 590 to 1,606 mg/L directly offshore the injection site and decreased to approximately 127 mg/L approximately 1 mile downcurrent (Sherman et al. 1998). Elevated concentrations quickly dissipated to background levels (25 mg/L) within 1 hour of cessation of activities (*ibid*). TSS concentrations of 24 to 66 mg/L were measured off Capistrano Beach when sands with 4% fines were discharged, and TSS concentrations of 389 to 515 mg/L were measured during placement off Baby Beach in Dana Point Harbor (County of Orange 2000).

Substantially higher TSS concentrations may occur when sediments are pumped as a slurry to the beach and contain relatively high proportions of fines. For example, TSS concentrations of 1,760 to 4,700 mg/L were reported in the surf zone offshore the unconfined slurry discharge into the intertidal swash zone for a project in North Carolina where dredged sediments included sands, shell hash, and clay balls (Reilly and Bellis 1983).

Reilly and Bellis (1983) surmised that the high turbidity (1,760 to 4,700 mg/L) inhibited larval recruitment of invertebrates during beach nourishment because juvenile mole crabs (*Emerita talpoida*) were not observed until 3 days after cessation of pumping operations and their recruitment lagged behind that of a control beach by approximately one month. In addition, little to no recruitment of *Donax parvula and D. variabilits* clams occurred during and up to two months after nourishment although substantial recruitment was documented on the control beach. They speculated that turbidity and burial resulted in mortality of adult mole crabs and *Donax* in nearshore overwinter grounds since recruitment of these species after

nourishment was only by young of the year; whereas, recruitment at the control beach was by juvenile through adult sizes for mole crabs and *D. parvula*. Overall diversity and species richness of the invertebrate community were reported as being lower during and up to two months after nourishment when the study was concluded.

Reviews indicate that marine and estuarine invertebrates generally are tolerant of high suspended solids concentrations over reasonably short durations (Stern and Stickle 1978, NRC 1985, LaSalle et al. 1991, O'Connor 1991, Clarke and Wilbur 2002). However, prolonged exposure to high concentrations may be lethal and/or substantially reduce habitat quality.

Limited information is available regarding response of grunion to turbidity plumes. Turbidity has the potential to adversely affect grunion, but has not been documented during beach nourishment. Grunion spawned during dredging and surf zone disposal in Santa Barbara, California (1998a); a run also was documented during a period of higher turbidity associated with storm water runoff from Mission Creek in Santa Barbara (USACE 1993).

Turbidity impacts to shorebirds have not been documented. Turbidity does not affect western snowy plovers, because this species does not forage in the water.

Recovery from Disturbance:

Recovery from disturbance of sandy beach habitat during beach nourishment mainly relates to cessation of human disturbance effects associated with construction, and recovery of the intertidal fauna. Disturbance impacts associated with equipment use and turbidity are associated with the construction period and cease after construction is completed.

Recovery rate from burial of the benthic invertebrate community, which represents prey base to higher trophic levels, has been the primary issue in reviews of ecological effects of beach nourishment (NRC 1985, Greene 2002). Invertebrates recolonize from larval settlement and immigration from surrounding areas (Dauer and Simon 1976, Reilly and Bellis 1983). Reported recovery rates of benthic invertebrates range from < 2 months to > 1 year, with slower rates generally associated with seasonal interference of recruitment from project timing and/or sediment incompatibility (refer to Section 4.2.6). These rapid rates generally are based on consideration of community metrics such as number of species and abundance, and may also be true of biomass at beaches where the community is dominated by few species such as sand crabs and bean clams. Rapid recovery rates do not apply to slow growing and long-lived species such as Pismo clams, particularly when considering recovery of age structure of populations.

Generally, potential impacts to sandy beach habitat are considered minimal when placement sediments are similar in grain size and composition to the existing beach (Thompson 1973, NRC 1995). Navqi and Pullen (1982) reviewed several beach nourishment studies off Florida that indicated no long term effects 4 years after nourishment at Treasure Island, 6 years after nourishment at Panama City, and 7 years after nourishment at Hallandale Beach.

However, sediment dissimilarity can lead to a delayed recovery and/or an altered community (Hurme and Pullen 1988). Sediments were considered less optimum to biological resources due to relatively high percentage of shell hash, coarser grain size, mud and/or clay balls, or limestone cobbles for some east coast beach nourishment projects (Reilly and Bellis 1983,

Petersen et al. 2001, Pilkey and Coburn 2005, Rice and Peterson 2005). Another beach nourishment project considered ecologically "bad" involved replacement of quartz sand with carbonate sand at Miami Beach, Florida (Pilkey and Coburn 2005). In a study conducted in Africa, placement of coarse sand (0.5 to 0.8 mm) on an otherwise fine sand (0.11 to 0.16 mm) beach apparently had limited and localized smothering effects on the invertebrates, but resulted in a 40 to 50% lower species richness and > 90% lower abundance than on a nearby similar beach (McLachlan 1996).

Sedimentation of sandy beach habitat adjacent and/or downcurrent of beach nourishment projects will occur. Generally, this is a beneficial impact and does not result in adverse impacts to fauna because the rate of sedimentation coincides with natural coastal processes of erosion and accretion. One potential exception could result if incompatible substrate was placed on the beach.

Turbidity generally is limited to the period of construction. However, placed sediment are more erodable than native sediments and higher suspended sediment concentrations may occur after storm events at nourished than unnourished beaches (Wilber et al. 2006).

Published reviews rarely discuss recovery of habitat functions for fish, birds, and/or marine mammals after sediment management impacts to sandy beach habitat. It generally is assumed that recovery of habitat functions for higher order species generally relate to recovery of their forage base and physical suitability of the habitat to support species functions. Birds were observed foraging and resting on nourished beach sites in Encinitas, San Diego two years after nourishment, which is when the study was initiated; although recovery rate was not measured, results indicated improved conditions relative to pre-project and no reduced foraging or use relative to control beaches (SAIC 2006). In contract, bird foraging was reduced after beach nourishment added substantial shell hash to a beach in North Carolina compared to an unaffected control beach (Peterson et al. 2002).

	Recovery Rates				
Impact	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	X				
Burial	X		Potential if dissipative or high intermediate beach type	Sediment dissimilarity	
Sedimentation	X			Sediment dissimilarity	
Turbidity	X			X	
Habitat Loss					X

Critical Impact Thresholds:

Little to no survival of benthic invertebrates occurs when buried by > 3 ft (1 m) of sediment. Sediment incompatibility that resulted in reduced habitat functions and values would be of ecological concern.

Data Gaps:

Few studies have examined the benefits of beach nourishment to sandy beach habitat functions at erosive beaches. Limited information is available regarding the impact of reduced benthic invertebrate forage on second order consumers (birds, fish). Few data are available on benthic invertebrate recovery in areas where there is periodic beach nourishment; this type of information could potentially improve planning decisions for such activities (e.g., location, frequency).

Restoration:

Beach nourishment does not result in habitat loss that would require restoration. Although not identified as restoration, beach nourishment has been reported to enhance functional habitat suitability for grunion spawning, increased suitability for bird foraging and/or resting, and increased suitability and/or protection of nesting habitat (NRC 1995, SAIC 2006).

Although sediments are required to meet compatibility requirements based on grain size and chemical characteristics, there have been instances when placed sediments resulted in undesirable beach characteristics. A nourished beach considered “hard, dirty” by local residents in Carlsbad, California due to a reddish color and percent fine content of 18% was remedied by moving the sediment off the beach and into the surf zone to allow wave action to “wash” the material (Sherman et al. 1998).

Summary:

Potential impacts to sandy beach habitat from beach nourishment generally are considered unavoidable (NRC 1995, Greene 2002). The types of impacts and their magnitude will vary depending on several factors including, location of sand placement, volume of placed material, compatibility between source sands and native sands, existing habitat quality, and occurrence of sensitive resources in the project area.

Direct impacts during beach or profile placement include destruction of immobile and sedentary invertebrates from burial and spreading of fill material with earthmoving equipment. Although some invertebrates may escape impacts, mortality is substantial and nearly complete. Indirect impacts during construction may include disturbance of mobile birds and marine mammals, if present on the beach, turbidity impacts to biota in nearshore waters, and reduced forage for shorebirds and surf zone fish until the invertebrate community recovers. Indirect impacts after construction may occur from sand transport sedimentation.

Disturbance and turbidity impacts generally cease with construction and recovery of the intertidal invertebrate community may occur within a year or less (Hurme and Pullen 1988, NRC 1995, Greene 2002, see Section 4.2.1). However, turbidity may persist and recovery may be slower when sediments substantially differ from native sediments (Reilly and Bellis 1983, Peterson et al. 2002). Recovery rates also may be influenced by project timing, beach morphodynamics, and substrate characteristics of source materials.

Recolonization occurs from settlement of larvae from the water column and immigration from relates to the life history characteristics (settlement from plankton, fast development, high reproductive rate) and/or mobility of species that adapt them for living in the unstable sediments of the dynamic coastal zone. Rates of recovery may vary depending on timing of

disturbance since many species have distinct peak periods of reproduction and recruitment (LaSalle et al. 1991). Some studies suggest that recovery may be slower if disturbance occurs during and/or after the peak recruitment period (Reilly and Bellis 1983). Burlas et al. (2001) stated that recovery may be delayed if disturbance occurs during the winter seasonal low (i.e., little settlement from plankton). It has been inferred that elevated turbidity during beach nourishment delays larval recruitment to the beach (Reilly and Bellis 1983).

Based on California beach recruitment patterns, invertebrate recovery would be expected to be quicker and result in higher end-of-season productivity if beach nourishment was completed before the onset of spring recruitment. Beach nourishment projects conducted later in spring and/or summer would be expected to result in lower end-of-season productivity due to interference with recruitment and shorter time interval for recovery.

Project timing also is of concern for sensitive wildlife such as California grunion, which spawns on beaches, and threatened snowy plover, which may forage in the intertidal and nest on back beach areas. Potential adverse impacts from sediment management activities have been avoided by scheduling projects outside their seasonal reproductive periods, which generally span March to September. However, this measure is unnecessary if the species are not present. Erosive beaches may have limited seasonal suitability to these species; consequently, pre-construction surveys to determine habitat suitability appear warranted. Other protective measures with concurrence from CCDFG, NMFS, and USFWS may include use of monitors and redirecting and/or restricting activities during construction, as necessary.

It's likely that rapid invertebrate recovery rates apply to the more simple species assemblages that characterize intermediate and reflective beaches. Relatively slower recovery would be expected for the more diverse assemblages associated with dissipative beaches and/or long-lived species such as Pismo clams. Generally, dissipative beaches are not sand limited; therefore, potential impacts can be minimized by selecting beach nourishment sites based on shoreline erosion concerns.

Recovery of habitat functions (e.g., resting, nesting, spawning) that rely on physical rather than biological features may occur soon after construction is completed. For example, habitat suitability for grunion spawning was reported within one month of beach nourishment (Parr et al. 1978). However, slower recovery may occur or not at all if sediment incompatibility adversely affects habitat functions. Petersen et al. (2002) showed reduced shorebird use during beach nourishment that included substantial shell hash compared to a control beach in North Carolina. The NRC (1995) also cautions that beach nourishment has the potential to adversely impact bird nesting if material is unsuitable or deposition occurs at a time or place that could disturb plovers (Melvin et al. 2001).

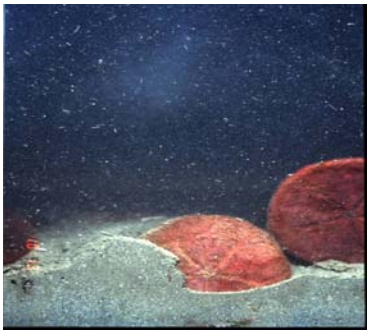
Sandy beach habitat may be enhanced by beach nourishment and indirect sedimentation in erosive beach areas. Sand is the limiting factor associated with seasonal development of the invertebrate community and functional use of the beach for spawning by grunion and foraging, resting, and/or nesting by shorebirds. When beaches are erosive, these habitat functions may be delayed until sufficient sand has accreted to the beach. Beach nourishment has been shown to extend habitat suitability across seasons and/or enhance habitat functions in areas with erosive beach conditions (Melvin et al. 2001, CZR 2003, SAIC 2006).

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities to sandy beach habitat.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	Documente d	Documented	Documented	Relevant reports	Relevant reports
Critical Impact Thresholds	NA	Destruction of habitat for semi-terrestrial crustaceans	Incompatible substrate that degrades habitat	Incompatible substrate that degrades habitat	Impair recruitment
Impact Responses	Enhance habitat function	Disturb and/or crush biota	Bury biota	Enhance habitat, alter habitat	Disturb and/or harm biota, delay recruitment
Duration of Impacts	Months-years	Days-Months	Months-years	Months-years	Hours-months
Potential for Restoration	NA	Unnecessary	Unlikely	Unnecessary	Unnecessary

NA = not applicable

3.3.3 Sandy Subtidal



Sediment Profile Photo by: SAIC

Regulatory Status:

Essential Fish Habitat	X

Subtidal sand habitat is Essential Fish Habitat for managed fishery species.

Description and Distribution:

Sandy subtidal habitat is widespread offshore from exposed and protected beaches of California. This habitat occurs offshore any type of shoreline either alone and/or around subtidal rocky bottom habitats. In protected coastal areas, sandy subtidal habitat may support eelgrass and/or giant kelp, as discussed in Sections 3.3.6 and 3.3.8. This section reviews unvegetated sandy subtidal habitat.

The nearshore sandy subtidal habitat ranges from below the intertidal zone to the edge of the continental shelf-slope interface (Shaffer 2002).

Function	California			On Land	Inter-tidal	Inshore < 30 ft	Off-shore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Primary Habitat	X	X	X			X	X	E, P

Potential Functions:

Subtidal sands are primary, foraging, and reproductive habitat for a variety of invertebrates and demersal fish. Marine mammals may forage on water column and benthic fish and invertebrates over sandy habitat. Subtidal sands represent important commercial and recreational fishing habitats for marine invertebrates (e.g., Dungeness crabs, sea cucumbers) and fish (e.g., California halibut, sanddabs) (CDFG 2001).

Nearshore invertebrate assemblages exhibit zonation along a gradient associated with wave activity and depth. Generally, there is a decrease in epifauna density and suspension feeders, and an increase in infauna, variety of feeding types, and sedentary species with increasing depth (Barnard 1963, Morris et al. 1980, Oliver et al. 1980, Thompson et al. 1993). Barros et al. (2002) found subtidal diversity in the surf zone to be lower for intermediate than reflective or dissipative morphodynamic beaches.

Gaper clam
Photo credit: Daniel Gotshall

The inshore zone is dominated by mobile and/or burrowing crustaceans adapted to living in unstable, shifting sands, including amphipods, ostracods, mole crabs, Dungeness crabs, swimming crabs (e.g., *Callinectes* spp., *Portunus xantusii*), Pismo clams, and northern razor clams (*Siliqua patula*). Common epifauna species include burrowing

anemones (*Harenactis attenuata*, *Zaolutus actius*), sand dollars (*Dendraster excentricus*), sea pansies (*Renilla kollikeri*), sea stars (*Astropectin armatus*), and moon snails (*Polinices reclusianus*). The offshore nearshore zone is dominated by tube-dwelling (*Diopatra* spp., *Owenia fusiformis, Nothria,elegans*) and burrow-dwelling (e.g., *Magelona sacculata*) polychaete worms, but also include a variety of crabs, clams, sea stars, heart urchins (*Brissopsis pacifica, Lovenia cordiformis*), sand dollars, sea cucumbers (*Parastichopus parvimensis*), sea pens (*Stylatula elongata*), and burrowing anemones.

Few comparative studies have been conducted of fish across surf zone to offshore depth gradients. Fish assemblages in the surf zone may be highly variable, and generally are dominated by large numbers of juvenile fish representing relatively few species (Wilber et al. 2003). Schooling water column fish dominate outside the surf zone and flatfish constitute an increasing proportion of catch from the surf zone to outer shelf (Cross and Allen 1993).

Associated Species	Primary Habitat	Forage Habitat	Reproductive Habitat	Resting/ Roosting Habitat	Fisheries Habitat		Forage /Prey
					Commercial	Sport	
Invertebrates	X	X	X		X	X	X
Fish		X	X	X	X	X	
Mammals		X					

Life History Facts – Associated Animals:

Subtidal sands provide habitat functions year round. Abundance patterns may vary across seasons associated with reproductive and inshore-offshore migratory patterns of some fauna. For example, invertebrates may exhibit higher abundance in spring-early fall than late fall-winter associated with greater wave activity and/or larval recruitment (Oliver et al. 1980).

A variety of reproductive methods apply to the invertebrates that live in nearshore sandy habitats. Generally, invertebrate species have high reproductive output. They may release gametes that develop into planktonic larvae capable of wide dispersal, brood eggs and release planktonic larvae, brood eggs and release larvae that quickly settle to the bottom, lay egg masses with release of larvae that quickly settle to the bottom, and/or lay eggs that develop into juveniles that immediately begin life on the bottom (MacGinitie and MacGinitie 1968, Shroeder and Hermans 1975, Morris et al. 1980). The life span of nearshore invertebrates depends on species; many of the smaller infauna species live one to three years; some clams (Pismo, razor), crabs (e.g., Dungeness crabs), and echinoderms (sand dollars) live several years (Morris et al. 1980).

Most nearshore fish release gametes that develop into larvae that reside in the plankton; some species lay demersal eggs that also have a pelagic phase when hatched; surfperch, round stingrays, and smoothhound sharks are livebearers (Cross and Allen 1983, Love 1996). Several nearshore species use shallow nearshore areas as nursery grounds and/or may use embayments for spawning and/or nursery habitats (see Sections 3.2.9, 3.2.10, and 4.2.3, 4.3.2, 4.3.4).

Marine mammals (dolphins, porpoises, whales, seals, sea lions, sea otters) generally use nearshore habitats as transient foraging habitats (Sections 4.5.2, 4.5.3). All marine mammals bear live young and live several years. Gray whales transit nearshore waters

offshore California during their southward seasonal migration to calve young and northward migration back to primary foraging grounds.

Life history characteristics of species associated with subtidal sands are described in greater detail for representative marine invertebrates in Section 4.2.7, demersal fish in Section 4.3.4, and water column fish in Section 4.3.5.

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Spawn Planktonic, Livebearer	Spring-fall invertebrates, winter-spring fish	Year round	Depends on species	Depends on species	< 1 to > 10 years	Mobile to sedentary, depends on species

Adaptations and/or Behaviors to Disturbance – Associated Animals:

Life Stage	Avoidance Behavior			High Reproductive Output and/or Growth
	Burrow	Fly	Swim Walk	
Adult	X		X	
Juvenile	X		X	
Egg/ Larvae				X

A variety of adaptations and behaviors to disturbance apply to animals that may use subtidal sand habitats. The mobility of invertebrates ranges from highly motile to sedentary; therefore, vulnerability to disturbance varies depending on species. Some invertebrates are able burrow or swim to avoid disturbance. Some have a hard carapace or shell for protection, some brood eggs, and most have high reproductive output. Sedentary invertebrates have limited mobility. Demersal fish may burrow into sands to escape predation, but generally swim away from disturbance. Water column fish and marine mammals generally swim from disturbance. The majority of fish species have high reproductive output with a planktonic larval phase.

Potential Impacts from Sediment Management Activities – Associated Animals:

Subtidal sands and supported habitat functions have the potential to be affected by sediment management activities. Some of the same concerns regarding impacts to sandy beach habitat apply to the nearshore sandy habitat depending on placement method. Sediment management activities involving beach nourishment may impact subtidal sand habitat by sediment burial, sedimentation, and elevated turbidity (Naqvi and Pullen 1982, NRC 1995, Greene 2002). Dredging to obtain sand sources for beach nourishment removes benthic habitat and results in elevated turbidity (NRC 1995, Greene 2002). These activities have the potential to impact invertebrates and fish in nearshore and offshore environments.

Relatively few studies have been conducted examining direct and indirect impacts from sediment management activities on subtidal invertebrates and fish in sandy substrate habitats. More data are available for the more sedentary invertebrates, which are relatively easy to sample. Much fewer studies have been conduced on fish response. Reviews have indicated that biological effects in the nearshore zone have not been well documented (NRC 1995), and that knowledge of effects of beach nourishment to surf zone fish in particular are generally inadequate (Hackney et al. 1996 and Petersen et al. 2000b). Few studies also are

available regarding effects from offshore borrow site dredging and recovery (Hurme and Pullen 1988).

Types of sediment management activities and potential impact factors to sandy, non-vegetated subtidal habitat include:

- Maintenance dredging of embayments – not applicable.
- Offshore borrow site dredging – equipment, sedimentation, turbidity.
- Nearshore placement – burial, sedimentation, turbidity
- Profile placement – burial, sedimentation, turbidity
- Beach placement – sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections. More comprehensive reviews are are given for different species and groups of species that use subtidal habitat in Section 4, as follows: invertebrates (4.2.7), fish (4.3.4), and marine mammals (4.5.1-4.5.3). Subtidal habitats in embayments are reviewed in Sections 3.2.9 and 3.2.10.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging	X	X		X	X	
Habitat Use		X	X	X	X	X
Reproduction /Recruitment		X	X	X	X	

Equipment

Borrow site dredging will remove sediment and associated benthic organisms and has the potential to entrain organisms as a result of near bottom water also being withdrawn by suction dredges. Generally, complete mortality is assumed for dredge removed and/or entrained organisms, although some small percentage may survive depending on discharge location (LaSalle et al. 1991). Noise and activites associated with equipment use may displace mobile animals. Indirect attraction and/or displacement may occur as a result of lights during night-time operations (Section 5.3).

Buial/Sedimentation

Sediment management activities may directly impact subtidal sand habitat from burial associated with nearshore and/or profile placement. Indirect sedimentation of nearshore benthic communities may result from any sand placement method as coastal processes winnow and transport placed sediments within the littoral zone. Indirect impacts to nearshore fish may result from reductions in invertebrate prey from burial and/or sedimentation associated with beach nourishment (Reilly and Bellis 1983).

Few studies have examined the influence of indirect sedimentation on adjacent nearshore populations from beach nourishment. Parr et al. (1978) reported some enhanced abundance and diversity were observed at 3.7 m and 6.1 m depths attributed to increased silts and associated organics after a 1,000,620 cy beach nourishment project at Imperial Beach, San Diego; however, effects were short-lived (generally less than 2 months). Population fluctuations due to seasonal storms and sand movement were more pronounced than observed from beach nourishment. Gorzelany and Nelson (1987) did not find any apparent effect on invertebrates at depths ≤ 10 ft (≤ 3 m) over a 1 year period following nourishment, nor did they observe substantial movement of sediment offshore. Versar (2004) detected elevated silt/clay content in the nearshore at one of four beach nourishment sites, but values were not elevated one year later; the benthic community displayed reduced abundance and biomass that was attributed by the authors to temporal variability in one polychaete species rather than a change due to beach nourishment.

In contrast, Rakocinski et al. (1986, 2001) reported elevated silt loading and altered invertebrate communities at inshore depths after placement of 5.5 million cy of sand on a beach at Perdido Key, Florida. Invertebrate communities had not recovered within two years of nourishment.

Naqvi and Pullen (1982) noted that effects of beach nourishment burial on food resources of motile nearshore populations have not been demonstrated to be of major significance. Reilly and Bellis (1983), considered the consequence of reductions in invertebrate populations to be dependent on type of beach, with drastic but ephemeral effects when invertebrate recovery is mainly from pelagic stocks and substantial when invertebrate recovery includes species whose entire life history is within the beach system. Peterson et al. (2000b) reviewed that most studies have been inadequate at addressing this issue. Studies on the east coast of the United States that have examined fish abundance and composition in the surf zone off beach nourishment sites or at offshore borrow sites have not detected adverse effects (e.g., NRC 1995, Burlas et al. 2001, Wilber 2003, Versar 2004) (Sections 4.3.4, 4.3.5). No substantial changes to fish were observed from sand bypassing at Oceanside, California (Chambers Group 1994).

Offshore borrow sites have been used for several southern California projects in support of beach nourishment off Imperial Beach, San Diego County, Surfside-Sunset Beach, and Goleta Beach. Borrow sites also have been used in Long Beach Harbor to provide landfill materials in support of port development. Thus, borrow sites in California generally have been located in areas outside the active littoral zone. On the east coast, borrow sites have been located both in nearshore and offshore areas.

Excavation depths in borrow sites have ranged from a few feet (< 1 m) to more than 50 ft (15m) (van der Veer 1985, Brynes 2004a,b, Szymelfenig et al. 2006). Reviews (NRC 1995) indicate that deep holes may result in altered water quality, such as decreased dissolved oxygen and increased hydrogen sulfide concentrations.

Direct impacts associated with borrow site dredging include habitat removal and disturbance from operation of the dredge equipment and vessel anchoring. These effects also may indirectly impact other species that feed on benthic invertebrates. Other indirect impacts are associated with sediment re-suspension and turbidity. Primary issues of biological concern

include potential for habitat modification, recovery rates of benthic fauna at the site, and proximity of dredging to sensitive resources.

Tubidity

Turbidity associated with sediment management activities has the potential to affect foraging, growth, respiration, and survival of subtidal sand associated species. Soft substrate benthic invertebrates generally are considered relatively tolerant of turbidity (Section 4.2.7, 5.5.3). Coastal fish also are relatively tolerant, although early life stages appear to be more vulnerable to turbidity (Section 5.5.3). Bottom feeding fish have been found to be more tolerant than water column fish (Wilber and Clarke 2001).

Recovery from Disturbance:

Disturbance impacts associated with equipment and turbidity are associated with the construction period and cease once construction is completed. Recovery after beach nourishment and/or borrow site dredging will depend on existing conditions. Recovery of invertebrates from nearshore or profile placement may take a few years, particularly to reestablish age structure and biomass relationships (Section 4.2.7). Nearshore benthic invertebrates are considered less resilient than intertidal fauna (McLachlan et al. 1984, Parr et al. 1978, Rakocinski et al. 1996). Effects from indirect sedimentation on nearshore invertebrates may range from minor enhancement to delayed recovery (Parr et al. 1978, Rakocinski et al. 1996, Versar 2004)

Recovery of benthic community structure after borrow site dredging may vary depending on sediment infill rates, hydrodynamics, and dredging method (Section 4.2.7). Recovery may be facilitated by shallow dredging over a larger area rather than creation of deep pits covering a limited area, dredging shifting sands rather than more stable bottoms, retaining similar surface sediment type, and leaving undisturbed areas within the larger dredged area (Thompson 1973, Hurme and Pullen 1988, Jutte 2002, Diaz et al. 2004).

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment (Dredging)		X	X	Changed substrate, hydrodynamics	
Burial	X	X	X		
Sedimentation	X	X	X		
Turbidity	X				
Habitat Loss					X

Critical Impact Thresholds:

Little to no survival of benthic invertebrates occurs when buried by > 3 ft (1 m) of sediment (Maurer et al. 1986).

Data Gaps:

Few data are available on benthic invertebrate recovery in areas where there is periodic dredging and/or beach nourishment; this type of information could potentially improve

planning decisions for such activities (e.g., location, frequency). Limited information is available regarding the impact of reduced benthic invertebrate forage on demersal fish foraging patterns. Few data are available on demersal spawning grounds (locations, time of year) and/or nurseries for commercially and/or recreationally important species. Such information would improve project planning to avoid and/or minimize potential burial, dredging, and/or entrainment impacts

Restoration:

Restoration generally is not applicable to sandy subtidal habitat since sediment management activities do not result in habitat loss.

Summary:

Direct impacts to sandy subtidal habitat from beach nourishment will occur during nearshore or profile. Burial impacts include destruction of immobile and sedentary invertebrates. Although some invertebrates may escape impacts, mortality is substantial and nearly complete when overburden depth is 3 ft or more (≥ 1 m). The extent of impacts will vary depending on volume of placed material, compatibility between source sands and native sands, existing habitat quality, and occurrence of sensitive resources in the project area. Recovery of shallow, subtidal invertebrate communities may take months to a year or more (Section 4.2.7). Recolonization occurs from settlement of larvae from the water column and immigration from surrounding areas. Recovery rates may vary depending on water depth and grain size characteristics, with slower rates when substantial sedimentation occurs (e.g., Rakocinski et al. 1996).

Direct removal of habitat and benthic invertebrates will occur with borrow site dredging. Recovery rates may range from approximately 2 to more than 10 years depending on sediment infill rates, hydrodynamics, and dredging method (Section 4.2.7). Nearshore habitat also may be impacted by nourishment on the beach as a result of sand transport and suspended sediment deposition. Silt-loading effects may vary depending on project volume, grain size chararcteristics, and hydrodynamics. Substantial and/or persistent silt-loading may result in altered benthic communities (Rakocinski et al. 1996, 2001).

Project timing may be of concern for sensitive wildlife such as California least tern that forage in nearshore waters. Potential adverse impacts from sediment management activities have been avoided by scheduling projects outside their breeding season, which generally span April to September. However, this measure is unnecessary if the species is not present. Other protective measures with concurrence from CCDFG and USFWS may include use of protective buffers, operational controls to reduce turbidity, and monitors (Section 6.6).

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities to sandy subtidal habitat.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Documented	Documented	Documented	Relevant reports
Critical Impact Thresholds	NA	Changed substrate and/or hydrodynamics that degrades habitat	Incompatible substrate that degrades habitat	Incompatible substrate that degrades habitat	Smother invertebrates
Impact Responses	NA	Disturb and/or crush biota	Bury biota	Enhance biota, delay recovery	Disturb and/or harm biota
Duration of Impacts	NA	Days-Months	Months-years	Months-years	Hours-months
Potential for Restoration	NA	Unnecessary	Unlikely	Unlikely	Unnecessary

NA = not applicable

3.3.4 Rocky Intertidal

Table Tops Reef, Solana Beach
Photo by: John Evans, SAIC

Regulatory Status:

Essential Fish Habitat	X
Other	Various Designations May Apply

Rocky Intertidal habitat may occur in designated Areas of Special Biological Significance (ASBS), State Ecological Reserves (SERs), California Marine Life Refuges (CMLRs), marine sanctuaries, and underwater parks. Rocky intertidal areas also occur in areas without special designation. Rocky intertidal areas are Essential Fish Habitat for managed fishery species.

Description and Distribution:

Life Stage or Function	California			On Land	Inter-tidal	Near-shore < 30 ft	Off-shore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Primary Habitat	X	X	X		X			E. P

Rocky intertidal habitat occurs throughout the state, but is more prevalent in central (61 percent) and northern (54 percent) California and around the Channel Islands (77 percent) than along the mainland of southern California (20 percent) (Ambrose et al. 1989). Maps with locations of rocky intertidal habitat are available in Ambrose et al. (1989) and environmental sensitivity index maps used for oil and hazardous materials response planning (RPI 1995). Locations of ASBSs, SERs, CMLRs, marine sanctuaries, and underwater parks are available from several online resources.

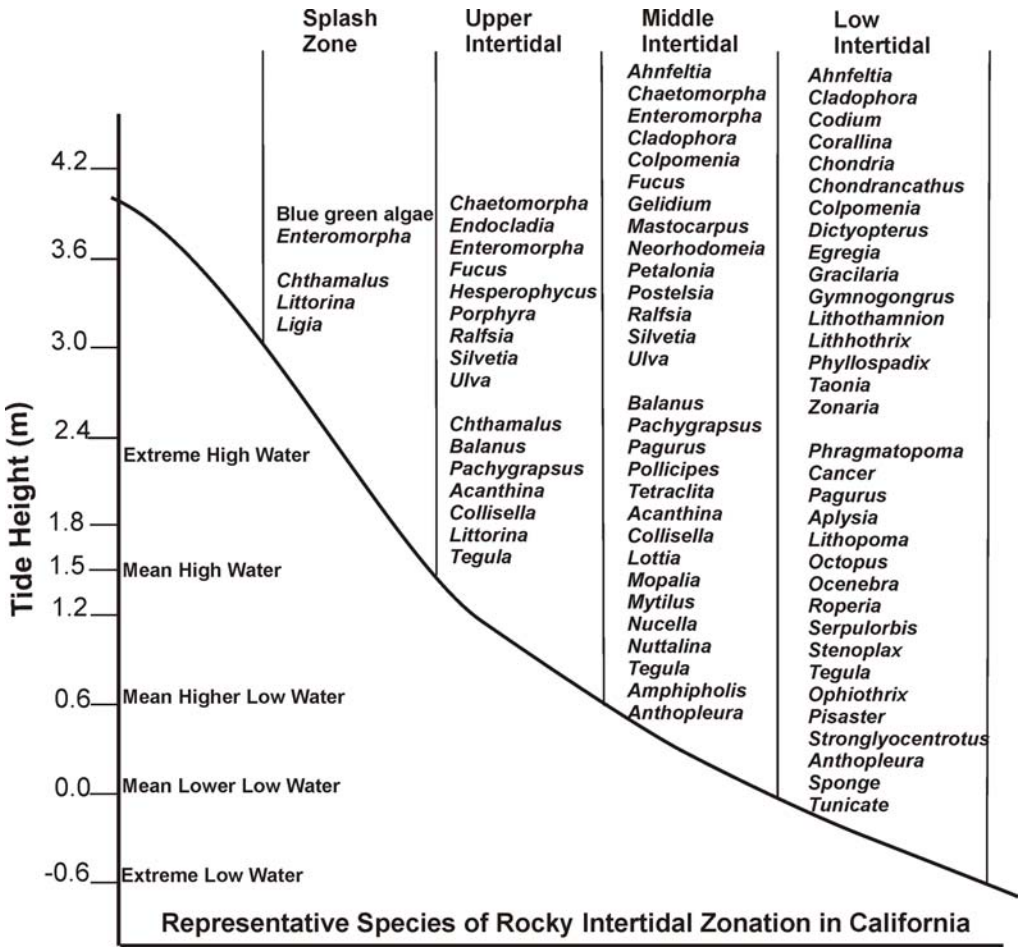
Useful references for California protected rocky intertidal habitats.

- http://www.CDFG.ca.gov/lands/lands.html
- http://www.mpa.gov/inventory/inventory. html
- http://www.swrcb.ca.gov/plnspols/oplans/asbs_info.html
- http://ceres.ca.gov/ceres/calweb/csp.html

Tidal characteristics and resultant periods of water immersion and exposure to air are the overriding physical gradients affecting the distribution of species along rocky shores. Rocky intertidal habitat exhibits pronounced vertical zonation in resource development associated with tolerance of plants and animals to exposure to air associated with the falling and rising tides. Four tidal zones are generally recognized: splash, upper, middle, and low (Thompson et al. 1993). Different species are associated with each of the tidal zones; however, several species may occupy more than one zone and many species characteristic of the low intertidal also occur subtidally.

Generally, species diversity is lower with increasing exposure to air, and the splash and/or upper intertidal zones are inhabited by opportunistic and/or hardy species, such as: blue green algae, green algae (*Chaetomorpha, Enteromorpha, Ulva*), brown algae (*Fucus, Ralfsia*), red algae (*Endocladia, Porphyra*), acorn barnacles (*Chthalamus*), limpets

(*Collisella*), periwinkles (*Littorina*), predatory snails (*Acanthina*), herbivorous snails (*Tegula*), lined shore crab (*Pachygrapsus crassipes*), and/or the terrestrial isopod *Ligia.*



Modified from Thompson et al. 1993, based on reference to Abbott and Hollenberg 1976, Morris et al. 1980, Murray and Bray 1993
Prepared by: K. Green

The middle intertidal may include additional species of green (e.g., *Cladophora*), brown (e.g., *Colpomenia, Petalonia, Postelsia, Silvetia*), and/or red algae (e.g., *Ahnfeltia, Chondranthus, Gelidium, Mastocarphus, Neorhodomeia*), and supports a greater variety of animals. Dominant animals may include California mussel (*Mytilus californianus*) and/or aggregating sea anemone (*Anthopleura elegantissima*). Other characteristic species include barnacles (*Balanus, Tetraclita, Pollicipes), lined shore crab, hermit crabs (Pagurus),* California mussel, limpets, owl limpet (*Lottia gigantea*), snails (e.g., *Acanthina, Nucella, Tegula*), chitons (e.g., *Mopalia, Nuttalina)*, and brittle stars (e.g., *Amphipholis*).

More plants and animals may occur in the low intertidal. Additional algae may occur including smaller, green (e.g., *Codium*), brown (e.g., *Dictyopterus, Taonia, Zonaria farlowi*),

and red algae (e.g., *Corallina, Gracilaria, Lithothamnion, Lithothrix*) and larger kelps (e.g., *Cystoseira, Egregia, Eisenia, Sargassum*), and/or surfgrass (*Phyllospadix* spp.). Representative animals may include the colonial sand tube worm (*Phragmatopoma californica*), crabs (e.g., *Cancer* spp.), Calfiornia sea hare (*Aplysia californica*), snails (e.g., *Lithopoma Ocenegra, Roperia, Tegula*), chitons (e.g., *Mopalia, Stenoplax*), octopus, brittle stars (e.g., *Ophiothrix* spp.), ochre starfish (*Pisaster ochraceus*), purple sea urchins (*Strongylocentrotus purpuratus*), sponges (e.g., *Haliclona*), and tunicates (e.g., *Clavelina*).

Potential Functions:

Rocky intertidal habitat may provide primary, foraging, and/or reproductive habitat for marine invertebrates, tidepool fish, and plants (algae, surfgrass). Shorebirds (e.g., turnstones), wading birds (e.g., herons, egrets), and gulls may forage on invertebrates and/or fish associated with rocky intertidal habitats. Birds and pinniped may rest on rocks.

Associated Species	Primary Habitat	Forage Habitat	Reproductive Habitat	Resting/ Roosting Habitat	Fisheries Habitat		Forage /Prey
					Commercial	Sport	
Vegetation	X		X				X
Invertebrates	X	X	X			X	X
Fish		X	X				
Birds		X		X			
Mammals							
T&E Species							

Some species of fishery importance may occur in rocky intertidal habitats (e.g., juvenile lobster, mussels, sea urchins); however, commercial fishing is not allowed in the intertidal habitat. Humans intensely use some areas with rocky shores for recreational fishing, exploration, and educational field trips. People also collect intertidal organisms for consumption, fish bait, home aquariums, and other purposes. California mussel is subject to recreational fishing limits (10 pounds/day) (CDFG 2005). Collection of the sea palm, *Postelsia palmaeformis,* which is attractive to some people, is prohibited. Many organisms in rocky habitats do not have specified fishing limits. Unfortunately people often disregard the protected status of rocky areas with special designation (e.g., CMLRs, SERs) and/or the existing harvest limits and prohibitions (Murray et al. 2000, CDFG 2001).

Table Tops Reef, San Diego County
Photo credit: Andrew Lissner, SAIC

Ecological functions provided by rocky intertidal habitat relates to the biological resource development and species present. Resource development largely relates to physical habitat characteristics and disturbance factors (see below). Generally, craggy, high-relief, bedrock that provides numerous microhabitats has more life than smooth, low-lying unstable rocks (Ambrose et al. 1989, Murray and Bray 1993). Also a greater diversity of plants and animals generally is found at rocky shores partially protected by a headland, island, or offshore reef than unprotected surf swept shores (*ibid*). Consequently, California rocky intertidal habitat may

vary considerably in ecological function and sensitivity depending on site-specific physical characteristics.

Life History Facts - Associated species:

Life history information is poorly known for many rocky intertidal species (Abbott and Hollenberg 1976, Morris et al. 1980). Available information indicates considerable variability among species regarding reproductive strategies, behavior, and life spans. Aspects of liffe history are briefly reviewed below; additional information may be found in the following subsections for surfgrass (3.3.7), rocky intertidal invertebrates (4.2.8), tidepol fish (4.3.7), gulls (4.4.4), shorebirds (4.4.5), and wading birds (4.4.6).

Most rocky intertidal invertebrate species have a planktonic larval phase and marine algae produce spores, both of which are dispersed by currents associated with water masses. There are north-south (cold and warm-temperate) gradients in community composition related to water temperature and the movement of water masses, and spawning and recruitment patterns also may vary along the coast (Morris et al. 1980). Generally, spring-summer is a period of higher productivity for both plants and animals; however, temporal variability or rocky intertidal habitats is poorly understood (Littler et al. 1979, Murray and Bray 1993, Thompson et al. 1993).

Many psammophytic (sand loving) species have two reproductive adaptations: regeneration of upright fronds from their bases, and incomplete alternation of generations (Daly and Mathieson 1977). Some species reproduce asexually (e.g., *Anthopleura*) or expand by vegetative propagation (e.g., corallines, *Rhodomela*, *Sphacelaria,* surfgrass), which are considered advantageous for acquiring dominance of space in the rocky intertidal (Daly and Mathieson 1977, Sousa 1979b, Dethier 1984).

Organisms inhabiting rocky intertidal habitat include plants and animals that attach to the rocky substrate, invertebrates that may move slightly while foraging, motile invertebrates that move up and down the shore with the tides and/or between low intertidal and subtidal zones. Rocky intertidal fish are mobile, but may display fidelity to certain tidelpools (Cross and Allen 1993). Birds foraging in rocky intertidal areas may include migratory gulls and shorebirds and non-migratory wading birds.

Life spans of rocky intertidal organisms range from short-lived to many years. Some species are effectively annuals that colonize bare substrate exposed after disturbance and do not survive subsequent predation and/or disturbance. Some opportunistic species may live 2 to 3 years after colonization (e.g., barnacles, periwinkles). Many species live 5 years or more. Some invertebrates may live > 100 years (e.g., aggregating sea anemones, purple sea urchins). Tidepool fish may live 1.5 to 18 years depending on the species.

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/spawn Egg/brood Planktonic Flower/seed Spores Vegetative Asexual	Year round to seasonal	Year round to seasonal	None	Some birds	Annual to years	Mobile to sedentary

Adaptations and/or Behaviors to Disturbance – Associated Species:

Various morphology, behavior, and life history adaptations and strategies apply to species that live in rigorous rocky intertidal habitat. Some species have morphological adaptations such as calcified or crustose anatomy (coralline algae, Ralfsiacea), a separate crustose stage (e.g., *Mastocarpus*), shells (some molluscs, hermit crabs), or hard exoskeletons (barnacles, crabs) that provide protection from disturbance. Feather boa kelp (*Egregia menziesii*) also has long fronds attached to a very strong stipe able to withstand wave forces (Section 3.3.6) Surfgrass has long blades with a protective sheath that may extend above seasonal sand levels and has a rhizomatous root system that binds with and helps anchor the plant in sand (Section 3.3.7).

Intertidal rock benches with mussels
Photo credit: Karen Green, SAIC

Mobile animals are able to move from areas of disturbance to refuge (e.g., shore crabs, turban snails, octopus, tidepool fish). Other species obtain protection based on microhabitat distribution, such as living on higher relief rocks and/or within crevices. In areas of higher-relief where rock heights provide refuge from sand inundation, long-lived and less tolerant species such as California mussel, black abalone (*Haliotis cracherodii*), and owl limpet (*Lottia gigantea*) may occur (Littler et al. 1983). The lower limits of the mussel *Mytillus edulis*, barnacle *Balanus balanoides*, and alga *Porphyra umbiliclis* approximated the highest summer sand elevations at an intertidal site in New Hampshire (Daly and Mathieson 1977).

Many rocky intertidal species have life history strategies characterized by high reproductive output and/or planktonic larvae with wide dispersal. Several species, termed opportunists, are able to quickly colonize bare substrate after disturbance due to high reproductive output and fast growth rates. Opportunistic rocky intertidal plants include several species of green algae (*Chaetomorpha linum, Cladophora columbiana, Ulva lobata, Enteromorpha intestinalis*), brown algae (*Ralfsia, Petalonia*), and red algae (*Ceramium*) (Littler et al. 1983, Murray and Bray 1993). Feather boa kelp also is an opportunistic colonizer due to high, spring recruitment and rapid growth and is often an annual in the intertidal (Black 1974). Opportunistic invertebrates include barnacles (*Chthamalus fissus/dalli*, *Tetraclita rubescens*) and colonial sand tube worm (*Phragmatopoma californica*) (Littler et al. 1983).

Life Stage	Physical Adaptation			Avoidance Behavior			Habitat	High Reproductive Output and/or Growth
	Long Blades, Fronds	Protective Sheath	Rhizomes	Burrow	Fly	Swim, Walk		
Adult	X	X	X	X	X	X	X	
Juvenile	X	X	X	X		X	X	
Egg, Larvae, Seed								X

Physical disturbance and substrate characteristics, which are highly site-specific, modify species assemblages of rocky intertidal habitats. Wave action, substrate stability, frequency and degree of sand inundation, and human disturbance influence species assemblages of rocky intertidal habitats (Littler et al. 1983, Ambrose et al. 1989, Murray and Bray 1993, Engle 2005). Rocky intertidal habitats exposed to greater wave shock may have shifts in species composition to more disturbance tolerant species, reduced numbers of herbivores and more filter feeding invertebrates, elevation shifts of some species to higher tidal zones, and some species displaying modified growth patterns (e.g., shorter, tougher, narrower, stronger attachment structures) (Murray and Bray 1993). Generally, wave-exposed shores have fewer species and proportionally fewer plants than macroinvertebrates than more protected coasts (Seapy and Littler 1978, Murray and Bray 1993); however, exceptions may occur. More plants and fewer invertebrates were observed at wave-exposed Ocean Beach, southern California possibly related to the soft, erodable nature of the sandstone substrate (Littler et al. 1991 cited in Murray and Bray 1993).

Photo permission: SANDAG
Photo credit: Merkel & Associates
http://nearshore.ucsd.edu/

Differences in resource development relative to substrate characteristics and sand influence are particularly relevant to beach nourishment issues, and are reviewed in greater detail below. Human disturbance impacts are briefly reviewed at the end of this section.

Stewart and Meyers (1980) conducted quantitative quadrat sampling at several relatively protected rocky intertidal sites, with low to high relief, in the La Jolla, Sunset Cliffs, and Point Loma areas of San Diego County over the course of a year. Cumulative species lists across surveys ranged from totals of 41 (31 plant species, 10 invertebrate species) to 77 (28 plant species, 49 invertebrate species). The number of species of plants and invertebrates was variable across sampling sites (i.e., cumulative total species of plants varied from 23 to 39 and the cumulative total species of invertebrates ranged from 10 to 49).

Surveys of rocky intertidal areas offshore Malibu, southern California, showed differences in numbers of species that appeared to be related to substrate development and nearshore turbidity levels. CRM (1997) found that total number of species ranged from 22 to 29 at sites with less variety of hard substrate (granite rip rap, cobble/boulder field with scattered rock outcrops) and/or at low to high relief reef sites where inshore underwater visibility was < 1 to 3 ft (< 1m) or less due to runoff. More species (40 to 52) were found where substrate consisted of low and/or high relief bedrock and boulders and inshore visibility exceeded 5 ft (1.7 m). Turbidity appeared to have more influence on algae (primarily leafy reds) than invertebrates. Areas with turbid waters had 7 to 15 species of marine plants and 15 to 17 species of invertebrates; whereas, areas with higher visibility had 20 to 26 species of marine plants and 21 to 26 species of invertebrates. Surfgrass was present at all but one location.

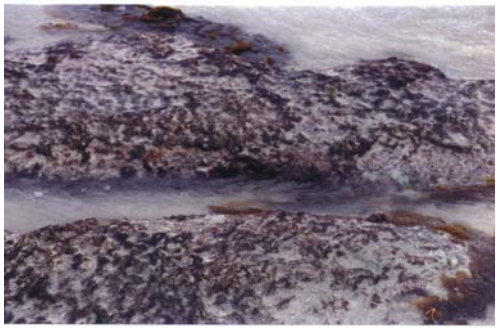
A two-year study of intertidal areas in New Hampshire showed reduced plant species diversity, a lower number of perennial species, and greater occurrence of psammophyte and opportunistic species where there were substantial, but irregular sand fluctuations than adjacent rocky shores (Daly and Mathieson 1977). Sand abraded rocks were dominated by

annuals and psammophytes. The observed species patterns were attributed to unstable environmental conditions, sand abrasion, and reduced light levels

The low to high relief rocky intertidal in the vicinity of the Portuguese Bend landslide has been substantially modified by sedimentation and associated turbidity (Pondella et al. 1996). This area of the Palos Verdes Peninsula, southern California, is geologically unstable. The beach received a sediment load of 8,940,000 metric tons between 1956 and 1986, and since then has continued to receive sediment. Comparison of the landslide affected site (Portugese Bend) with partially affected Abalone Cove (0.75 mile upcoast), and unaffected Palos Verdes Point (4 miles upcoast) indicate that habitats have been substantially modified by landslide sedimentation and turbidity. For example, rocky intertidal areas at the Portuguese Bend active landslide area had 15 species (5 to 7 plants, 8 to 10 invertebrates), headlands bordering Portuguese Bend had 29 to 34 species (6 to 7 plants, 22 to 27 invertebrates), Abalone Cove had 46 species (10 plants, 36 invertebrates), and unaffected Palos Verdes Point had a total of 53 species (17 plants and 36 invertebrates). Results showed a gradient of decreasing resource development with proximity to the landslide area that was more pronounced for plants than invertebrates. For example, reductions in invertebrate species did not appear to extend beyond the Portuguese Bend headlands; whereas, reduced numbers of plant species extended to Abalone Cove. Surfgrass was present at Palos Verdes Point, but absent from Portuguese Bend and Abalone Cove.

Laboratory-based experiments showed that light dusting of sediment reduced the percentage of zygote attachment to primary substrate for the fucoid alga (*Hormosira banksii*) and bull kelp (*Durvillaea antarctica*) by 34 and 71%, respectively, in New Zealand (Schiel et al. 2005).

Low-relief hard substrates subject to substantial sand movement generally are poorly developed. Plants may include annual ephemeral species and/or sand-tolerant algal turf and few to no invertebrates may occur (Daly and Mathieson 1977, Stewart 1991, MEC 2000a). For example, MEC (2000a) found low-relief (< 3 ft , < 1 m) rocky substrates at several sand-influenced locations between Carlsbad and Solana Beach in San Diego County to have limited resource development with 1 to 9 species representing different combinations of opportunistic and/or sand-tolerant red turf algae, coralline algae, feather boa kelp, surfgrass, aggregating sea anemone, chitons, and/or hermit crabs.



Close up of low-relief rocks with sand
Photo credit: Karen Green

Differences in species assemblages between areas subject to different levels of sand inundation were reviewed by Taylor and Littler (1982) and Littler et al. (1983). They summarized that areas subject to routine sedimentation generally develop subclimax associations consisting of opportunistic strategists (examples noted above) and stress-tolerant strategists. Invertebrates found to be tolerant of seasonal sand inundation included aggregating sea anemones, mossy chiton (*Mopalia muscosa*), and black turban snails (*Tegula funebralis*) (Taylor and Littler 1982, Littler et al. 1983). Aggregating sea anemones withstood shallow burial by extending its columns so the oral disc and tentacles remained

above the surface, and metabolism of body tissue was considered likely during prolonged burial (> 3 months). The mossy chiton tolerated sand burial for several weeks. Black turban snails, which are highly mobile, migrated from sand inundated areas. Sand-tolerant plants included surfgrass, calcified coralline algae (*Corallina, Lithothamnion, Lithorhrix*), and crustose *Ralfsia.* As noted above, surfgrass has several morphological adaptations for living in sand-inundated areas (also see Section 3.3.7). The persistence of coralline algal turf relates to its ability to rapidly re-grow from persistent crusts that remained viable after prolonged periods of sand burial (Stewart 1989, Murray and Bray 1993).

In addition to the sand tolerant species noted above, some plants are considered sand-loving, with distribution best represented in sand inundated rocky habitats (Daly and Mathieson 1977, Murray and Bray 1993). Examples of psammophytes that occur in California include *Ahnfeltia plicata, Chaetomorpha linum, Chondria nidifica, Gigartina papillata, G. volans, Gracilaria* spp*., Gymnogongrus leptophylluss, Neohodomela larix, Phaeostrophion irregulare, Pterocladia media, Taonia lennebackeriae,* and *Zonaria farlowii* (Abbott and Hollenberg 1976, Littler et al. 1983, Turner 1985, Murray and Bray 1993).
Rocky beaches with cobble and/or boulder substrates provide another example of variable resource development related to disturbance. Unstable cobbles or boulders may support few resources due to abrasion from being overturned by waves. Differences in resource development with size of boulder and disturbance level were demonstrated by Sousa (1979a) at Ellwood Beach, southern California. For example, small boulders subject to frequent overturning by waves (>40%/month) were characterized by sparse, early successional assemblages of opportunistic green algae (*Ulva*) and barnacles, intermediate size boulders with intermediate disturbance frequencies (9%/month) had greater diversity (6 to 7 algae species) comprised of both early and late successional species, and large boulders that almost never moved were dominated by late successional *Chondracanthus (*= *Gigartina*) *canaliculata*. In contrast, a stable boulder beach at Cayucos Point, central California, characterized by a variety of habitat structure and reduced wave action had a diverse assemblage consisting of 41 algae species and 22 invertebrate species (Seapy and Littler 1978).

Human disturbance impacts on rocky intertidal habitats are of increasing concern, particularly for southern California where rocky intertidal areas are limited and most border densely populated areas (Thompson et al. 1993). Mussels, trochid (turban) snails, limpets, urchins, and octopuses were found to be the most commonly collected organisms during a study of rocky shores in Orange County (Murray et al. 2000). Generally, fewer and smaller individuals result where collecting occurs. Murray et al. (2000) caution that most of the collected invertebrates are broadcast spawners that require high densities of fertile individuals to optimize reproduction; consequently, the cascading effects of collecting on community structure and the reproductive success of exploited populations are unknown. Thompson et al. (1993) point out that biological studies conducted in “urban intertidal” areas should explicitly consider human predation and disturbance effects before drawing ecological inferences from sampling data.

Potential Impacts from Sediment Management Activities – Associated Species:

Ecological values of intertidal rocky habitat vary depending on site-specific substrate and disturbance factors. Rocky intertidal areas may include variable height substrates and tidepools that support substantial living, foraging, and reproductive functions of vegetation, invertebrates, fish, and/or birds. In contrast, rocky intertidal habitat also may include low-

relief substrate subject to seasonal sand burial and scour with poorly developed biological resources and/or unstable cobbles or small boulders devoid of all but the hardiest of organisms. Consequently, potential impacts from sediment management activities could vary greatly depending on the site-specific characteristics of the rocky intertidal habitat and the associated resources.

Types of sediment management activities and potential impact concerns to rocky intertidal habitat include:

- Maintenance dredging of embayments – not applicable.
- Offshore borrow site dredging – not applicable.
- Nearshore placement – sedimentation, turbidity.
- Profile placement – equipment, burial, sedimentation, turbidity.
- Beach placement – equipment, burial, sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging	A	A	A	A	A, P	A
Growth			A, P	A, P	A, P	A, P
Habitat			X	X		X
Reproduction			A, P	A, P	A, P	A, P
Respiration				A	A	
Resting/ Roosting	A	A		A		

A = associated animals, P = plants, X = substrate

Equipment

Placement of pipelines in order to convey sands to the beach from offshore hopper vessels has the potential to overturn rocks if conducted in rocky intertidal habitat. Disturbance of rocks could result in removal of plants and displacement and/or damage to marine invertebrates and/or tidepool fish, if present. Equipment and/or noise could disturb birds foraging on rocky intertidal resources or roosting of rocks. Pinnipeds also could be disturbed if activities occurred near haul outs.

Temporary construction impacts would be of concern in rocky intertidal areas supporting diverse and/or sensitive biological resources and uses of habitat. Equipment use in areas with cobble substrate and/or low relief ephemeral reefs with few biological resources would have little potential for adverse impact.

Avoidance of direct disturbance of sensitive rocky intertidal areas has been incorporated into project design of some California beach nourishment projects (e.g., SANDAG and USDN 2000, Moffatt & Nichol 2001). Pre-construction environmental surveys also were used to minimize the potential for impacts to sensitive rocky reef resources during the 2001 San Diego Regional Beach Sand Project (AMEC 2002) and 2003 Goleta Beach Demonstration Project (Chambers Group 2003, Moffatt & Nichol 2003). Pre-construction surveys to finalize pipeline routes in areas with intertidal reefs have been recommended as a beach nourishment mitigation measure (Chambers 1992, 2000b).

Burial/Sedimentation

Direct sand placement on rocky intertidal habitat with diverse plant and invertebrate communities and/or with tidepools supporting fish would be a significant concern. Burial could result in sensitive habitat loss for years until coastal processes removed excess sand, and several years more to recover lost habitat functions. Similar to the above discussion of potential equipment impacts, avoidance of direct disturbance of sensitive rocky intertidal areas has been incorporated into project design of beach nourishment projects in California (e.g., SANDAG and USDN 2000, Moffatt & Nichol 2001).

Indirect sedimentation of rocky intertidal habitat from post-construction sand transport from a receiver site is of potential concern with any placement method, depending on project volume and proximity to this habitat. Sand inundation and scour can substantially modify species assemblages, causing displacement of some mobile species and dominance by opportunistic, sand-tolerant, and/or sand-loving species. This disturbance naturally affects rocky intertidal habitats to varying degrees throughout California on a seasonal basis. Lower relief reefs are more vulnerable to sand disturbance, while higher relief reefs tend to remain above the sand. Impact concerns relate to the potential for indirect sedimentation occurring above natural levels and adversely impacting sensitive rocky intertidal habitat and resources.

The degree of potential sedimentation is difficult to predict, being related to project volume, site-specific physical characteristics, and temporal oceanographic conditions. In addition, rocky intertidal organisms have different morphology, behavior, and life history characteristics with differing levels of tolerance to sedimentation impacts. For example, dominant species such as aggregating sea anemones and surfgrass are sand-tolerant and can withstand substantial seasonal burial (Sections 3.2.7, 4.2.8); however, critical impact thresholds are unknown.

Other dominants such as California mussel and barnacles are known to be sensitive to sand burial; however, they tend to occur in highest abundance on higher relief substrate less vulnerable to substantial impact. Because of potential impact uncertainties, monitoring has been required with some beach nourishment projects when sensitive rocky intertidal habitat occurs in the vicinity.

No direct burial of intertidal reefs occurred with the 2001 San Diego Regional Beach Sand Project, although some placement occurred in areas with cobble and/or sand scoured low relief rocks with few biological resources (SANDAG and USDN 2000). No obvious sedimentation impact to rocky intertidal reef attributable to the 2001 San Diego Regional Beach Sand Project was reported based on comparison of pre-construction and four years of post-construction monitoring data (Engle 2005). Monitoring was conducted at an

intertidal rocky reef 3,400 ft (1,000 m) downcoast of a receiver site that received 101,000 cy and comparative monitoring at locations outside the littoral cell.

Changes in densities of some target species were observed at all locations suggestive of larger regional patterns, response to changes in sand levels also were observed; however, effects downcoast of the receiver site were considered within the range of measured natural variation and no obvious impacts from the beach nourishment project were reported (Engle 2005). Target species were selected using the following criteria: ecologically important in structuring intertidal communities, species characteristic of discrete intertidal heights, species that have been well studied, species especially vulnerable to human impacts, and species practical for long-term monitoring. The following target species were monitored: rockweed (*Silvetia compressa*, formerly *Pelvetia fastigiata*), acorn barnacles (*Chthamalus* spp.), pink-thatched barnacles (*Tetraclita rubescens*), California mussels, goose neck barnacles, owl limpets, red turf algae (Corallina spp. and other tufted algae), surfgrass, feather boa kelp, sargassum weed (*Sargassum muticum*), aggregating sea anemones, colonial sand tube worms (= sand castle worms), ochre sea stars, and black abalone.

Intertidal reefs were monitored before and quarterly for 1 year after the Goleta Beach Nourishment Demonstration project. Sediment deposition was observed during the first year of monitoring at intertidal sites 6,500 ft (2000 m) to 7,874 ft (2,400 m) downcoast of the Goleta Beach Nourishment Demonstration Project, which placed 79,000 cy of sand onto the beach and was followed by an additional project with 18,600 cy of sand placement (Chambers Group 2004). Increased sand depth and cover was only observed during one survey at each of the two monitoring sites and changes in sand were within natural variability shown at the sites prior to beach nourishment. Chambers Group (2004) concluded that the beach nourishment project may have had a temporary impact on rocky intertidal habitat, but did not appear to have caused any long term change.

Burial of worm reefs in low to shallow subtidal nearshore was reported for a 457,000 cy project that directly buried and indirectly inundated reef outcroppings directly offshore a beach nourishment site in Florida (Lindeman and Snyder 1999). Although some uncovering of reefs occurred after the first storm season, effects were still evident 15 months later. The project required an artifical reef to be constructed as compensatory mitigation for impacts (Section 4.3.6).

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<u>Turbidity</u>

No specific information on the response of intertidal rocky habitats and associated species to suspended solids concentration levels associated with beach nourishment activities is available. Substantial impact would not be expected with temporary exposures similar to that experienced under natural storm and high wave conditions. However, large projects with the potential to generate turbidity over periods of months could be of concern if implemented close to diverse rocky intertidal habitats. Relevant studies indicate that chronic turbidity reduces intertidal habitat diversity, with the most pronounced effect on marine plants; intertidal invertebrates appear to be more tolerant (Pondella et al. 1996, CRM 1997).

Recovery from Disturbance:

Intertidal rocky habitats are rigorous habitats due to hydrodynamic forces of wave shock, ebb and flow of tides, and seasonal sand movement. Species living in this environment

have life history and behavioral strategies that are adapted across a broad range of disturbance, and species assemblages reflect response to site specific disturbance factors.

Recovery rates of rocky intertidal invertebrates vary depending on species. Recovery of intertidal communities does not follow an orderly succession, but rather may be characterized as colonization by opportunists followed by different dominants (Dayton 1971) or colonization by opportunists and/or dominants (Connell 1972). Initial colonizing opportunistic species (noted previously) include several species of algae, barnacles, and colonial sand tube worms (Emerson and Zedler 1978, Sousa 1979a, b, Littler et al. 1983).

Recovery rates of dominant rocky intertidal species range from < 1 year for minor disturbance to several years for complete recovery. For example, recovery rates of mussel patches range from > 2.5 to 10 years (Morris et al. 1980, Littler et al. 1983, Dethier 1984, Ambrose et al. 1989). According to Paine and Levin (1981) it takes 2 years for recovery to begin and take 5 to 7 years for full recovery (Paine and Levin 1981). Recovery of aggregating sea anemones may range from 1 year for partial losses to > 3 years for total losses (Taylor and Littler 1982, Dethier 1984).

No reports of significant rocky intertidal impacts and subsequent recovery from beach nourishment projects in California were identified from the literature review. Therefore, recovery rates associated with different aspects of sediment management activities (e.g., equipment, burial, sedimentation, turbidity) would be expected to vary depending on site specific characteristics of rocky substrate, biological resource development, and degree of impact.

Recovery would be expected to be rapid from temporary construction related impacts for unstable and/or low-relief substrates characterized by early successional algal turf and limited resource development. Sand burial and/or substantial sedimentation of low-relief substrate would result in complete and/or partial conversion to sandy beach habitat. Unstable cobble substrate covered by sand placed during beach nourishment from the San Diego Regional Beach Sand Project was still covered with sand four years after the project (SAIC 2006).

In areas with well developed rocky habitats, direct impacts (burial, equipment) would be unlikely to be permitted by resource and regulatory agencies due to ecological sensitivity of habitat. Recovery from indirect impacts (turbidity, sedimentation) from projects implemented in the vicinity of sensitive rocky intertidal areas would depend on the duration and degree of impact.

Indicator species cover and/or sand levels exhibited variability, some of which may have been related to upcurrent beach nourishment projects, but effects were temporary and within the range of natural variability for two beach nourishment projects implemented within 3,400 to 6,500 ft (1,000 to 2,000 m) of rocky intertidal habitat in southern California (Chambers 2004, Engle 2005).

Recovery rates of rocky intertidal assemblages from higher concentrations and/or prolonged exposure to turbidity are unknown and would depend on the severity of the impact. Recovery could take years if substantial sedimentation resulted in loss of dominant species such as California mussels, aggregating sea anemones, and/or resulted in substantial reduction in invertebrate and algae assemblages.

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	X			X	
Burial			X		
Sedimentation	X	X	X		
Turbidity	X			X	
Habitat Loss			X		

Critical Impact Thresholds:

Burial of tidepools with sensitive resources and/or substantial inundation that resulted in lost habitat functions (e.g., shelter, occupied space) would be of ecological concern. Studies demonstrate that chronic turbidity and/or frequent sedimentation disturbance reduce biological resource development.

Data Gaps:

Limited information is available on sedimentation and turbidity impacts on rocky intertidal habitat.

Restoration:

It may be technically feasible to create rocky intertidal habitat; however, successful restoration of tidepools has not been demonstrated

Summary:

Concerns regarding potential impacts from sediment management activities on rocky intertidal habitat range from protective conservatism to unnecessary. The reason for this disparate range of concerns relates to the highly variable and site-specific nature of rocky intertidal habitat, which may range from ecologically rich to depauperate.

Concerns primarily relate to rocky intertidal areas with diverse species assemblages and ecological functions, which generally are associated with stabilized rocky habitats with heights ranging above the depth of natural seasonal sand inundation and scour. Such habitats may support a variety of plants and invertebrates, tidepool fish, and provide forage for birds and/or subtidal fauna. These areas also may provide important juvenile habitat for lobsters and potential habitat for sensitive black abalone.

The most productive of these habitats are rocky shores partially projected by a headland, island, or offshore reef. Rocky intertidal areas that support surfgrass beds also are of particular concern because they represent important nursery and sheltering habitat for lobster and fish. Documented rates of recovery of diverse rocky intertidal communities following substantial disturbance are on the order of years.

Impact concerns and recovery rates are less for unstable and/or low-relief rocky intertidal habitats supporting few biological resources. Such areas may be associated with sand starved beaches and/or where reef development is patchy. Cobbles and boulders subject to

wave tumbling and sand abrasion may be devoid of marine life or support few early colonizing opportunistic species capable of rapid recovery. Similarly, low-relief reefs subject to seasonal sand burial and erosion (i.e., ephemeral reefs) support subclimax assemblages.

Direct impact concerns from equipment use and/or and sand placement burial in areas with sensitive rocky intertidal habitat have been avoided in California during project design and permitting. Beach nourishment in areas with cobble substrate and/or limited low-relief substrate has resulted in conversion to functional sandy beach habitat.

A key concern is the potential for indirect turbidity and/or sedimentation to impact sensitive rocky intertidal areas that may occur in the vicinity of erosive beaches where beach nourishment needs are identified. Intertidal species are naturally adapted to a broad range of turbidity associated with wave and storm conditions; however, chronic turbidity may result in reduced habitat diversity (especially plants, herbivores).

Turbidity associated with sediment management activities has the potential to range on the order of days to months depending on project size, and also will vary depending on construction method. Therefore, impacts to rocky intertidal habitat have the potential to range somewhere between natural and above-normal (not chronic) levels depending on project characteristics and proximity to rocky intertidal habitat. Critical impact thresholds associated with turbidity levels and duration in rocky intertidal habitats are unknown.

Similarly, sedimentation is a natural disturbance that affects rocky intertidal habitats to varying degrees on a seasonal basis. Lower relief reefs are more vulnerable to sand disturbance, while higher relief reefs tend to remain above the sand. Species have various strategies of tolerating or avoiding natural sedimentation, ranging from morphological adaptations to sand inundation, moving to higher relief refuge as needed, and/or living on higher relief substrates above natural sedimentation levels. Therefore, impact concerns relate to the potential for indirect sedimentation occurring above natural tolerance limits and/or sanding-in higher relief substrates. Impacts that resulted in reduced habitat diversity and/or loss could take years to recover. Critical impact thresholds associated with sedimentation level and duration in rocky intertidal habitats are not well understood.

Monitoring of rocky intertidal areas before and after implementation of beach nourishment may be required when there was uncertainty regarding the potential for indirect impacts. Results of available monitoring studies indicate beach nourishment can be implemented in the vicinity of sensitive rocky intertidal habitat without significant impacts. Given the limited number of available monitoring studies and wide range of potential project impact scenarios, monitoring requirements for rocky intertidal habitat should continue to be decided on a project specific basis depending on potential impact concerns and uncertainties.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities to rocky intertidal habitat.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Protective conservatism	Documented	Documented	Relevant reports
Critical Impact Thresholds	NA	Surfgrass removed, rocks overturned	Habitat loss	Degrade habitat, habitat loss	Vegetation loss
Impact Responses	NA	Damage, Disturbance	Reduce diversity, displace biota	Reduce diversity, displace biota	Disturb and/or harm biota
Duration of Impacts	NA	Days-Months	Months-years	Months-years	Hours-months
Potential for Restoration	NA	Unnecessary	Feasible, but not demonstrated	Feasible, but not demonstrated	Unnecessary

NA = not applicable

3.3.5 Rocky Subtidal

Photo credit: San Diego Nearshore Program http://nearshore.ucsd.edu/

Regulatory Status:

Endangered	White abalone
Essential Fish Habitat	X
Other	Various protected habitat designations may apply; black abalone candidate for listing

Rocky subtidal habitat may occur in Areas of Special Biological Significance (ASBS), State Ecological Reserves (SERs), California Marine Life Refuges (CMLRs), marine sanctuaries, and underwater parks. Subtidal reefs also occur in areas without special designation. All rocky subtidal areas represent Essential Fish Habitat for managed fishery species.

Description and Distribution:

Rocky subtidal habitats occur throughout California, although they are more prevalent in central and northern California and around the Channel Islands, and less extensive along the mainland of southern California (Ambrose et al. 1989). Locations of subtidal rocky habitats may be indicated by surface canopies of kelp, but not always; generally subtidal rocky habitat occurrence is less well known than rocky intertidal and/or kelp forest/bed habitats (*ibid.*). Locations of known rocky subtidal reefs were summarized in Ambrose et al. (1989), online resources listed in Section 3.3.4 provide relevant information, and selected areas of the coast have additional mapped resource information (e.g., San Diego County - http://nearshore.ucsd.edu/).

	California			On Land	Inter-tidal	Near-shore < 30 ft	Off-shore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Habitat	X	X	X			X	X	X

Potential Functions:

Subtidal reefs may provide habitat for a variety of aquatic vegetation (e.g., algae, seagrasses), fish, invertebrates including the endangered white abalone, and foraging habitat for birds and marine mammals (including threatened sea otters). Reef associated plants (e.g., giant kelp) and animals (e.g., abalone, lobster, sea urchins, sea cucumbers, reef-associated fish) support commercial fisheries and attract considerable recreational sport diving and fishing.

Several factors affect the distribution and abundance of marine life on subtidal hard bottom habitats. Important substrate qualities include size (boulder, bedrock), vertical relief (low, high), composition (sandstone, basalt, granite), surface texture (smooth, pitted, cracked), and orientation relative to waves (Pequegnat 1964, Dayton et al. 1984, Ambrose et al. 1989,

Ambrose 1994). Generally, there is a positive correlation between marine life diversity and substrate diversity.

Associated Species	Primary Habitat	Forage Habitat	Reproductive Habitat	Fisheries Habitat		Forage /Prey
				Commercial	Sport	
Vegetation	X			X		X
Invertebrates	X	X	X	X	X	X
Fish	X	X	X	X	X	X
Mammals		X				
T&E Species	X	X	X			X

Hard bottom areas with a range of rock sizes, heights, and surface textures provide multiple shelter opportunities for motile organisms and surface areas for attachment by sessile organisms. Overall diversity also relates to development of vegetation. Macroalgae provides food, structural complexity, refuge from predation, and spawning/nursery sites for invertebrates and fish (Foster and Schiel 1985, Levin and Hay 2002, Blackmon et al. 2006). Generally, higher relief, vegetated reefs support more diverse communities than low-relief reefs that experience excessive siltation or sand scour (Ambrose et al. 1989). Low-relief reefs that experience periods of burial and exposure from natural, sand level change sometimes are referred to as “ephemeral” (e.g., Coastal Engineering & Planning 2004).

Low relief reef next to sand channel
Photo credit: L. Homma, Merkel & Associates

High relief vegetated reef
Photo credit: San Diego Nearshore Program
http://nearshore.ucsd.edu/

Over 100 species of fish have been reported to inhabit rocky reefs and kelp beds off California (Quast 1968, Feder et al. 1974). The number of species and abundance of fish at a particular reef location relates to substrate characteristics and presence of kelp (Cross and Allen 1993). Quast (1968) reported more fish species were associated with moderate to high relief than low relief reefs regardless of depth; however, a greater number of species was generally associated with high relief reefs in deeper (> 60 ft, > 18 m) than shallower waters with some exceptions. Substrate relief > 3 ft (> 1 m) reportedly has little additional effect on fish species or diversity (Patton et al. 1995 cited in Cross and Allen 1993). Reports

of number of fish species may range from < 15 for shallow nearshore reefs to > 40 for a high-relief offshore kelp reef (Pequengnat 1964, Ebeling et al. 1980, Larson and DeMartini 1983, Ambrose 1986, CRM 1997; USDN 1997a, b; MEC 2000a). (Also see Section 4.3.6).

Several hundred species of invertebrates range from intertidal to subtidal depths in California (Morris et al. 1980). Reports of conspicuous macroinvertebrate taxa have ranged from < 10 species to 37 on low to high relief reefs at depths < 30 ft (9 m) (CRM 1997; USDN 1997a, b; MEC 2000a). Over 30 macroinvertebrate species was reported from a sand kelp bed in waters > 35 ft (11 m) (Chambers Consultants 1982). Reports of 200 and 300 species of conspicuous and encrusting invertebrates have been reported from high relief reef and rocky bottom kelp beds at depths > 30 ft (9 m) (Section 4.2.9).

Life History Facts – Associated Species:

Relevant life history facts are associated with the flora and fauna associated with subtidal reefs (see Sections 3.2.6 kelp, 3.2.7 surfgrass, 4.2.9 subtidal reef invertebrates, and 4.3.6 subtidal reef fish). Generally, species display a variety of morphology, behavior, and reproductive strategies. Algae display different reproductive strategies, ranging from spore release and sexual reproduction to being self-fertilizing, and may range from annuals to perennials that live > 10 years. Surfgrass reproduces sexually, but mainly grows by vegetative propagation. Invertebrates display a variety of reproductive modes and//or asexual reproduction; many species have planktonic larval stages. Many invertebrates live several years. Reef fish also display different reproductive modes, from nest layers to livebearers, with many species releasing eggs with that have a planktonic larval stage. Reef fish generally live several years.

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Nest Egg/Spawn Flower/Seed Planktonic Spores Vegetative	Year Round	Year Round	None	None	Years	Mobile to Sedentary, depending on species

Adaptations and/or Behaviors to Disturbance – Associated Species:

Various morphology, behavior, and life history adaptations and strategies apply to species associated with rocky subtidal habitat. Some of the same and/or related species that occur in the intertidal range to subtidal depths and have many of the same adaptations previously described. For example, several species have calcified and/or crustose anatomy (coralline algae), shells (some molluscs, hermit crabs), or hard exoskeletons (crabs, lobsters, cup corals) that provide protection from disturbance. Several kelp species living in shallow nearshore environments have morphological adaptations for for wave stress (Friedland and Denny 1995, Denny et al. 1997, Gaylord and Denny 1997).

Juvenile Garibaldi

Photo by: D. Heilprin, SAIC

Many species of invertebrates (e.g., brittle stars, crabs, lobsters, octopus, sea stars) are mobile and may move from disturbance; some seek shelter

in crevices and/or among turf algae. Fish tend to react to disturbance by swimming away, although some reef fishes are closely associated with substrate and may become more vulnerable to predation if they leave their protected habitat (Lindeman and Snyder 1999). Foraging predators such as marine mammals are highly mobile. Many rocky subtidal species have reproductive strategies characterized by high reproductive output, planktonic larvae, or spores with various dispersal abilities. Rapid growth rates also characterize several canopy-forming kelps.

Life Stage	Physical Adaptation			Avoidance Behavior			Habitat	High Reproductive Output and/or Growth
	Long Blades, Fronds	Protective Sheath	Rhizomes	Burrow	Fly	Swim, Walk		
Adult	X	X	X			X	X	
Juvenile	X	X	X			X	X	
Egg/ larvae							X	X

Some species are tolerant of sand inundation. Surfgrass has several adaptations for tolerating seasonal sand inundation (Section 3.3.7). Some rocky subtidal invertebrates obtain protection from sedimentation by living on higher relief substrate above the depth of seasonal sand inundation (e.g., abalones, sea fans) (Littler et al. 1983, AMEC 2005).

Species of algae vary in their tolerance to sedimentation. Giant kelp is vulnerable to impacts from sedimentation and scour across all life stages (North 1986, Foster and Schiel 1985, Murray and Bray 1993) (Section 3.3.6). Other species of kelp have different tolerances to sand inundation. For example, feather boa kelp is considered relatively tolerant of sedimentation based on occurrence of low relief reefs with interspersed sand patches (AMEC 2005). *Eisenia* and *Pteryogophora* were considered relatively more tolerant than giant kelp, but possibly less than feather boa kelp (North 1986, AMEC 2005).

Experimental studies have shown erect algae to be sensitive to sedimentation (Airoldi and Cinella 1997, Maughan 2000). Experimental studies of sedimentation (up to 7 mm per 2 to 3 months) on colonization of new substrate (bricks) indicated reduced number of plant species, reduced plant and animal cover, but favored a few small opportunistic taxa (e.g., *Ulva* and *Enteromorpha*) compared to unstressed bricks (Thomsen and McGlatery 2005). Similarly, settlement of trapped drift algae reduced animal cover, but plant richness and cover were intermediate, and cover of *Ulva* and *Enteromorpha* was high. Experimental studies showed that filamentous turf (*Polysiphonia sectacea*) was tolerant of sedimentation, but growth was potentially enhanced by reduced sedimentation rates (Airoldi and Cinelli 1997). Airoldi and Cinelli (1997) suggested that small-scale spatial variability of depositional environments may affect within-habitat diversity either through direct effects on individual species or on their propagules, and through indirect effects mediated by competitive interactions.

Experiments by Duggins et al. (1990) showed various recruitment responses of invertebrates to sedimentation and reduced light levels associated with understory kelp canopies. For example, increased sedimentation and reduced light adversely affected recruitment of serpulid and spirobid polychaetes, increased sedimentation affected recruitment of *Membranipora* bryozoans, and increased sedimentation and higher light intensity affected recruitment of *Tubulipora* bryozoans.

Chronic sedimentation impacts can have profound influence on subtidal reef resources. In an area of continuing landslide activity off Palos Verdes, southern California, the Portuguese Bend landslide area supported only sparse occurrence of giant kelp and few invertebrates (2 to 5 species) compared to other areas along the Palos Verdes Peninsula (Pondella et al. 1996). Areas within the center of the slide area were devoid of kelp and few species of invertebrates (2 to 5) were present. Headlands bordering the slide area had sparse occurrence of kelp and substantially more invertebrates (19 to 24 species). Partially affected Abalone Cove had a low density of kelp and 18 species of invertebrates. Unaffected Palos Verdes Point had a substantial kelp bed, more understory algae, and 25 species of invertebrates. The results demonstrate that chronic turbidity reduced kelp cover over a larger distance than effects on invertebrates, which were more localized. Review of the invertebrate species lists indicates there was a reduction in herbivores and filter/suspension-feeders with proximity to the landslide.

Differences in substrate type and sedimentation (associated with silty sands and elevated turbidity) appeared to influence resource development on nearshore hard substrate habitats offshore the Malibu region in Los Angeles County (CRM 1997). Transect-based surveys were conducted at depths between 10 and 24 ft (3 to 7.3 m) and marine resources occurring on sand and hard substrate were recorded. The total number of subtidal species was 3 to 8 times greater at beaches with some hard bottom substrate (18 to 56 species) compared to just sand (7 species) in the nearshore. At sites with hard bottom habitat, the fewest number of species (16 species invertebrates, 2 species algae) was reported where hard substrate was cobble/boulder and sedimentation (silt on rocks) was evident. An intermediate number of species (28 species of invertebrates, 6 species of algae) occurred where hard substrate was low relief (< 3 ft) boulders and/or boulder/bedrock. The numbers of species ranged higher (25 to 37 species of invertebrates, 14 to 15 species of vegetation) where hard substrate ranged from low to high relief boulder/bedrock. CRM (1997) observed 2 to 4 species of fish at sites where there was boulder and/or bedrock substrate, and no fish at locations where substrate was cobble/boulder or sand; but also added that observations may have been limited by poor visibility at some sites.

Potential Impacts from Sediment Management Activities – Associated Species:

Potential impacts to rocky subtidal reefs from sediment management activities are reviewed below from the perspective of reefs as habitat. More detailed reviews of impacts to reef associated species of vegetation, fish, and invertebrates related to life functions (e.g., foraging, growth, reproduction) are presented in Sections 3.2.6, 3.2.7, 4.2.9, and 4.3.6.

Similar to intertidal habitat, ecological values of rocky subtidal habitat vary depending on site-specific substrate and disturbance factors. Nearshore rocky reefs may range from low-relief and seasonally inundated with sand to mixed heights. Biological resource development may range from opportunist, dominated turfs to diverse communities supporting surfgrass and/or a variety of algae, invertebrates, and fish. Kelp forests and beds often are associated with hard substrates further offshore. Consequently, potential impacts from sediment management activities could vary greatly depending on the site-specific characteristics of the rocky subtidal habitat and the associated resources.

Types of sediment management activities and potential impact concerns to rocky subtidal habitat include:

- Maintenance dredging of embayments – not applicable.
- Offshore borrow site dredging – equipment, turbidity.
- Nearshore placement – equipment, burial, sedimentation, turbidity.
- Profile placement – equipment, burial, sedimentation, turbidity.
- Beach placement – sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging		A	A	A, P	A, P	A
Growth			A, P	A, P	A, P	A, P
Habitat			X	X		X
Reproduction			A, P	A, P	A, P	A, P
Respiration					A	

A = associated animals, P = plants, X = substrate

Equipment

Anchoring associated with offshore dredging of sand borrow areas, nearshore or profile placement, and/or temporary pipeline placement activities associated with conveying sands to the beach from offshore hopper vessels have the potential to overturn rocks and/or damage marine life living on subtidal reefs. Equipment noise and activities may result in temporary displacement of mobile invertebrates and fish. Indirect attraction and/or displacement may occur as a result of lights during night-time operations.

Although direct damage to reefs from dredges, barges, pipelines or other equipment involved in beach nourishment projects has not been documented in California such damage has been recorded by equipment involved in offshore oil development (Chambers Consultants and Planners 1982, MEC 1995). Anchors have been shown to cause long-term damage to deepwater reefs (MEC 1995).

Damage to reefs during borrow site dredging has been reported off the east coast. Coral reefs were damaged from dredge equipment, anchor, and/or cable dragging across reefs or when cutting heads of the dredge dug into reef surfaces off Hallandale and Delray, Florida (Courtney et al. 1972; Spadoni 1978 cited in Naqvi and Pullen 1982). Courtney et al. (1972) considered these as unnecessary accidents resulting from inadequate surveying prior to construction. Reef damage off Hallandale was not evident 5 years later (Marsh et al. 1981). Direct damage to corals by dredging was reported off Broward County, Florida in 1977 at

John Lloyd Park when dredges that went off course starting dredging coral reefs; it was estimated that 36,300 corals were directly damaged (Raymond et al. 1977 cited in Goreau 2001).

Damage to reef habitats by offshore equipment can be avoided by pre-construction surveys to identify mooring, anchor, and pipeline locations as well as vessel access routes that avoid sensitive habitat. Prior to construction of SANDAG's 2001 San Diego Regional Beach Sand Project, the dredging contractor provided pipeline/anchor plans that were reviewed by the environmental monitor for any potential concerns. Pre-construction environmental diving surveys were determined to be warranted for 4 of the 13 receiver sites, and resulted in several recommendations that the contractor complied with to avoid direct impacts to kelp canopies and subtidal reef resources (AMEC 2002). Prior to BEACON's 2003 Goleta Beach Nourishment Demonstration Project an underwater survey was conducted to identify pipeline and mooring locations that would avoid significant subtidal habitat (Moffatt & Nichol 2005c). Pre-construction surveys to finalize pipeline and vessel routes in areas with nearshore reefs were recommended as a mitigation measure for the SANDAG and BEACON projects (Chambers 1992, 2000b, SANDAG and USDN 2000).

Burial/Sedimentation

Nearshore and/or profile placement potentially could result in direct burial of the rocky subtidal habitat, if present. Burial could be partial and/or complete depending on height of rocky substrate and sand overburden depth. Burial of ephemeral reefs, which have reduced species assemblages when exposed, could result in their complete burial for years until coastal processes removed excess sand.

No examples of direct burial of sensitive rocky subtidal habitat as a result of California sediment management activities were identified withfrom the literature review. Direct burial of sensitive rocky subtidal habitat would not be permitted in California because of its value as essential fish habitat.

Indirect sedimentation of rocky subtidal habitat from post-construction sand transport from a receiver site is of potential concern with any placement method, depending on project volume and proximity to rocky habitat. Sand inundation and scour can substantially modify species assemblages and/or reduce habitat functions. This disturbance naturally affects nearshore subtidal reefs to varying degrees throughout California on a seasonal basis, particularly through the surfzone. Low relief reefs are more vulnerable to sand inundation and scour. Impact concerns relate to the potential for indirect sedimentation occurring above natural levels and adversely impacting sensitive rocky subtidal habitat and resources.

Similar to the discussion for rocky intertidal habitat, the degree of potential sedimentation is difficult to predict, being related to project volume, site-specific physical characteristics, and temporal oceanographic conditions. In addition, the potential significance of the impact will relate to site-specific ecological values and tolerances of potentially affected species. Because of potential impact uncertainties, monitoring has been required with some beach nourishment projects when sensitive rocky subtidal habitat occurs in the vicinity.

Monitoring studies indicate that beach nourishment sedimentation may have no, limited, or substantial effect on subtidal reefs depending on site- and project-specific factors. Several

projects are reviewed below starting with relevant California projects, followed by available information for several projects on the east coast of the United States.

AMEC (2005) reported limited to no obvious impacts to biological resources on rocky subtidal reefs attributable to the 2001 San Diego Regional Beach Sand Project, based on comparison of pre-construction and four years of post-construction monitoring data (AMEC 2005). Approximately 2 million cy of sand was placed at 12 San Diego beaches; a total of 984,000 cy was placed between Carlsbad and Solana Beach (101,000 to 225,000 cy per beach site) in an area of coastline with patchy occurrence of subtidal reefs. A total of 18 reef sites were surveyed between Carlsbad and Solana Beach, 6 served as controls and 12 were located offshore or downcoast of receiver sites, and/or within areas that were predicted prior to construction as being vulnerable to substantial sedimentation. The rocky areas at all study sites included low to high relief (< 3 to > 3 ft; < 1 to > 1 m) substrate that was discontinuous (i.e., separated by sand channels that ran perpendicular to shore). AMEC (2005) suggested that the sand channels may provide avenues for sand movement, decreasing the likelihood of impacts from sand scour and burial on the reef tops.

Large fluctuations in sand cover were observed at several sites, suggestive of seasonal sediment transport. Only 2 of the 18 monitoring sites had an increase in sand cover that persisted across seasons and was beyond that observed prior to the project. However, AMEC (2005) concluded that the increase in sand cover at those two locations did not appear to have any biological effects, as the cover or abundance of indicator species did not appear to be affected. The following target species were monitored: giant kelp (*Macrocystis pyrifera*), feather boa kelp (*Egregia menziesii*), surfgrass (*Phyllospadix* spp.), sea palms (*Eisenia arborea*), and sea fans (*Muricea* spp). AMEC (2005) also conducted monitoring of subtidal reefs that had kelp beds (see Section 3.2.6), and performed additional analyses of surfgrass cover and density on subtidal reefs compared to changes in sand cover (see Section 3.2.7).

Nearshore reef partially covered with sand.

Photo credit: Lawrence Homma, from AMEC 2005

Subtidal reefs with kelp beds were monitored before and quarterly for 1 year after the Goleta Beach Nourishment Demonstration project, which placed 79,000 cy of sand onto the beach and was followed by an additional project with 20,000 cy of sand placement (Moffatt & Nichol 2005c). Results indicated no obvious sedimentation impacts to kelp beds established on rocky substrate (Chambers Group 2004, see Section 3.2.6).

Burial and/or sedimentation impacts to hard substrate reefs as a result of beach nourishment projects have been reported for several projects on the east coast of the United States. Sedimentation and partial burial of low profile coral reefs resulted from beach nourishment off the Florida east coast (Courtenay et al. 1980 cited in Naqvi and Pullen 1982). Burial of coral reefs from previous dredge-fill projects off Broward County, Florida was reported by Goreau (2001).

A total of 12 to 14 acres (4.9 to 5.7 ha) of nearshore hard bottom was buried at Carlin Park, Florida from a 457,800 cy beach nourishment project, which extended the fill seaward

approximately 200 ft (60 m) seaward (Lindeman and Snyder 1998). Little to no hard bottom was observed 15 months after the project. A significant reduction in fish species and abundance was observed after the project compared to before. A 3.7 acre (1.5 ha) artificial reef was constructed as mitigation three years after the project.

Burial of nearshore hard bottom also was reported for beach nourishment projects at Anna Maria Island and Boca Raton, Florida; artificial reefs were required as mitigation for those projects (Coastal Planning & Engineering 2004a,b). A subsequent beach nourishment project at Anna Maria Island in 2002 did not indicate any obvious impacts to the nearshore hard bottom community from the 1.9 million cy project during the first two years after construction (Coastal Planning & Engineering 2004a). Hard bottom consisted of low relief (<1 to < 2 ft) limestone rock platforms in water depths ≤ 8 ft (≤ 2.4 m). Seasonal sand inundation of the low relief habitat in the nearshore zone was similar or less than pre-project levels. The ephemeral hard bottom communities were dominated by species that rapidly colonize newly available habitat (e.g., green algae, turf algae, hydroids), and included few invertebrates and fish. Improved water visibility, increases in macroalgae, more cryptic invertebrates, and fish were observed two years after nourishment compared to pre-project conditions (*ibid*).

Monitoring two years after a beach nourishment project at Boca Raton documented sand burial effects. However, the effects were attributed to movement of the substantial ebb tide shoal that forms from littoral transport around Boca Raton Inlet rather from the 343,000 cy South Boca Raton Beach Nourishment Project (Coastal Planning & Engineering 2004b). Sand inundation occurred to both natural hard bottom low relief and the newly constructed artificial reef, the placement of which was determined to have been too close to the inlet. The hard bottom areas included low relief reef (1 ft, 0.3 m) dominated by colonizing turf and coralline algae and higher relief reef (2 to 3 ft, 0.6 to 1 m) with a greater diversity of benthic organisms (macroalgae, sponges, tunicates, octocorals) and fish.

No sedimentation impacts to patch reefs occurring at depths of 35 to 70 ft (11 to 21 m) that could be attributed to borrow site excavation or placement of 500,000 cy from the Central Boca Raton Beach Nourishment Project were noted during and immediately post project compared to pre-project conditions (Coastal Planning and Engineering 2004c). Patch reefs ranged from low (~ 1 f, 0.3 m) to moderate (~ 3 ft, 1 m) relief, with greater occurrence of scleractinian corals associated with higher relief. Patch reefs were subject to consistent presence of sediment both before and after construction, with no apparent trend relative to project activities. .

<u>Turbidity</u>

Increases in turbidity during sediment management activities are of concern for vegetation and animals living on rocky subtidal reefs. These types of impacts are discussed in more detail for selected key species of vegetation in Section 3.3.6 and fish and invertebrates in Sections 4.2.9 and 4.3.6. The potential for impact to reef organisms relates primarily to proximity of dredging and/or discharge locations to hard substrate reef areas, methods used during dredge and fill operations, and duration of operations.

Available reviews and studies indicate that turbidity and sedimentation have been a concern for beach nourishment projects on the east coast (Pullen and Naqvi 1983, NRC 1995). Courtnay et al. (1972) provided qualitative summaries of ecological monitoring of coral reef

habitats after two beach nourishment projects off Florida. For one project, they reported negligible to no obvious differences between coral reef communities (i.e., corals, algae, sponges, burrowing mollusks, fishes) in the vicinity of a dredged borrow area and offshore from the beach fill site compared to non-affected reefs near the Pompano Beach and Lauderdale-by-the-Sea project.

For a second project off Hallendale, Florida Courtenay et al. (1972) reported no damage at inshore patch reefs that had received substantial turbidity due to rehandling of materials between the dredge and beach. However, substantial damage was reported for offshore patch reefs within a radius of 1,300 to 2,600 ft (400 to 800 m) of the dredged borrow area that included loss of algae, hard corals, and attached mollusks from turbidity/sedimentation, temporary movement of motile invertebrates (lobsters, crabs, shrimp) and fishes from the area (with some species of invertebrates absent from the area for 9 months), and evidence of physical damage to some patch reef formations from dredge equipment. The authors attributed the difference in impacts between the two projects to inadequate planning for the Hallandale project. They recommended that surveys of biological communities be conducted before and after dredging and beach nourishment projects so reef protection can be included in project planning and to assure recommendations are carried out, and that rehandling of fill material between borrow and beach areas be avoided wherever possible to reduce turbidity impacts.

Marsh et al. (1981) conducted a post nourishment study five years later comparing reef areas offshore Hallandale with reefs approximately 3,000 ft (900 m) away, and found no evidence of long-term effects on sand or reef communities from the beach nourishment project. They also reported that no evidence of the substantial damage to the outer reef reported by Coutenay et al. was found, stating that either the site of damage was not encountered or damage was no longer evident.

Recovery from Disturbance:

Recovery of rocky subtidal habitat from disturbance associated with sediment management activities would relate to degree of impact and organisms living in association with the reef. Generally, reefs with early successional species characteristic of low relief reefs naturally subjected to sand scour impacts would be expected to quickly recover. Reefs with slow growing sensitive species may require years to recover from substantial disturbance.

Disturbance to subtidal reefs due to anchoring and/or temporary pipeline placement activities could take < 1 year for minor disturbance to > 3 years if the impact resulted in substantial removal of slow growing species such as surfgrass or giant kelp (Sections 3.3.6, 3.3.7). Recovery of reef associated vegetation, fish, and invertebrates from turbidity impacts during sediment management generally would be expected to be rapid after cessation of operations (Sections 3.3.6, 4.2.9, and 4.3.6). However, impacts and recovery would be of concern if dredging and/or disposal operations in proximity to reefs occurred over extended periods that exceeded species tolerance thresholds.

Recovery from burial and/or sedimentation impacts would depend on reef height, depth of inundation, and oceanographic conditions. Sands do not remain static after placement in the littoral zone and would be subject to natural sediment transport dynamics. Obviously, nearshore placement of sands on subtidal reef habitat would bury reef habitat, the extent of

which would depend on placement volume and reef height considerations. The duration of burial would depend on these same considerations as well as oceanographic conditions.

Recovery of subtidal reefs from sedimentation associated with sand transport from a beach receiver site also would depend on reef height, degree of inundation, and oceanographic conditions. The significance of these impacts would depend on the degree of sand inundation, species affected, and affected reef functions.

Recovery from burial and/or sedimentation impacts would follow natural succession time frames that relate to reef characteristics and the type of assemblages those characteristics potentially support. For example, burial of low relief subtidal reefs that support reduced early successional assemblages would be expected to rapidly recover subclimax functions once substrate was exposed. Recovery of subtidal reef functions associated with reef complexity and diversity of species assemblages could take years to recover.

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	X	X	X		
Burial	X	X	X		
Sedimentation	X	X	X		
Turbidity	X				
Habitat Loss			X		

Critical Impact Thresholds:

Burial of reefs with sensitive resources and/or loss of habitat functions (e.g., shelter, occupied space) would be a significant ecological concern.

Data Gaps:

Limited information is available on effects of sedimentation and turbidity on rocky subtidal habitat.

Restoration:

Loss of sensitive rocky subtidal habitat due to persistent burial would require restoration to avoid significant impact to Essential Fish Habitat. Reef construction is considered technically and economically feasible with over thirty constructed in southern California by the CDFG since 1958 using a variety of materials, including quarry rock, concrete rubble, car bodies and steel structures, ships, and pilings/poles (Lewis and McKee 1989). Most of these reefs were constructed to attract fish and found to be very successful. Since the 1980's there has been more emphasis on design and construction of reefs to enhance a greater variety of marine resources and contribute to fish production. The CDFG pioneered a successful construction technique consisting of a number of separate modules that increased the total effective area of the reef (Ambrose 1986). Fish growth and production have been demonstrated at the Torrey Pines Artificial Reef, which is a module design off San Diego County, through various studies in the 1990s (DeMarini et al. 1994, Johnson et al. 1994).

Attraction versus production funtions of artificial reefs may be distinguished; however, comprehensive reviews have concluded that artificial reefs offer tremendous potential for habitat enhancement (Bohnsack and Sutherland 1985), and may be a feasible mitigation alternative for resource replacement (Ambrose 1994). Carr and Hixon (1997) suggest that artificial reefs with structural complexity and other abiotic and biotic features similar to those of natural reefs best mitigate in-kind losses. A few reefs have been constructed for mitigation (e.g., Long Beach Harbor, San Diego Bay) and mitigation design planning (Pendleton reef) in southern California. The largest mitigation reef (150 acres, 61 ha) in the United States is being built in phases using a module design off San Clemente in southern California. The first phase included construction of 22.5 acres (9 ha) of reef habitat in 1999, results of research studies will be used to guide the design of the remaining reef (www.sce.com/SC3/PowerandEnvironment/PowerGeneration/MarineMitigation/KelpReefProject.htm).

Summary:

Impacts from sediment management activities on sensitive rocky subtidal habitat have been documented. However, similar to the discussion for rocky intertidal habitat (see Section 3.2.4), the nature of concern varies depending on the site-specific nature of rocky subtidal habitat, which may range from ecologically rich to depauperate depending on substrate characteristics and degree of sand inundation.

In the nearshore littoral zone, reefs with heights that exceed the natural seasonal change in sand level support a greater variety of plants and animals. Vegetated subtidal reefs, particularly those supporting kelp, are some of the most productive of marine habitats (also see Section 3.2.6). Generally, seasonal sand level change decreases with increasing distance offshore within the depth of closure (Coastal Frontiers 2004). Consequently, the height of reefs that are above maximum seasonal sand level may vary depending on water depth and site-specific conditions.

Low-relief reefs, subject to seasonal sand burial, scour, and erosion may support few organisms (Ambrose et al. 1989, MEC 2000a, AMEC 2005). However, surfgrass, which is a habitat of special concern, may be associated with low relief reefs (Section 3.3.7).

Sediment management activities have the potential to impact rocky subtidal habitat and associated species, if present. Direct burial potentially could result from nearshore and/or profile placement. Equipment impacts from temporary pipeline placement and/or anchoring, could overturn rocks, damage, and/or disturb reef organisms. Equipment use in areas with cobble/boulder substrate and/or low relief, ephemeral reefs with few biological resources would have little potential for adverse impact.

Sand inundation and scour can substantially modify species assemblages, causing displacement of some mobile species and dominance by opportunistic, sand-tolerant, and/or sand-loving species. This disturbance naturally affects rocky subtidal habitats to varying degrees throughout California on a seasonal basis. Lower relief reefs are more vulnerable to sand disturbance, while higher relief reefs tend to remain above the sand. Impact concerns relate to the potential for indirect sedimentation occurring above natural levels and adversely impacting sensitive rocky subtidal habitat and resources.

Turbidity generally is a short term impact limited to the construction period. Substantial impact would not be expected with short term exposures similar to that experienced under natural storm conditions. However, prolonged exposure to turbid waters may be of concern. Relevant studies indicate prolonged turbidity reduces subtidal habitat diversity, with the most pronounced effect on marine plants and to a lesser extent, intertidal invertebrates.
Significant impacts to subtidal reefs from beach nourishment and/or borrow site dredging have been documened on the East Coast. Many of those impacts were considered to have been avoidable with adequate pre-project surveys and project design. Avoidance of direct disturbance of sensitive rocky subtidal areas has been incorporated into project design of several California beach nourishment projects. Pre-construction environmental surveys also have been used to finalize temporary pipeline placement and equipment use areas to minimize the potential for adverse impacts to sensitive rocky subtidal habitats and associated organisms. A key element of pre-project avoidance and minimization measures is appropriate evaluation of subtidal reef resources and ecological sensitivity.

Monitoring has been required for some beach nourishment projects when there was uncertainty regarding the potential for impacts. Creation of artificial reefs to compensate for burial of rocky subtidal reefs has been required for some beach nourishment projects on the East Coast. Creation of artificial reefs has been identified as a contingency mitigation measure for some California beach nourishment projects in the event significant impacts were identified from required monitoring; no significant impacts requiring reef construction have been identified for any California project to-date.

Sediment management activities represent a concern when sensitive rocky subtidal habitat is in the vicinity. Nelson (1989) made a case for caution when conducting beach nourishment in proximity to hard bottom habitats in Florida because of their ecological productivity and the unknown specific effects of borrow area dredging and fill placement on the vast majority of hard bottom flora and fauna. This caution also is appropriate for California where sensitive rocky subtidal habitat occurs. However, not all hard bottom areas are equivalent in ecological sensitivity; e.g., low-lying, ephemeral reefs in the littoral zone have poor resource development due to seasonal sand inundation and scour.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities to rocky subtidal habitat.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Documented	Documented	Documented	Documented
Critical Impact Thresholds	NA	Holdfasts removed, rocks overturned	Habitat loss	Degrade habitat, habitat loss	Vegetation loss
Impact Responses	NA	Damage, Disturbance	Reduce diversity, displace biota	Reduce diversity, displace biota	Disturb and/or harm biota
Duration of Impacts	NA	Days-months	Months-years	Months-years	Hours-months
Potential for Restoration	NA	Unnecessary	Demonstrated feasibility	Demonstrated feasibility	Unnecessary

NA = not applicable

3.3.6 Kelp Forest and/or Bed

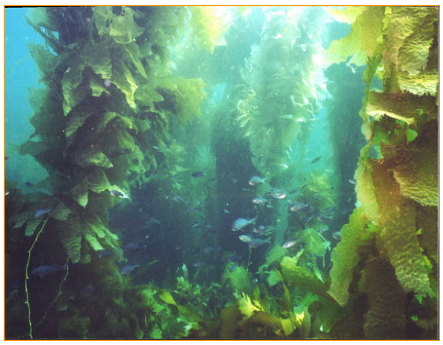


Photo credit: San Diego Nearshore Program; http://nearshore.ucsd.edu/

Regulatory Status:

CDFG Managed	X
Essential Fish Habitat	X
Other	Various protected habitat designations may apply

Kelp forests and beds may occur in designated Areas of Special Biological Significance, Ecological Reserves, Marine Life Refuges, Marine Sanctuaries, Underwater Parks, and may also occur in areas without special designation. All kelp forests and beds represent Essential Fish Habitat.

Giant kelp (*Macrocystis pyrifera*) and bull kelp (*Nereocystis luetkeana*) are managed commercial species, with harvest regulated within designated and numbered kelp beds (CDFG 2001). Other species of kelp have been collected on a small scale for commercial sale or home use such as wakame (*Alaria*) and kombu (*Laminaria*), which must be collected by picking or cutting without removal of the holdfast (CDFG 2001, Hillmann 2005). The intertidal sea palm (*Postelsia palmaeformis*) also has been collected, but its take is now restricted (CDFG 2001, 2005a). The daily recreational limit for taking of marine plants is 10 pounds wet weight in aggregate (CDFG 2005a).

Seven species of kelp may form surface canopies in California (Abbott and Hollenberg 1976, Foster and Schiel 1985). Giant kelp, bull kelp, and elk kelp may exceed 80 ft (25 m) in length and dense growths are commonly referred to as kelp forests due to their substantial vertical structure. Giant kelp and bull kelp are the most common deeper-water, kelp forest species in California.

Canopy-forming Kelps

Giant kelp (*Macrocystis pyrifera*)
Bull kelp (*Nereocystis luetkeana*)
Elk kelp (*Pelagophycus porra*)
Feather boa kelp (*Egregia menziesii*)
Macrocystis integrifolia
Bladder chain kelp (*Cystoseira osmundacea*)
Japanese Wireweed (*Sargassum muticum)*

Source: Foster and Schiel 1985

Feather boa kelp, bladder chain kelp, and Japanese wireweed (*Sargassum muticum*) form canopies in shallow waters and/or mix as understory kelps in inshore portions of giant and/or bull kelp kelp forests.

The terms kelp forest and kelp bed frequently are used interchangeably; for example, kelp forests subject to commercial harvest often are referred to as kelp beds (e.g., CDFG 2001). The term kelp forest sometimes is used to distinguish dense growths of larger canopy-forming species (giant kelp, bull kelp, and/or elk kelp) from beds of smaller kelp species with limited vertical structure and canopies (e.g., Bushing 2000).

Description and Distribution:

Giant kelp ranges from Alaska to Baja California, but form forests in southern and central California (to Santa Cruz) (Abbott and Hollenberg 1976, Foster and Schiel 1985). On exposed coasts, kelp forests usually occur from 16 to 65 ft (5 to 20 m), although they may range deeper around the offshore islands (Aleem 1973, Foster and Schiel 1985, North 1986). Records as shallow as 6.5 ft (2 m) are reported in some protected areas (Foster and Schiel 1985).

Habitat	California			On Land	Inter-tidal	Near-shore < 30 ft	Off shore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Giant kelp	X	X	X			X	X	E, P
Bull kelp		X	X				X	E
Elk kelp	X						X	E
M. integrifolia		X	X		X	X		E
Feather boa kelp	X	X	X		X	X		E, P
Bladder chain kelp	X	X	X		X	X		E, P
Japanese wireweed	X				X	X		P

Kelp plants include a holdfast, which anchors the plant to the bottom, stem-like stipes, and leaf-like blades that extend upward to the water surface (Foster and Schiel 1985, CDFG 2001). Stipes and blades, termed fronds, are supported in the water column by one or more pnematocysts (gas-filled bladders). Kelp plants derive energy from photosynthesis that occurs in the blades, and also uptake nutrients from the water; the holdfast serves no other function than anchoring the plant (Foster and Schiel 1985). The characteristics of holdfast, stipe, blade, and pneumatocyst are species-specific.

The giant kelp holdfast has several stipes with many moderate-length blades, each supported by a pnematocyst. Two varieties occur; the most common attaches to rocky substrate and develops a holdfast generally < 3 ft (< 1 m) in diameter. The other variety (sometimes referred to a *M. angustifolia*) has a much larger holdfast (up to > 6 to 10 ft, 2 to 4 m) for anchoring on sand (CCP 1982; D. Reed 2005, personal communication). Although living on sand, recruitment is still on solid surfaces (e.g., holdfasts, worm tubes, etc.) (Foster and Schiel 1985). Currently, the sand variety is limited to the Santa Barbara Channel. This variety once occurred from Dana Point to San Mateo Rocks, Orange County; but did not recover after the 1957-1959 El Niño event (W. North cited in Tegner and Dayton 1987).

Bull kelp ranges from Alaska to Point Conception, but is most common north of Carmel (Abbott and Hollenberg 1976). Plants are most abundant between 30 and 56 ft (10 to 17 m) along exposed coastlines. Bull kelp has a single pneumatocyst near the end of the stipe with a cluster of long blades above the pneumatocyst; stipes may reach 80 to 120 ft (25 to 36 m) (Abbott and Hollenberg 1976, Denny et al. 1997). Bull and giant kelp may form mixed forests in central California.

Elk kelp also has a large pneumatocyst from which two, branch-like stipes extend with huge blades (resemble antlers). The blades may not reach the surface. Elk kelp occurs in relatively deep waters > 100 ft (> 30 m) along the outer margins of giant kelp forests. It occurs in southern California around the southern Channel Islands and along the mainland in San Diego County. Elk kelp ranges south to Baja California.

Macrocystis integrifolia, which is closely related to giant kelp, may form thick canopies in shallow, protected waters from the low intertidal to depths < 26 ft (8 m) from Monterey north to Alaska (Foster and Schiel 1985). Unlike its relative the giant kelp, *M. integrifolia* grows to maximum lengths of 20 ft (6 m) in California (Abbott and Hollenberg 1976).

Feather boa kelp occurs throughout California along exposed and protected shores. Feather boa kelp may mix with giant kelp along the inshore portion of kelp forests, but more often forms sparse canopies inshore and may form extensive belts in the low intertidal (Abbott and Hollenberg 1976). Feather boa kelp may reach lengths of 16 to 50 ft (5 to 15 m). Feather boa kelp has numerous small blades and pneumatocysts along its stipe.

Bladder chain kelp occurs from the lower intertidal to depths of 32 ft (10 m) from Oregon to Baja California (Abbott and Hollenberg 1976). It may form monotypic stands in shallow water, and/or mix with other surface canopies along the inshore edges of kelp forests (Foster and Schiel). Generally, *Cystoseira osmundacea* is most abundant between depths of 13 to 26 ft (4 to 8 m) (Rais 2005). Bladder chain kelp may reach heights of 25 ft (8 m) and mean lengths of 40 ft (13 m) (Abbott and Hollenberg 1976, Rais 2003).

Japanese wireweed, which is an introduced species, may form dense stands in shallow, protected waters (Abbott and Hollenberg 1976). The species has been found from British Columbia to Baja California, primarily in embayments and in localized areas along the mainland and Channel Islands of California (Cohen 2005). This species is distinguished by its small, spherical float bladders. The main stems branch repeatedly to form a bushy plant of 3 to 13 ft (1 to 4 m), which may reach maximum lengths of

Elk kelp
Photo credit: Kathy DeWet-Oleson
http://sanctuaries.noaa.gov/

Feather boa kelp on sand
Photo credit: http://www.marine.gov/

Bladder chain kelp
Credit: Amber Rais http://www.mbari.org/

Japanese wireweed, San Franciso Bay
Credit: Andy Cohen
http://www.exoticsguide.org/

about 30 ft (10 m) in southern California (Abbott and Hollenberg 1976, Cohen 2005). Japanese wireweed occurs in low intertidal to shallow subtidal sites to approximately 6 ft (2 m) in San Franiciso Bay; in southern California it is common to 25 ft (8 m), although it has been reported deeper off Catalina Island presumably when water currents carried it out of its normal depth range (Cohen 2005).

Potential Functions Supported:

Giant kelp forests with their extensive vertical structure form the most extensive vegetated habitats in the marine environment. Kelp forests support nearly 1,000 species of algae, invertebrates, and fish, and offer forage opportunities for birds and marine mammals (Foster and Schiel 1985, Davis 2005). Kelp and several invertebrates (e.g., red abalone, lobsters, sea urchins, sea cucumbers) support commercial fisheries, and invertebrates and fish are taken by recreational fishermen and sport divers. Recreational and educational diving is prevalent in kelp forests and beds.

Associated Species	Primary Habitat	Forage Habitat	Spawning Nesting Habitat	Fisheries		Forage/ Prey
				Commercial	Sport	
Invertebrates	X	X	X	X	X	X
Fish		X	X		X	
Birds		X				
Vegetation	X			X		X
Mammals		X				
T&E Species		X				

The diversity of a kelp forest community relates to several factors including type and density of the canopy forming species, substrate type and complexity, and spatial extent of the kelp bed. Kelp forests and beds support a greater variety of marine organisms than kelp stands, which consist of a localized group of plants (Foster and Shiel 1985). Diversity generally is higher for kelp forests growing on hard substrate than on sand. For example, a hard substrate, giant kelp forest off Del Mar, San Diego County had > 130 species (few algae, 98 invertebrate species, 38 fish species (Rosenthal et al. 1974 cited in Foster and Schiel 1985). In contrast, 47 species (2 algae, 33 invertebrates, 12 fish) were observed in a giant kelp forest growing on sand-bottom off Corral Canyon in the Santa Barbara Channel, California (Chambers Consultants and Planners 1982).

Vegetation in kelp forests occurs in four different layers: kelp species forming surface canopies, understory kelps of the Orders Laminariales and Fucales, filamentous and foliose species, and encrusting species (Foster and Schiel 1985).

As previously mentioned, large stature species that form kelp forests include giant kelp, bull kelp, and/or elk kelp. Canopy-forming species in shallow waters, which may also function as understory kelps in giant and/or bull kelp forests include feather boa kelp, bladder chain kelp, and Japanese wireweed.

Other kelps, which do not form surface canopies and may be common understory species in kelp forests, include a variety of plants with fairly long stipes and species with short stipes and long blades. Common stipitate species that may extend over 3 ft (> 1 m) above the

substratum include southern sea palm (*Eisenia arborea*), winged kelp (*Pterygophora californica*), and *Laminaria setchelli* (Foster and Schiel 1985). Common short stipe species include *Laminaria farlowii, Agarum fimbriatum*, and *Costaria costata*. Some of these understory species (*Eisenia, Pterogophora*) may form dense subsurface beds or "groves" (Abbott and Hollenberg 1976), which can substantially affect recruitment of giant kelp and other algae (Foster and Schiel 1985).

Southern sea palm
Public domain credit: NOAA

Common turf algae in kelp forests and beds include a mix of brown (e.g., *Colpomenia, Desmerestia, Halidrys*) and red algae (e.g., *Gigartina, Gelidium*, *Plocamium*, *Pterospiphonia, Rhodymenia*) (Abbott and Hollenberg 1976, Foster and Schiel 1985). Articulated coralline algae (e.g., *Bossiella*, *Calliarthron*) and encrusting species (*Lithothamnium, Lithophyllum*) are very common on hard substrate.

Kelp forests provide habitat and food for a diverse array of invertebrates. Several hundred species of invertebrates have been reported from giant kelp and bull kelp forests, occurring in association with the substratum, kelp holdfasts, and as epiphytes on kelp blades (Foster and Schiel 1985). Some of the conspicuous and/or commonly observed species include abalone, crabs, California spiny lobster, giant keyhole limpet, octopus, nudibranchs, sea anemones, sea cucumbers, gorgonian sea fans, sea hares, sea stars, sea urchins, sponges, and tunicates. Generally, invertebrate variety and biomass in kelp beds increase with increasing depth (Aleem 1973).

Nearly 100 species of fish are associated with giant kelp forests in California (Feder et al. 1974). Species composition is similar among giant kelp and bull kelp forests; however, fish density and biomass are generally higher due to greater structural complexity in giant kelp forests (Bodkin 1986). Fish diversity increases with relief of the rocky substrate and presence of kelp (Quast 1968, Larson and DeMartini 1983, Foster and Schiel 1985). Generally, bottom relief greater than 3 ft (> 1 m) has little additional effect on fish diversity and abundance (Patton et al. 1985 cited in Cross and Allen 1993). Fish common to kelp forests include blacksmith (*Chromis punctipinnis*), California sheephead (*Semicossyphus pulcher*), garibaldi (*Hyosypops rubicunda*), gobies, greenling (*Hexagrammos* spp.), halfmoon (*Medialuna californiensis*), kelp bass (*Paralabrax clathratus*), giant kelpfish (*Heterostichus rostratus*), lingcod (*Ophiodon elongatus*), rockfish, (*Sebastes*), sculpins, senorita (*Oxyjulis californica*), and surfperch (e.g., *Brachyistius frenatus*) (Bodkin 1986, Ebeling et al. 1980, Foster and Schiel 1985).

Giant kelp may have a positive effect on the abundance of fish that use the habitat as a nursery ground and/or adult habitat; and may have positive or negative indirect effects on fish depending on their resource requirements related to understory algae (Hollbrook et al. 1990). For example, abundance of cryptic fish species is higher in the absence of giant kelp because of the increase in understory algae (Carr 1989).

Fish and invertebrates in kelp forests provide forage for marine birds and mammals. Cormorants feed on fish at mid-water depths within kelp beds, terns may pick small fish from the canopy by plunge diving, and gulls scavenge on the canopy surface (Foster and Schiel

1985). Kelp canopies also may be used as resting habitat by terns and gulls (Foster and Schiel 1985). Sea otters feed on invertebrates (e.g., sea urchins, abalone, clams, lobster, octopus, sea stars, snails) associated with kelp beds. The sea otter has been shown to have a significant influence in maintaining kelp forest communities, primarily by eating sea urchins. Other mammals such as sea lions, harbor seals, and whales use kelp forests as transitory foraging areas for feeding on fish (Foster and Schiel 1985, Connor and Baxter 1989).

Commercial harvest of kelp canopies has occurred off California since the early 1900's, and currently supports a wide range of food products, cosmetics, pharmaceutical, industrial applications, and food to aquaculture companies (Bakus 1989, CDFG 2001). Kelp harvesting also is used for the herring-roe-on-kelp fishery in San Francisco Bay (CDFG 2001). Commercial harvest of giant kelp involves the upper canopy and does not result in plant loss; in contrast, bull kelp harvest results in its loss (CDFG 2001).

Life History Facts:

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Spores	Year round, giant kelp recruitment peak in spring (March-May in southern CA and Apr-May in central CA). Bull, elk, and feather boa kelp recruit winter-spring. Bladder chain kelp recruit in spring.	Spring, Summer	None, but giant kelp canopy deteriorates late summer-fall in south southern CA, and winter in central CA	NA	Giant kelp (2-8 years), bull and elk kelp annuals, feather boa kelp (<1-few years)	Sessile

Laminarian kelps (e.g., giant kelp, bull kelp, elk kelp, feather boa kelp, and *M. integrifolia*) are characterized by two life stages (microscopic gametophyte and macroscopic sporophyte) (Abbott and Hollenberg 1976, Foster and Schiel 1985). Adult plants have special reproductive blades, sporophylls, which release spores that are dispersed with currents. Spores settle to the bottom and develop into microscopic male and female gametophyte plants, which produce sperm and eggs, and fertilized female gametophytes develop into sporophytes thus completing the life cycle.

Giant kelp has a prolonged period of reproduction, sporophylls may be observed on plants year round (Aleem 1973). However, sporophyte recruitment has been reported to be greatest in spring, March to May in the southerly range of southern California and April to May in the northerly range of southern California to central California (Foster 1975, Reed 2006 personal communication). Giant kelp sporophylls occur just above the holdfast, and spore dispersal generally is within 33 to 130 ft (10 to 40 m) due to spore settlement within hours to days (Shanks et al. 2003, Reed et al. in press). Dampened current speeds within kelp beds likely contribute to spore settlement near adults (Reed et al. in press). Current speeds within kelp forests may be two to three times slower than the surrounding water (Jackson and Winant 1983 cited in Murray and Bray 1993). Storms may represent a mechanism for more widespread spore dispersal due to spore resupension and transport by currents (Ebeling et al. 1985, Reed et al. 1988). Dislodged and drifting adults also disperse

spores, possibly providing opportunities for establishing the species in areas lacking attached kelp (North 1986). Giant kelp may grow up to 2 ft (0.6 m) per day and develop into full sized adults within 7 to 14 months (Neushul 1962, CDFG 2001).

Giant kelp is a perennial that may live up to 8 years, although 2 to 4 years is more typical (Lobban 1978, Dayton 1984, North 1986). Individual fronds survive 6 to 10 months (Lobban 1978, CDFG 2001). However, the canopy of kelp forests varies seasonally. In southern California, seasonal deterioration of canopy in late summer-fall occurs due to nutrient limitation and higher temperatures (Aleem 1973, Jackson 1977, Lobban 1978, Zimmerman and Kreme 1984, Foster and Schiel 1985). In central California, giant kelp forests are not similarly limited but they do undergo a regular seasonal canopy cycle with a maximum in summer and minimum in winter due to storm swells (Foster and Schiel 1985). Detached kelp fronds often are carried to beaches associated with fall and winter storms; kelp wrack supports a variety of invertebrates that provide forage for shorebirds (Foster and Schiel 1985, Duggan et al. 2003, 2004).

Bull kelp generally is an annual, although it may live up to 18 months (Abbott and Hollenberg 1976, Foster and Schiel 1985). Bull kelps produce sori on sporophyll blades between May and December (Abbott and Hollenberg 1976), and are synchronized in spore release, which is likely of adaptive advantage (Amsler and Neushul 1997). Bull kelp recruit in late winter-early spring, grow to full height by early summer, and reproduce and become senescent in late summer-fall (Denny et al. 1997). Elk kelp also develops sori on blades and is an annual species. Bull and elk kelps have rapid growth rates 0.3 to 0.6 ft (0.1 to 0.2 m) per day (Abbott and Hollenberg 1976, Denny et al. 1997).

Feather boa kelp functions as an annual in the intertidal, but is a perennial species (Black 1974, Gunnill 1980). Feather boa kelp have sporophylls intermingled with vegetative blades along the stipe (*ibid*). Feather boa may be reproductive year round (Abbott and Hollenberg 1976); however, sporophylls are most prevalent between November and April and recruitment mainly occurs between January and April (Black 1974, Gunnill 1980). Feather boa kelp grows rapidly and is reproductive within several months of recruitment (Black 1974, Gunnill 1980).

Cystoseira and *Sargassum* are members of the Order Fucales, which have one visible life stage. Reproductive organs develop within conceptacles, which are embedded at apices of vegetative branches (e.g., *Cystoseira*) or borne on special branches (e.g., *Sargassum*). They also display seasonal reproductive and growth characteristics. Bladder chain kelp bears reproductive fronds beginning in late spring that persist through the summer and are shed in late autumn, only the basal portion of the plant remains over winter (Rais 2003).

Japanese wireweed reproduces at different times related to temperature; in southern California, populations start becoming fertile in January and reach maximum fertility in April and May (Deysher 1984). Japanese wireweed is unique in being capable of self fertilizing; some embryos are released while the branches are still attached to the plant; others are transported with branches after they break off and disperse in currents and by wind drift (Cohen 2005). After reproduction, fronds become senescent and die back leaving the perennial holdfast and basal leaves (Deysher 1984).

Understory kelp also exhibit variable life spans. For example, Dayton et al. (1984) estimated that *Pterogophora californica* and *Eisenia arborea* may live > 10 years, and *C. osmundacea*

and *L. farlowii* generally live < 2 years, but a smaller percentage may live longer. Bottom-associated perennial red algae with rapid growth include *Pterospiphonia dendroidea* and *Rhodymenia californica,* and slow growing perennials include *Gigartina* spp. and *Gelidium robustum* (Foster and Schiel 1985). Common brown (*Desmerestia ligulata*) and red (*Plocamium cartilagineum*) algae are annuals.

Environmental factors such as available substrate, light, nutrients, temperature, and grazing affect giant kelp recruitment (Dean et al. 1983, 1984, 1989; Reed and Foster 1984, Foster and Schiel 1985). Murray and Bray (1993) identified that "recruitment windows" occur when temperatures are below 61.3^{o}F (16.3^{o}C) and light levels are suitable. Although recognized as an oversimplification, giant kelp is limited where irradiance is reduced to approximately 1 % of that at the surface (Foster and Schiel 1985). Near-bottom light levels typically are near that low light level due to a variety of light attenuating factors (e.g., cloud cover, surface canopy cover, understory canopy cover, phytoplankton blooms, storm turbidity) (Reed and Foster 1984, Foster and Schiel 1985, Murray and Bray 1993). Consequently, competition for available light is a major factor in determining community composition in giant kelp forests. Juvenile giant kelp exploit favorable conditions by rapid growth above lower stature species.

Light thresholds for different life stages of giant kelp were estimated from field and laboratory studies based on measurements of photon flux energy of Photosynthetic Active Radiation (PAR) reported in units of Einsteins/area/time. Relationships are step functions, with a minimum threshold (compensation) below which the function does not occur and an upper threshold (saturation) above which additional irradiance produces no additional effect. Approximate minimum (compensation) thresholds are 0.2 to 0.25 m^{-2} d^{-1} for gametogenesis, 0.4 E m^{-2} d^{-1} for sprophyte production, 0.4 to 0.9 E m^{-2} d^{-1} for juvenile growth, and 0.1 E m^{-2} d^{-1} for adult growth (Neushul and Haxo 1963, Dean and Jacobsen 1984, Deysher and Dean 1984, Dean 1985, Deysher and Dean 1986). Saturation thresholds are 0.8 E m^{-2} d^{-1} for sporophyte production, 1.8 to 3 E m^{-2} d^{-1} for juvenile growth, and 10 E m^{-2} d^{-1} for adult growth (*ibid.*). As a point of reference, 1 % surface irradiance approximately equals 0.2 E m^{-2} d^{-1} (Foster and Schiel 1985).

Species composition and diversity in giant kelp forests vary considerably among different locations due to physical differences such as nature and profile of substratum, wave exposure and surge, sand scour, turbidity, temperature, and sometimes nutrients (Dayton et al. 1984, Foster and Schiel 1985, North et al. 1986, Murray and Bray 1993). Some kelp forests also display considerable within-bed patch variability that relates to biological relationships (competition, dispersal, grazing pressure) and various disturbances that create open space (Foster 1975, Dayton et al. 1984). Reviews point out considerable variety in giant kelp forests among different locations (Foster and Schiel 1995 and Murray and Bray 1993), indicate that each kelp forest is a unique reflection of its site-specific physical and biological characteristics and disturbances.

Substantial interannual variability also characterizes giant kelp forests. Notable recruitment of giant kelp sporophytes is highly variable and may occur on the order of every few years, often following catastrophic events, such as major storms, El Niño and Southern Oscillation (ENSO), and atypical grazing (Ebeling et al. 1985, Reed 1990, Murray and Bray 1993, Reed et al. 2004). Reed et al. (in press) reviewed a 34-year time series of monthly aerial surveys and determined that southern California patches underwent frequent "extinctions" (defined as no surface canopy for > 6 months) and recolonization that occurred over time scales

ranging from several months to as much as 13 years, with most recolonization occurring within less than two years. Organisms that recruit to living habitat such as kelp forests can be substantially influenced by this variability in kelp development (Carr 1994).

Adaptations and/or Behaviors to Disturbance:

Giant kelp's life history traits as a perennial with high reproductive output, limited spore dispersal, and fast growth rates under favorable conditions likely contribute to its success as the competitive dominant of kelp forest habitat (North et al. 1986). High reproductive output and rapid growth also characterize other canopy-forming kelps.

Several species of kelp have morphological adaptations that help them survive wave stress. Well developed holdfasts anchor giant kelp. Bull kelp is extremely resistant to breakage from water drag and tend to "go with the flow" as adults, and their more vulnerable younger stages quickly grow up during a period when wave climate is generally less (Denny et al. 1997). Feather boa kelp also is resistant with a low drag coefficient due its strap-like morphology and high degree of flexibility (Friedland and Denny 1995). The seasonal shedding of canopy fronds by bladder chain kelp is thought to reduce vulnerability to wave stress during winter storms (Rais 2003). The common undertory kelp *Eisenia* was found to be highly tolerant of wave stress, whereas *Pterogophora* was more vulnerable to stipe breakage and/or holdfast dislodgment (Gaylord and Denny 1997).

Life Stage	Physical Adaptation			High Reproductive Output and/or Growth
	Long Blades	Flexible Stipes	Holdfast	
Adult	X	X	X	X
Juvenile	X	X	X	X
Seed				X

Dayton et al. (1984) recognized four basic adaptations of algae in kelp communities with exploitation of light enhanced at higher canopy levels and tolerance of physical stress from wave surge and grazing at lower canopy levels. Giant kelp was identified as adapted to "exploitive competition" for light and nutrients. Bull kelp with its annual life history was considered a ruderal or opportunistic species; this category also would apply to elk kelp. Smaller (understory) *Cystoseira, Dictyoneurum, Eisenia, Laminaria,* and *Pterygophora* were identified as being adapted to physical stress especially wave stress; this category also would apply to *Egregia*. Coralline algal pavement, *Agarum, Codium*, and *Desmerestia* (cells contain acid) were identified as grazer-tolerant.

Abiotic and biotic factors responsible for substantial disturbance and/or population fluctuations of kelp communities include water motion from winter storms, sedimentation and sand scour, turbidity, and grazing (Foster and Schiel 1985, North 1986). During ENSO conditions, giant kelp may succumb to extreme storm effects, nitrogen limitation, temperature stress, and/or atypical grazing pressure (Dean and Jacobsen 1986, Tegner and Dayton 1987). Substantial grazing pressure unrelated to El Niño, most notably by sea urchins also can substantially disrupt kelp communities on a local scale (Ebeling et al. 1985, Harrold and Reed 1985). Response of giant kelp and other canopy-forming kelp to physical and biological disturbance factors are reviewed below, with greater emphasis given to

factors relevant to sediment management activities. Response to El Niño is treated in more detail at the end of this section.

Response of kelp to water motion disturbance provides some insight to tolerance to physical disturbance. Giant kelp is vulnerable to impacts involving entanglement of fronds and dislodgement associated with storm surge and swell, which are the primary causes of mortality (Dayton et al. 1984, Dayton and Tegner 1984, Ebeling et al. 1985, Foster and Schiel 1985, Seymour et al. 1989).

Giant kelp may be affected by turbidity, particularly early life stages. Effects of cloudy days or turbid water are less for adult giant kelp since the fronds are near the surface than for life stages near the bottom (e.g., cloudy days may affect kelp productivity but not survival of adult plants) (North 1986). Giant kelp does not store sufficient carbon and nitrogen to sustain growth when light limited for extended periods. Dean and Jacobsen (1984) noted that adult giant kelp probably store only a two-week supply of nitrogen and juveniles may have less storage capacity (cited Wheeler and North 1981, Gerard 1982). In contrast, some species of *Laminaria* have reserves that enable continued growth during extended periods of low irradiance or nitrogen availability (cited Chapman and Craigie 1978, Luning 1979).

Substrate type may influence water clarity in kelp beds. Dean (1985) found changes in water clarity related to vertical sediment flux in a kelp bed where the substrate was a mix of cobble and sand off San Onofre, California. He suggested that effects of resuspended sediment may be more important in mixed substrate beds compared to more consolidated reef outcroppings.

There is some evidence that kelp bed characteristics (e.g., structural development) have the potential to influence turbidity and sedimentation effects. Eckman et al. (1989) showed there was weaker fluid transport and greater particle deposition beneath canopies of understory algae. Additionally, the understory kelps inhibited transport of suspended particles from the overlying water column to the bottom. Thus, the higher rates of deposition beneath the canopies probably were caused by longer particle residence times and higher probabilities of redeposition beneath the canopies and not by higher rates of particle import. These results suggest that kelp forests with well developed understory species may be less susceptible to short term turbidity exposure than sparser developed kelp beds. However, exposures to turbidity that overcome shielding by understory algae could be cumulatively deleterious from the increased probability of becoming trapped within the beds due to algal dampening of near bed hydrodynamics.

Effects of turbidity on kelp beds also may be more pronounced in protected waters. North (1986) reported that light sedimentary deposits are detrimental to giant kelp blades, which may disintegrate after a few weeks of coverage, such as may occur in quiet waters of bays and inlets where scrubbing action by wave surge is lacking.

Wastewater and power plant discharges that result in chronic turbidity and redistribute sediments have been associated with adverse effects to kelp beds and associated communities (Murray and Bray 1993, CDFG 2001). Several studies conducted in the vicinity of the San Onofre Nuclear Generating Station (SONGS) provided evidence of adverse impacts associated with increased particulate loads. Increased seston (particulates) and lower irradiance resulted in reduced recruitment leading to an overall 60% reduction in a kelp bed as a result of operation of SONGS (Bence et al. 1989). The relative importance of

increased near bottom sedimentation versus reduced irradiance on survivorship of early life stages was not determined; however, the overall average decrease in near bottom irradiance ranged between 0.21 and 0.27 E m^{-2} d^{-1}. Adverse effects on the kelp bed invertebrate community also were demonstrated (Schroeter et al. 1993) (see Section 4.2.9).

Foster and Schiel (1985) recounted that changes in sediment cover may have been responsible for some of the historical changes in the areal extent of kelp forests in the vicinity of San Onofre, Orange County, and substantial sand inundation from land erosion was responsible for destroying kelp forests off San Miguel Island in the 1800's. Dayton et al. (1989) reported substantial impacts to kelp, encrusting algal communities, and invertebrates from damage to subtidal reefs due to extreme waves associated with an approximate 200-year event storm off San Diego in 1988.

Some of the other canopy-forming species of kelp are considered more tolerant of sedimentation effects than giant kelp. AMEC (2005) reported that feather boa kelp occurrence on low relief reefs (< 3 ft, < 1 m) with interspersed sand patches suggests tolerance of moderate amounts of sand burial. Intertidal plants frequently have the base of the plant buried in sand. North (1986) reported that the basal stipes of *Eisenia* and *Pteryogophora* seem more resistant to burial than giant kelp. AMEC (2005) suggested *Eisenia* and *Pterygophora* as probably being less tolerant of sedimentation than feather boa kelp due to their occurrence on higher relief nearshore reefs monitored in San Diego County.

Several reports of landslide effects are reviewed below that describe responses of kelp communities to sedimentation impacts, ranging from decreased density, altered species composition, to multi-year loss.

Sedimentation impacts to bull kelp beds associated with the Lone Tree landslide, northwest of San Francisco, northern California, indicates impact to this species but limited impact to other species. This landslide was gradual, but became more acute following the 1989 Loma Prieta earthquake (Komar 1997). Approximately 1,308,000 cy of material covered an area extending 115 ft (35 m) over the position of the natural beach at the toe of the slide, and extended 200 to 230 ft (60 to 70 m) seaward of the former beach. In 1991 another landslide occurred resulting in 760,000 cy of soil and rock being moved more than 200 ft (60 m) into the intertidal and subtidal environments (Konar and Roberts 1996). Algae were surveyed at water depths of 23 ft (7 m) at sites within a turbidity plume caused by wind and wave action and in nearby unimpacted kelp beds in 1990, 1992, and in 1993. Similar total numbers of species were observed at impacted sites (4 brown and 16 red algal species) and unimpacted sites (5 brown and 16 red algal species) over time (Konar and Roberts 1996). Few differences were noted in species composition, with a few notable exceptions. Bull kelp formed a surface canopy at the unimpacted site, but did not occur at the impacted site. Understory species such as feather boa kelp (*Egregia*), bladder chain kelp (*Cystoseira*), *Laminaria*, and winged kelp (*Pterogophora*) were observed at both areas. Thin foliose and coralline red algae dominated the bottom layer at both sites. A few red alage (*Bossiella, Microcladia, Neoptilota*) were only at the unimpacted sites, while *Dilsea, Fauchea,* and *Gelidium* were only at the impacted sites. The density of brown algae was somewhat less at the impacted site.

In central California a landslide moved nearly 5,228,000 cy of soil approximately 246 ft (75 m) into the marine environment off Big Sur during and after a major slide in 1983 (Konar and

Roberts 1996). Algae were surveyed at water depths of 23 ft (7 m) at sites within the landslide plume caused by wind and wave action and in nearby kelp beds outside the plume in 1991, a period when the landslide was considered stable but suspended sediment plumes extended in front of the slide. Species numbers were similar at both impacted (5 brown and 10 red algal species) and unimpacted (5 brown and 7 red algal species) sites. Species composition also was similar, but density of giant kelp was less and percent cover of encrusting coralline algae was greater at plume impacted sites.

A substantial impact to the Barn Kelp bed (local name) in north San Diego County, southern California, occurred from storm triggered creek runoff and a landslide and cliff erosion that deposited enormous amounts (unquantified) of sediment offshore, creating a series of offshore sand bars between 1978 and 1980 (Bence et al. 1989, Kuhn and Shepard 1984, Schroeter et al. 1993). Sand movement into the giant kelp bed was localized, but a fine layer of sediments covering kelp fronds and hard substrate was widespread throughout the bed in the summer of 1980 (Bence et al. 1989). Substantial reduction leading to loss of the kelp bed was observed between the summer and fall of 1980. The authors considered the loss of the kelp bed probably the result of recruitment being inhibited by sedimentation, and perhaps also by an increase in the mortality rate of adult plants. It was seven years before substantial recovery of kelp canopy at the surface was noted, and the authors suspected that earlier recovery was probably prevented because no local source of spores remained. Although not mentioned by the authors, it is also possible that El Niño conditions, which substantially reduced kelp beds throughout southern and central California between 1982 and 1984, may have slowed recovery.

In an area of continuing landslide activity off Palos Verdes, southern California, the Portuguese Bend area supports only sparse occurrence of giant kelp in contrast to other areas along the Palos Verdes Peninsula (Pondella et al. 1996). Comparison of the landslide affected site (Portugese Bend) with partially affected (Abalone Cove) and unaffected (Palos Verdes Point) sites showed substantial differences in kelp cover and evidence of sedimentation. Areas within the center of the slide area were devoid of kelp, and one of headland areas bordering the slide area had sparse occurrence of kelp (0.2 plants per square meter) at 30 ft (9 m); fewer kelp were observed at 20 ft (6m), and none were observed at 40 ft (12 m). Bottom substrate was a mix of rock and sand, and silt was visible along all transects surveyed at depths between 20 ft (6 m) and 40 ft (12 m). Understory kelp, including bladder chain kelp and southern sea palm were also observed at one of the headland sites. Abalone Cove had a low density of kelp with much of the bottom being sand, and sand was evident on top of the rocks. Palos Verdes Point had a substantial kelp bed that increased in density (0.16 to 0.36 plants per square meter) from 20 to 40 ft (6 to 12 m) depths. Understory kelp were common, including southern sea palm, bladder chain kelp, and feather boa kelp.

Oceanographic conditions associated with El Niño conditions, including reduced nutrients, higher temperature, and/or storm episodes with large swells, resulted in widespread reductions in kelp beds in southern California in 1957-1959 and throughout California in 1982-1984 (Tegner and Dayton 1987). Recovery of plants appeared to be retarded by the warm, nutrient poor water. In the 1990s there were two additional El Niño events, 1992-1994 and subsequent storms, and 1997-1998 with substantially warmer temperatures. During the 18 year period from 1981 to 1998, sea surface temperatures exceeded the previous 60-year mean in all but a single year (1988) (CDFG 2001). Kelp beds throughout California exhibited a 56% reduction from 40.7 to 17.8 square miles (65.1 to 28.5 square

hectares) between 1989 and 1999 (*ibid*.). Most kelp beds have exhibited substantial recovery from the El Niños of the past two decades, however, the storm-related loss of giant kelp from sandy substrates offshore Santa Barbara during the 1982-1984 El Niño has not substantially recovered in the intervening 20 years (D. Reed 2005, personal communication). Recoveries of these beds were predicted to be slow due to the loss of holdfasts, which represent important recruitment sites for the plants (Tegner and Dayton (1987).

Atypical over-grazing by sea urchins and/or amphipods also may occur with substantial disturbance to kelp. Sea urchins normally feed on drift algae, however, when it becomes limiting urchins may form large aggregations termed "fronts" that together may denude an area of kelp and macroalgae and continue to keep the area barren by grazing new recruits (Dean et al. 1984, Ebeling et al. 1985, Harrold and Reed 1985). Development of sea urchin fronts may be a secondary effect of disturbance to food supply initiated by storms and/or El Niño conditions, and/or due to sea urchin populations increasing as a result of reduced predation and then outstripping their normal food supply (Tegner and Dayton 1987).

Sea urchin grazing substantially affected recovery of a kelp bed severely disturbed by storm swells at Naples Reef in 1980, but the 1983 El Niño storms caused a reversal when exposed urchins were decimated by that storm allowing subsequent successful recruitment and growth of giant kelp (Ebeling et al. 1985). Sea urchin fronts have been reported to varying degrees after El Niño events. Sea urchin fronts had localized impacts on kelp beds in association with the 1982-1984 El Niño with reports at kelp beds off the Channel Islands, Palos Verdes, and San Onofre (Dean et al. 1984, Tegner and Dayton 1987). Sea urchin grazing delayed recovery of many coastal kelp forests in southern California after the 1957-1959 El Niño (North and Pearse cited in Tegner and Dayton 1987). Outbreaks of amphipods caused substantial grazing damage in recovering kelp beds in 1985 at several locations in southern California (Santa Barbara, Point Dume, Point Loma), presumably due to a reduction in populations in kelp surf perch (Tegner and Dayton 1987).

Potential Impacts from Sediment Management Activities – Kelp:

Types of sediment management activities and potential impact factors to kelp bed habitat include:

- Maintenance dredging of embayments – turbidity.
- Offshore borrow site dredging – equipment, turbidity.
- Nearshore placement – equipment, burial, sedimentation, turbidity.
- Profile placement – equipment, burial, sedimentation, turbidity.
- Beach placement – sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity Indirect	Indirect Sediment Transport
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging		A	A	A	A	A
Growth			A, P	A, P	A, P	A, P
Habitat			X	X		X
Reproduction		A	A, P	A, P	A, P	A, P
Respiration					A	

A = associated animals, P = plants, X = substrate

Equipment

Noise and activites associated with equipment use may displace mobile animals. Indirect attraction and/or displacement may occur as a result of lights during night-time operations (Section 5.3). Transit of dredge vessels and workboats and anchoring associated with offshore dredging of sand borrow areas, nearshore or profile placement, and/or pipeline placement to convey sands to the beach from offshore hopper vessels have the potential to reduce kelp if the bed is not avoided. A relevant example includes a report of canopy damage and dislodgement of holdfasts due to vessel traffic and anchoring associated with pipeline construction in Santa Barbara in the 1980s (Chambers Group 1982). Heavy vessel traffic alone may result in reduction in adult giant kelp density and an increase in juvenile kelp and understory red algae (North 1957 cited in Foster and Schiel 1985).

The concern with vessel impacts is not so much associated with the potential for canopy cutting since intact fronds would be expected to recover by vegetative regrowth similar to what occurs after commercial harvesting. Instead the concern is dislodgement of holdfasts either indirectly from vessel entanglement and pulling of fronds and/or directly from anchors and/or anchoring cables. The significance of such impacts not only would depend on the degree of impact, but also on the variety of giant kelp affected.

Giant kelp rapidly grows above lower stature species under conditions of “scramble competition” when hard substrate patches become exposed within an existing giant kelp bed (Dayton et al. 1984, Reed and Foster 1984, Tegner and Dayton 1987). Therefore, equipment related impacts to kelp established on hard substrate would be expected to be adverse, but not significant provided the impact was localized. In contrast, equipment related impacts to the variety of kelp that occurs in sandy substrate in the Santa Barbara Channel could be significant if holdfasts, which represent a primary site of recruitment, were damaged. In this case, the potential for recovery would be uncertain.

Damage to reef habitats by offshore equipment can be avoided by pre-construction surveys to identify mooring, anchor, and pipeline locations as well as vessel access routes that avoid sensitive habitat. For example, prior to the Goleta beach nourishment project an underwater survey was conducted to identify pipeline and mooring locations that would avoid significant subtidal habitat (Moffatt & Nichol 2005b).

Burial/Sedimentation

Foster and Schiel (1985) reported that while coastal construction usually does not directly impact offshore kelp forests, turbidity and sedimentation could have indirect impacts but these effects have not been documented as they are often impossible to separate from natural changes associated with varying oceanographic conditions, storm intensity, and terrestrial runoff. Similar considerations apply to sediment management activities associated either with offshore dredging and/or nearshore or beach disposal of sandy sediments, which result in elevated turbidity within the expected range of values observed under natural conditions.

Based on distribution of kelp forests and beds, nearshore and/or profile placement have the potential to directly impact this habitat, if present. Indirect sedimentation impacts may be a potential concern with any placement method depending on project and site specific characteristics. Giant kelp and bull kelp forests generally occur at depths outside the beach depth of closure; however, the inshore portion of the kelp forest may extend into inshore waters during years without major storm disturbance. Other kelp beds may occur in deeper or shallower waters depending on species. Burial and/or sedimentation impacts have the potential to scour and increase mortality of adults and juveniles, and reduce the survivorship of microscopic life stages.

Movement of sediment and scour can adversely affect all life stages of giant kelp depending on degree of impact (Foster and Schiel 1985, North 1986, Murray and Bray 1993). Aleem (1973) reported that accumulation of sand on juvenile kelp retards their development. North (1986) pointed out that the thin sedimentary deposits that may bury microscopic stages of giant kelp are ineffective against larger plants; however, damage to juveniles and adults were observed with major sedimentary shifts. Partial burial of holdfasts of the sand-living variety of giant kelp does not adversely affect the holdfast; however, burial of the primary or secondary stipes at the holdfast apex can lead to rot of the stipes in a few days (North 1986).
Laboratory study has shown that sediment cover of as low as 10 mg/cm^2 over substrate before spores are introduced or 108 mg/cm^2 (450 μm thick) of sediment over spores reduces gametophyte survival by 90% (Devinny and Volse 1978).

Several studies have documented impacts to kelp forests and beds from large scale pulses and/or chronic sedimentation associated with landslides (Bence et al. 1989, Konar and Roberts 1996, Pondella et al. 1996).

No impacts to kelp beds from beach nourishment have been identified in California. The 2001 San Diego Regional Beach Sand Project involved placement volumes ranging from 101,000 to 245,000 cy on beaches where kelp beds occurred offshore. No adverse sedimentation was measured within monitored kelp beds over four years of post-construction surveys compared to pre-project conditions, and giant kelp persistence and recruitment increased throughout the region after sand placement probably in response to oceanographic conditions (AMEC 2005).

Kelp beds were monitored before and quarterly for 1 year after the Goleta Beach Nourishment Demonstration project, which involved a total placement of 97,600 cy on the beach from that project and an addtitional source (Moffatt & Nichol 2005c). Results indicated no increase in sand cover within monitored kelp beds and observed changes in

kelp density were related to impact and recovery to winter storms similar to what was observed at control monitoring locations in the vicinity (Chambers Group 2004).

Turbidity

Giant kelp and bull kelp are canopy forming species; therefore, adult plants are tolerant to changes in light levels but early life stages near the bottom are sensitive (Foster and Schiel 1985). Approximate minimum (compensation) thresholds are 0.4 E m^{-2} d^{-1} for sprophyte production and 0.7 E m^{-2} d^{-1} for juvenile growth (Neushul and Haxo 1963, Dean and Jacobsen 1984, Deysher and Dean 1984, Dean 1985).

Giant kelp, bull kelp, and a number of other understory species of kelp are sensitive to chronic turbidity and/or sedimentation. Giant kelp does not store sufficient carbon and nitrogen to sustain growth when light limited for periods more than a couple of weeks (Dean and Jacobsen 1984). Giant kelp and bull kelp were absent and other species of algae often were reduced from areas of ongoing and stable landslides where sediment resuspension resulted in chronic turbidity plumes and/or sedimentation (siltation) was observed (Konar and Roberts 1986, Bence et al. 1989, Pondella et al. 1996).

Turbidity associated with beach nourishment and/or offshore dredging of borrow areas has the potential to adversely affect kelp recruitment and/or juvenile growth depending on proximity of operations to kelp forests, duration of impact related to project size, sediment characteristics of the dredged or discharged material, and current speed and direction. Dredging in embayments has the potential to affect kelp, if present.

Buffer distances have been recommended to minimize potential impacts from turbidity, with distances ranging from 350 to 500 ft (100 to 150 m) (MEC 2000a) to 1,000 feet (300 m) (Chambers Group 1992). The distances were specified based on consideration of sediment characteristics and site-specific conditions.

Recovery from Disturbance

Acting alone or in concert, several different abiotic and biotic factors are responsible for small scale to widespread mortality of giant kelp forests. Recovery times may be equally complex, depending on patch size (i.e., area of kelp), proximity of adult plants, spore dispersal, oceanographic conditions, and grazing pressure. Recovery of giant kelp forest may range from several months to as much as 13 years, with most recolonization taking less than two years (Reed et al. in press). Recolonization occurs when favorable conditions of light, nutrients, and primary space coincide with periods of abundant spore supply (Deysher and Dean 1986, Reed 1990), all of which are most likely to co-occur in winter and spring (Reed et al. in press). Patch size and degree of isolation of kelp patches influence loss and recovery. Probability for loss increases with decreasing patch size and degree of isolation, and recolonization probabilities increase with increasing patch size and proximity to other patches (Reed et al. in press).

Hard substrate areas that become cleared within a kelp forest become sites for new recruitment. Giant kelp often is the successful competitor when adults are nearby due to the area being swamped by spores and juveniles quickly outshading the competition because of their high growth rate (Dayton et al. 1984, Foster and Schiel 1985). However, small *Macrocystis* and other laminarians appear to recruit poorly on substrata thickly covered by

encrustations of coralline algae and animals when compared to non-encrusted surfaces (North 1986).

Ebeling et al. (1985) reported extensive recovery of giant kelp, from recruitment to maturity, in less than 1 year from a substantial storm that cleared sea urchins previously responsible for entire loss of the kelp forest and most living vegetation at Naples Reef.

Recovery from catastrophic impacts associated with El Niño oceanographic conditions and secondary effects such as grazing pressure were on the order of 10 years between the 1950s and 1960s and 20 years with the multiple El Niño events spanning the 1980s and 1990s for the hard substrate variety giant kelp (Tegner and Dayton 1987, CDFG 2001).

Recovery of the sandy bottom variety of giant kelp from catastrophic loss is uncertain. This variety used to occur in Orange County in southern California, but still has not recovered from the 1957-1959 El Niño and kelp forests of this variety have not recovered in the Santa Barbara Channel since the series of El Niño events between the 1980s and 1990s (Tegner and Dayton 1987; D. Reed 2005, personal communication).

Bull and elk kelp are annual plants that naturally recruit every year from spores released from the previous generation (Abbott and Hollenberg 1976, Foster and Schiel 1985). Feather boa kelp is a perennial that may function as an annual in the intertidal (Black 1974).

Recovery from disturbances associated with sediment management activities would vary depending on the type of impact. Recovery from turbidity disturbances would be expected to be rapid (< 1 year) given the short term and transient nature of the impact.

Recovery from equipment damage and/or sedimentation impacts could range from < 1 year for minor damage and/or sedimentation that did not persist more than a season. For larger scale damage and/or persistent sedimentation impacts resulting in habitat loss, recovery could be on the order of years. Successful recolonization of deforested areas is a multi-step process that involves spore recruitment and survival, successful competition over other colonists, survival of grazing pressure, and favorable oceanographic conditions for growth, survival, and subsequent reproduction (Reed et al. in press).

	Recovery Rates				
Impact	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	H	H	H	S	
Burial	H	H	H	S	
Sedimentation	H	H	H	S	
Turbidity	H, S				
Habitat Loss		H	H	S	

(H = hard substrate kelp variety, S = sandy substrate kelp variety)

Critical Impact Thresholds:

A light level of approximately 1% of surface irradiance (PAR of approximately 0.2 E $m^{-2}d^{-1}$) limits the distribution of giant kelp. Available information indicates that chronic reduction of near bottom light levels to less than 2% of surface irradiance can result in loss of giant kelp habitat (Bence et al. 1989). Light levels near compensation thresholds are not sufficient to protect kelp values. Light levels near saturation may be more precautionary. Because adult

giant kelp is rarely affected by turbidity due to surface canopy, juvenile growth and recruitment are more appropriate to consider with respect to protecting kelp bed habitat. The light saturation thresholds for juvenile growth range from approximately 9 to 15% of surface irradiance (1.8 to 3 E m^{-2} d^{-1}); the saturation level for recruitment is lower (01.8 E m^{-2} d^{-1}).

Although adult and juvenile kelp plants may withstand some sedimentation, recruitment is adversely affected by thin sediment layers (Foster and Schiel 1975, Devinny and Volse 1978, North 1986). Burial of attachment substrate would be of ecological concern.

Data Gaps:

Recovery rates of the sandy substrate variety of giant kelp are unknown. Critical thresholds associated with sedimentation under field conditions are not well understood.

Restoration:

If impacts resulted in loss of kelp bed habitat, it should be possible to mitigate the loss through habitat creation (e.g., artificial reefs) that provides appropriate substrate and structure to replace lost habitat and functions. Various methods have been used to increase giant kelp abundance and survival in areas, to repopulate disturbed areas, or to introduce populations to newly created substrates (Foster and Schiel 1985, Ambrose 1986, CDFG 2001). Microscopic sporophytes have been grown with success in the laboratory and used to "seed" areas, juvenile plants have been grown and outplanted, adult plants from healthy beds have been used as source material for transplanting elsewhere, and strategies for controlling sea urchin densities have been developed.

Although there is a long history of kelp restoration efforts dating from the 1960s, not all projects have been successful and research is ongoing. Results of monitoring the recently completed 22.5 acre artificial reef offshore San Clemente will be used to complete another 127.5 acres of planned reef construction and provide valuable information for future restoration efforts (www.sce.com/SC3/PowerandEnvironment/PowerGeneratin/MarineMitigation/KelpReefProject.htm). Restoration efforts are continuing in the Santa Barbara Channel to assist recovery of the sandy substrate variety of kelp (D. Reed 2005, personal communication). Ultimate success of that effort will not be known for several years.

Summary:

Kelp forests and beds are ecologically sensitive habitats supporting diverse marine life, commercial fisheries, educational, and recreational values. These habitats are dynamic environments characterized by predictable (seasonal) and unpredictable (storm, El Nino, grazing) variability of occurrence. Therefore, kelp canopy may or may not be present when sediment management activities are scheduled. Although many functional values are tied to the presence of kelp canopy, habitat values persist in the absence of canopy (e.g., understory and bottom-dwelling algae, invertebrates, and cryptic fish species). Consequently, evaluations of the potential to impact these habitats from sediment management activities should take into account the potential for habitat occurrence based on available suitable substrate and historic occurrence rather than just surface canopy.

Significant impacts to kelp forest and kelp bed habitats have not been documented for the few sediment management projects that have been conducted in the vicinity of this habitat in California. Therefore, the basis of concern for impacts from sediment management activities is largely protective conservatism of the ecological sensitivity and potential functional values associated with this habitat.

Kelp plants are vulnerable to impacts resulting in frond entanglement and/or dislodgement of holdfasts. Although significant habitat loss would not be expected if a vessel transited through or anchored in a kelp bed, these types of adverse impacts are unnecessary and can be avoided. Pre-construction surveys have been used as a protective measure to finalize vessel routes and anchoring locations associated with sediment management projects. This is considered an effective impact avoidance measure provided the survey is conducted sufficiently close to when operations will commence (e.g., within 30 days), a greater time separation between survey and project initiation may not be as informative (particularly if conducted during winter) due to the seasonal nature of canopy development.

Kelp forest and associated understory and bottom associated vegetation are sensitive to changing light levels and are limited when light transmission is substantially impaired. Light reduction does not impact adult plants with surface canopies, but can reduce establishment of early life stages and growth of juvenile plants. Light limitation is common in kelp forests and beds due to canopy shading, phytoplankton blooms, and storms and short-term turbidity impacts would not be expected to produce measurable impacts.

Prolonged turbidity is of concern for canopy-forming species because of their limited storage of carbon and nitrogen reserves. Nutrient reserves for adult giant kelp do not extend beyond two weeks and juveniles are considered to have less storage capacity; consequently, turbidity impacts to kelp growth potentially could result from projects spanning a week or more in close proximity to kelp beds. Reduced juvenile growth may occur when light saturation levels are not met; e.g., < 15% surface irradiance, which Impacts from reduced growth could range from minor to substantial depending on project schedule relative to seasonal kelp canopy development. Light levels lower than saturation levels Buffer distance between sediment management activities and kelp beds may minimize potential impacts.

Light thresholds for protecting kelp forests and beds from turbidity impacts have not been established. Light levels > 10% of surface irradiance are near or exceed light saturation thresholds for juvenile growth.

Kelp forests are highly vulnerable to sedimentation impacts, which can potentially damage plants from abrasion and scour and/or preclude recruitment when sediment covers hard substrate. The inshore edge of giant kelp forests is dynamic due to disturbance from water motion (surge stress) and sedimentation, which vary each year with oceanographic conditions. The main portion of kelp forests is outside the zone of normal littoral transport, but can be affected by sedimentation during extreme storm events. Sediment management projects would not likely involve direct sand placement burial within a kelp bed either from a project design standpoint or through environmental review and permitting. The greater concern is for indirect sedimentation impacts from post-project sand transport. The risk is greater for inshore portions of kelp forests during more benign wave climates when they may extend into the littoral zone.

Kelp beds of understory species occurring in the littoral zone inshore of kelp forests are adapted and more tolerant of sedimentation impacts. Critical impact thresholds for sedimentation are unknown. However, inshore kelp requires hard substrate for attachment; therefore, persistent burial impacts would result in habitat loss. Long-term impacts would not be expected from transient sedimentation given the opportunistic life history characteristics of inshore kelp species. The potential for and significance of sedimentation impacts would require analysis on a project specific basis based on considerations such as substrate characteristics (e.g., height, presence of sand channels between rocky substrate), prevailing current direction, proximity between project and kelp bed habitat, and project volume. Monitoring has been used as a permit requirement to address uncertainty associated with potential project impacts to kelp forest/kelp bed habitat.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities to kelp forest and/or bed habitat.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Protective Conservatism	Protective Conservatism	Protective Conservatism	Protective Conservatism
Critical Impact Thresholds	NA	Holdfasts removed	Burial of attachment substrate	Burial of attachment substrate	Minimum irradiance saturation levels not met
Impact Responses	NA	Mortality, habitat damage	Impaired recruitment, scour damage	Impaired recruitment, scour damage	Reduced growth
Duration of Impacts	NA	Days-months	Months-years	Months-years	Hours-months
Potential for Restoration	NA	Yes, but uncertain for sand substrate variety	Yes, except uncertain for sandy substrate variety	Yes, except uncertain for sandy substrate variety	Unnecessary

NA = not applicable

3.3.7 Surfgrass Bed

Species Scientific Name	***Phyllospadix* spp.**

Regulatory Status:

CDFG Managed	X
Essential Fish Habitat	X

Surfgrass is Essential Fish Habitat. Surfgrass is a proposed Habitat Area of Particular Concern (HAPC) (Hoffman, personal communication 2006). Cutting or disturbing of surfgrass is prohibited in California (CDFG 2005a).

Photo by: Karen Green

Description and Distribution:

Surfgrass is a type of submerged aquatic vegetation (SAV) of interest to coastal managers (NOAA 2001b). Two species occur off the coast of California, *Phyllospadix. scouleri* with short flowering stems and *P. torreyi* with long flowering stems. Both species range from Vancouver Island to Baja California (Turner and Lucas 1985). Surfgrass grows in rocky habitats from low intertidal to subtidal depths. *P. scouleri* ranges to depths of approximately 5 ft (1.5 m) and *P. torreyi* may range to depths of 50 ft (15 m), although surfgrass becomes patchy and gradually disappears below 23 ft (7 m) (Phillips 1979, Williams 1995, NOAA 2001b). A depth of approximately 25 ft (7.6 m) is the lower limit for reproductive surfgrass (Williams 1995). When the species co-occur, *P. scouleri* grows on more exposed locations and *P. torreyi* grows at less exposed locations and/or deeper tide level (Phillips 1979, NOAA 2001b).

Life Stage or Function	California			On Land	Intertidal	Near shore <30 ft	Off shore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Habitat	X	X	X		X	X	Rare	E, P

Potential Functions Supported:

Surfgrass supports a variety of habitat functions ranging from attachment location (primary habitat), forage for herbivores and foraging habitat for associated animals, and reproductive and/or nursery habitat for a variety of species. Surfgrass seeds are eaten by a variety of birds, fish, and invertebrates (reviewed in Holbrook et al. 2000).

Over 150 species of algae and invertebrates and several species of fish were associated with surfgrass beds in San Diego, County (Stewart and Meyers, DeMartini 1981). Most species also occur in rocky intertidal habitat and were not restricted to surfgrass. The number of species at any particular surfgrass bed location is variable depending on site characteristics. For example, a total of 20 to 34 species of algae and 10 to 49 invertebrate species were found in surfgrass-dominated intertidal habitats in San Diego County (Stewart and Meyers 1980). Three species of epiphytes (*Erythrocladia subintegra, Melobesia mediocris, Smithora naiadum*) and one invertebrate species (*Notoacmea paleacea*) were restricted to blades of surfgrass (*ibid.*). Surfgrass dominates cover in persistent beds and

prevents other algae from establishing dominance, although the mechanisms for exclusion are largely unknown (possibilities may include shading, allelopathy, whiplash by blades, blocking of propagules, herbivory by associated animals) (Turner and Lucas 1985).

Surfgrass is nursery habitat for the commercially important California spiny lobster (*Panuliris interruptus*) (Engle 1979, Stewart and Meyers 1980, Williams 1995). Lobsters are only fished in subtidal waters (see Section 4.2.1.2). Surfgrass is grazed on by fish (e.g., opaleye, *Girella nigricans*) and invertebrates (e.g., mollusks, crabs, and urchins) (Turner and Lucas 1985, Williams 1995). Shorebirds and gulls may feed on associated invertebrates when surfgrass habitat is exposed during minus low tides, and wading birds such as herons and egrets also may forage in this habitat in areas close to coastal lagoons (Green, personal observation). Surfgrass also is considered a beach builder, stabilizing beaches by binding sands with its rhizomatous roots (Gibbs 1902).

Associated Species	Primary Habitat	Forage Habitat	Reproductive Habitat	Fisheries Habitat		Forage /Prey
				Commercial	Sport	
Vegetation	X		X			X
Invertebrates	X	X	X	X	X	X
Fish		X	X		X	X
Birds		X				X

Life History Facts:

Surfgrass are perennial and may or may not exhibit seasonality in standing stock (Littler et al. 1979, Stewart 1989). Surfgrass species are dioecious (separate sexes) with seasonal flowering and fruit production; however, most expansion of surfgrass beds is by vegetative growth.

P. torreyi begins to flower in mid- to late February, flowers and fruits are found into mid-summer, and fruits are released between August and October (Phillips 1979, Stewart 1989, Williams 1995). *P. scouleri* produces flowers in April-May; fruits develop over summer and are released in August-November (Phillips 1979, Turner 1985). The soft exocarp of the fruit decays and the seed endocarp has two, arm-like appendages with inwardly pointing bristles (barbs), which facilitates attachment to algae; unless attached, seeds wash away (Gibbs 1902, Turner 1985, Turner and Lucas 1985, Blanchette et al. 1999).

Seed attachment mainly occurs on branched red algae at moderate flow (Blanchette et al. 1999). Seed germination is very high (Williams 1995, Reed et al. 1998); however, seedlings appear to be particularly vulnerable with very low survival (Williams 1995). Seed predation rates can be substantial; however, effects of seed predation on population dynamics are not well understood (Hollbrook et al. 2000).

Surfgrass beds expand by vegetative propagation (Turner and Lucas 1985; Stewart 1989). Rhizome growth rates of 0.1 to 0.6 in (2.8 to 14.7 mm) per week were measured in San Diego County, California, with faster growth from mid-winter to spring (Stewart 1989). Annual rhizome growth rates are similar between Oregon and Baja California, ranging from 3.1 in (8 cm) to 3.4 inches (8.6 cm) per year (Turner and Lucas 1985, Ramirez-Garcia et al. 1998). Williams (1995) considered the clones comprising surfgrass beds as relatively old given that recruitment from seeds is a rare event.

Surfgrass leaves are the site of photosynthesis and uptake of nutrients, with roots functioning primarily in attachment (Terrados and Williams 1997). The majority of carbon is stored in leaves; however, some storage also occurs in rhizomes based on leaf clipping and re-growth experiments (Stewart 1989).

Intertidal surfgrass blade lengths generally range from 1.5 to 3 feet (0.5 to 1 m), although blades less than 1 ft (0.3 m) may occur at more exposed sites (Turner 1985, Stewart 1989). Subtidal surfgrass blade lengths generally are on the order of 2 to 3 ft (0.6 to 1 m); however, lengths of 4 to 6.5 ft (1.2 to 2 m) are not uncommon (CRM 2000, NOAA 2001b); subtidal blade lengths to 9.8 ft (3 m) have been reported in the Pacific Northwest (Phillips 1979). Leaf growth rates vary during the year; clipping experiments in San Diego County demonstrated leaf re-growth of nearly 1 ft (30 cm) in two months (Stewart 1989).

Adventitious roots from the rhizomes secure surfgrass to rocky substrate (Turner 1985). Sand is trapped by the rhizomatous root system, facilitated by root hairs, with the sand-enmeshed rhizomes providing a solid anchored layer (mat) (Stewart 1989). Sand trapping to depths of approximately 3 ft (1 m) by surfgrass has been reported (Gibbs 1902).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Flower/seeds Vegetative	Feb- Sep Peak Jun-Jul	Peak – mid winter to spring	NA	NA	Years	Sedentary

NA = not applicable

Adaptations and/or Behaviors to Disturbance:

Surfgrass is adapted to live in the hydrodynamic surf zone; leaves are very flexible and easily bend with wave surge, roots produce mucilaginous adhesive for attachment to rocks, rhizomes nodes are modified to cope with strong water movements, and *P. torreyi* growing in shallow waters have stronger attachment to rocks than plants in deeper water (Barnabas 1994, Williams 1995, Marin-Spiotta 1996).

Surfgrass bed with sand inundation
Photo credit: Karen Green, SAIC

Surfgrass attaches to hard substrate, but may experience variable sand cover depending on height of attachment substrate. Surfgrass is considered a sand-tolerant or sand-enhanced species (Littler et al. 1983). Several morphological adaptations contribute to its sand tolerance, including long leaves that may extend above the sand surface, rhizomatous root system that binds sediment, and fibrous leaf sheaths and thick-walled roots that provide protection from sand abrasion (Littler et al. 1983, Cooper and McRoy 1988, Stewart 1989, Barnabas 1994, http://www.coastal/researchcenter.ucsb.edu/cm/surfgrass.html).).

Gibbs (1902) reported tufts of surfgrass leaves appeared to be growing in the sand, but in reality were anchored to rock perhaps a meter below, and noted that as long as the tips of

the leaves waved free the plant thrived. Surfgrass seedlings also appear to be tolerant of some sand cover. Wet sand may keep rhizomes and developing leaf-shoots damp for many months (Stewart 1989). However, complete and prolonged sand burial was suspected as causing widespread loss of surfgrass near Santa Barbara (Reed et al. 2003). Substantially lower seedling survival also was reported when persistently buried by sand with cover depths of 2 to 10 in (5 to 25 cm) (Reed et al. 2003).

Sand deters settlement of algal spores and excludes or keeps invertebrate abundance low, which favors surfgrass development; however, sand also deters settlement of surfgrass seedlings, which makes vegetative propagation critical for the species (Stewart 1989). Removal of sand during storm conditions can also remove rhizomes that may be loosely or unattached to rock substrate, contributing to interannual variability in the landward edge of surfgrass relative to coralline algal turf (Stewart 1989).

Leaves of surfgrass have morphological adaptations for turbid nearshore waters associated with reduced lacunae and thickened leaf epidermal layers where gas exchange and photosynthesis occur (Cooper and McRoy 1988, Marin-Spiotta 1996). Seagrasses have relatively high light saturation irradiance levels ($\geq$ 40% surface irradiance) (Williams and McRoy 1982), and vegetative shoot density and number of flowering shoots decrease with increasing depth (Williams 1995). Growth decreases with lower light, lower salinity, and higher temperatures, although tolerance ranges of *P. torreyi* are relatively broad (Drysdale and Barbour 1975). Growth of surfgrass transplants may be limited by shading by kelp and other algae (de Wit et al. 1997).

Surfgrass leaves are more prone to breakage and damage at the landward edges of beds that become exposed to air during low tides, indicating that the shoreward extension of surfgrass beds is constrained by physical factors (Stewart 1989). Leaf clipping experiments indicated less regrowth and recovery for intertidal plants when leaves were exposed to air compared to plants that were covered by leaves of undisturbed plants and/or were always submerged. Stewart (1989) presumed that regrowth of successively clipped leaves was facilitated by reserves stored in rhizomes, and suggested that continuing low productivity could lead to plant loss.

Life Stage	Physical Adaptation			High Reproductive Output and/or Growth
	Long Blades, Fronds	Protective Sheath	Rhizomes	
Adult	X	X	X	
Juvenile		X	X	
Seed				X
Clone			X	

Potential Impacts from Sediment Management Activities:

Potential impacts to surfgrass could result from direct burial and equipment disturbance/damage and/or indirect turbidity and sedimentation depending on proximity to and nature of sediment management activities. The primary concern relates to burial/sedimentation and/or turbidity affecting plant productivity and/or habitat functions.

Commercial fishermen expressed concern that sedimentation and turbidity associated with beach nourishment may result in loss and/or degradation of surfgrass habitats that could reduce recruitment and/or growth of lobster to harvestable size and/or result in movement of lobster from harvestable areas (SANDAG and USDN 2000).

Types of sediment management activities and potential impact concerns to surfgrass habitat include:

- Maintenance dredging of embayments – not applicable.
- Offshore borrow site dredging – not applicable.
- Nearshore placement – equipment, burial, sedimentation, turbidity.
- Profile placement – equipment, burial, sedimentation, turbidity.
- Beach placement – equipment, burial, sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging	A	A	A	A	A	
Growth			P	A, P	A, P	A, P
Habitat			P	P	P	P
Reproduction /Recruitment			A, P	A, P	A	A, P
Respiration					A	

A = associated animals, P = plant

Equipment

Noise and activites associated with equipment use may displace mobile animals. Indirect attraction and/or displacement may occur as a result of lights during night-time operations (Section 5.3). Anchoring associated with nearshore or profile placement, and/or pipeline placement activities associated with conveying sands to the beach from offshore hopper vessels have the potential to overturn rocks and/or damage marine life living on subtidal and/or intertidal reefs, including surfgrass. No reports of damage to surfgrass beds from beach nourishment activities was found with the literature review. However, experimental studies involving cutting plugs from existing beds provide relevant documentation that removal of patches of rhizome mat can undermine the mat and result in loss of surfgrass in excess of recovery rates (Bull et al. 2004).

Pre-construction surveys were used to refine beach nourishment project design and final pipeline and anchor plans to avoid direct impacts to sensitive resources, including surfgrass beds from the 2001 San Diego Regional Beach Sand Project (SANDAG and USDN 2000, MEC 2000, AMEC 2002). Pre-construction surveys to finalize pipeline routes in areas with

intertidal and subtidal reefs were recommended as an impact avoidance mitigation measure for the BEACON Beach Nourishment Demonstration Project (Chambers Group 1992).

Burial/Sedimentation

A concern with sediment management activities is the potential for burial/sedimentation to impact surfgrass habitat. Surfgrass beds range from low intertidal to shallow nearshore depths; therefore, sediment management activities involving beach, nearshore, and/or profile placement have the potential to directly bury surfgrass beds, if present. Although surfgrass is sand-tolerant, prolonged burial would likely result in habitat loss. Similar to the above discussion for equipment, the literature review did not identify any reports of direct burial impacts from sediment management activities on surfgrass beds. Direct impacts to surfgrass beds were avoided during project design of the 2001 San Diego Regional Beach Sand Project (SANDAG and USDN 2000, MEC 2000).

Indirect sedimentation of surfgrass beds from post-construction sand transport from a receiver site is of potential concern with any placement method, depending on project volume and proximity to this habitat. Because surfgrass is morphologically adapted and highly tolerant of sedimentation, potential impacts may range from no effect to significant depending on project- and site-specific characteristics and unpredictable oceanographic and climate conditions.

Field studies have reported adult plants are tolerant of sedimentation when some portion of the leaves extend above the substrate, and seedlings and young shoots also may be tolerant but apparently at lower sand inundation levels (Gibbs 1902, Littler et al. 1983, Stewart 1989, Reed et al. 2003). However, prolonged sand inundation that leads to continued low productivity may be inadequate to support regrowth based on insights provided by Stewart's (1989) leaf clipping experiments. Information is lacking regarding critical impact thresholds associated with depth and duration of sedimentation in surfgrass beds.

Because of impact concerns and uncertainties, monitoring has been required with some beach nourishment projects when reefs with surfgrass occur in the vicinity. Available information from two monitored projects is reviewed below. One project involved pre-construction and post-construction monitoring over a four-year period. Monitoring of the other project is ongoing.

Pre-construction surveys and locations of surfgrass beds were taken into consideration during project design of the 2001 San Diego Regional Beach Sand Project to avoid direct burial and to minimize sedimentation impacts (SANDAG and USDN 2000, MEC 2000a). As noted previously, a total of 984,000 cy was placed between Carlsbad and Solana Beach, an area of coastline with patchy occurrence of low to high relief reefs, some with surfgrass (see Section 3.3.5). Post-construction monitoring of 18 rocky subtidal sites showed no change in sand cover or surfgrass at 8 sites, sand cover increased without apparent change to surfgrass at 5 sites, and 5 sites had changes in surfgrass cover and/or density (AMEC 2005). Of the 5 sites where there was a change in surfgrass, 2 sites were controls, 1 site had no change in sand cover, and 2 sites had changes in surfgrass possibly influenced by change in sand cover. One of the affected sites may have been influenced by other projects, and the other site had a change in surfgrass density but not cover. AMEC (2005)

concluded that short term impacts were observed at several locations, but no long-term adverse environmental impacts were observed.

The Goleta Beach Nourishment Demonstration Project involved placement of 97,600 cy of sand onto the beach from three sources between 2003 and 2004 (Moffatt & Nichol 2005c). Two transects were established at the first significant rocky intertidal habitat (approximately 6,500 ft (2000 m) and 7,874 ft (2,400 m) downcoast, and control transects were established upcoast and outside of potential project influence. Percent cover and depth of sand and percent cover of surfgrass and other algae were monitored at approximately 1, 3, 6, and 12 months after the initial placement. Relatively low percent cover of surfgrass (17 to 30%) and high percent cover of sand (91 t 100%) to a depth of approximately 5 in (11.6 to 12.5 cm) were noted during one survey each at the two downcoast transects, but not on the following survey (i.e., surfgrass cover of 77 to 98%) indicating sand cover was transient and did not result in loss of surfgrass (Chambers Group 2004). The duration of sand cover between surveys was not monitored. The transect location closest to the project site showed greater variability in surfgrass cover among surveys than the farther downcoast transect. Chambers Group (2004) concluded that changes in surfgrass and sand cover may have been related to the project, but were within the variability at the site prior to beach nourishment.

<u>Turbidity</u>

Light is a limiting factor to surfgrass depth distribution (Aleem 1973, Williams 1995). However, surfgrass is considered relataively tolerant to turbid conditions based on several morphological adaptations and storage of carbon resuerves in the rhizomes (Stewart 1989). While temporary light reduction may have little impact, effects of prolonged turbidiy may be of conern.

No substantial impact to surfgrass was noted at rocky subtidal sites based on monitoring before and after the 2001 San Diego Regional Beach Sand Project. Construction of beach fills for the SANDAG project involved pumping of sands behind temporary longitudinal dikes to minimize turbidity, and construction spanned 1 to 2 weeks per receiver site (AMEC 2002). No project-related change in surfgrass was noted based on monitoring before and one-month after the 2003 Goleta Beach Nourishment Demonstration Project; construction involved pumping sand into a temporary beach swale to control turbidity and spanned 3.5 weeks (Moffatt & Nichol 2003). Turbidity was reported to be mainly confined to the surf zone during both those projects.

Recovery from Disturbance:

Recovery of surfgrass to physical disturbance such as pipeline placement and/or anchoring would depend on size of damaged area and whether rhizome mat was removed. Recovery of damaged surfgrass beds occurs by vegetative growth of rhizomes surrounding the damaged area and/or by seed recruitment (Stewart 1989, Turner 1985, Turner and Lucas 1985, Reed et al. 1988).

Surfgrass is slow to recover (> 3 years) when the rhizome mat is removed (Dethier 1984, Stewart 1989, Turner 1985, Turner and Lucas 1985). Rhizomes grow slowly; generally < 3 in (8 cm) per year (Turner 1985, Turner and Lucas 1985). Growth of isolated patches of surfgrass from seedlings that attached within a turf-dominated zone was 3 to 5 years (Stewart 1989). Recovery time may be substantially quicker if rhizomes are not removed

and/or vegetative propagation occurs from neighboring individuals (Dethier 1984, Turner 1985, Engle et al. 1998, Reed et al. 1988).

Complete burial of surfgrass from beach nourishment would likely result in loss due to persistence of burial for one or more years until coastal processes removed and redistributed sediments, and several more years until surfgrass was able to recolonize and recover. Surfgrass is sand-tolerant and adapted to seasonal inundation; therefore, recovery from post-project sedimentation within natural ranges would be expected. Potential impacts associated with prolonged, substantial sedimentation are unknown. Similarly, surfgrass is adapted to nearshore turbidity; therefore, temporary light reductions may have little if any impact. However, prolonged turbidity may be of concern, if surfgrass is present. .

Surfgrass is sand-tolerant and adapted to seasonal inundation; therefore, recovery from post-project sedimentation within natural ranges would be expected. Prolonged burial may result in loss (Reed et al. 2003). Critical impact thresholds with respect to partial burial are currently unknown.

	Recovery Rates				
Impact	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	X	X	X		
Burial	X	X	X		
Sedimentation	X	X	X		
Turbidity	X				
Habitat Loss			X		

Note: A wide range of recovery rates may apply depending on nature of the impact.

Critical Impact Thresholds:

Light levels < 40% surface irradiance are below saturation and may affect surfgrass growth and distribution (Williams and McRoy 1982). Subtantial removal of rhizomes can lead to habitat loss that can take years to recover. Prolonged burial of surfgrass leaves results in habitat loss (Reed et al. 2003). Substantial sedimentation that resulted in loss of surfgrass and/or its structural function as essential fish habitat would be significant.

Data Gaps:

The depth and duration of sedimentation that surfgrass can tolerate without adverse impact are unknown.

Habitat Restoration:

Few habitat restoration projects involving surfgrass have been conducted. Experimental studies have demonstrated technical feasibility with rhizome growth, new blade production, and seed production achieved with transplants. and provide important information on efficacy of different methods. Techniques have involved harvesting from donor beds and attaching transplants to rock (directly or with nylon netting) and attaching laboratory reared seedlings to rock (de Wit et al. 1997, Bull et al. 2004).

Transplant survival of harvested plugs (cohesive clumps of shoots and rhizomes, ranging in size from 25 to 400 cm^2) was < 50% on boulders (14 to 18 kg) due to wave energy moving the boulders (de Wit et al. 1997), but was up to 100% when attached to intertidal and subtidal reef (Bull et al. 2004). However, recovery in donor beds from harvest of plugs can result in additional loss of surfgrass due to water motion undermining the edges of cut rhizomous mats (Bull et al. 2004).

Bull et al. (2004) found transplanting of sprigs (short lengths of rhizome containing few shoots) to be much more effective because donor beds fully recovered within a six-month study period and transplant survival ranged from 48 to 71% on intertidal and subtidal reefs, respectively (Bull et al. 2004). Successful techniques have been developed for laboratory seed germination; however, field outplants of laboratory reared seedlings have had low survival (< 3%), although seedlings that did survive grew well (Reed et al. 1988, Bull et al. 2004). Given that seed collection has minimal impact to existing beds and growth of laboratory-reared seedlings has been demonstrated, additional research to develop methods of reducing seedling losses in the field is considered warranted (Bull et al. 2004).

Summary:

Surfgrass beds are Essential Fish Habitat. This habitat occurs in association with rocky substrate within a limited depth range mainly from lower intertidal to shallow nearshore waters. Surfgrass beds are ecologically sensitive, supporting habitat functions for a variety of invertebrates, fish, and birds, and nursery habitat for commercial fishery species.

Surfgrass is a clonal species that maintains highly persistent beds through vegetative propagation of rhizomes, but also produces a high output of seeds that are modified for hooking onto other vegetation associated with rocky habitats. Surfgrass recovers relatively quickly from small-scale disturbance by vegetative expansion. However, recovery can take years when there is substantial disruption and/or loss of the rhizome mat and/or when recovery is from seedlings. Surfgrass growth rates are relatively slow.

Sediment management activities have the potential to impact surfgrass beds and associated species, if present. The basis of concern for impacts to surfgrass beds from sediment management activities is protective conservatism of the ecological sensitivity and functional values associated with this habitat.

Concerns associated with direct impacts from equipment use and/or burial in surfgrass beds may be avoided during project planning and design. For example, pre-construction surveys were used to refine locations and footprints of beach nourishment sites to avoid surfgrass beds during a regional beach nourishment project in San Diego County.

Concerns regarding indirect impacts from sedimentation and turbidity are based on uncertainty-based conservatism. Surfgrass is morphologically adapted to and highly tolerant of sedimentation and turbidity; therefore, no adverse effects would be expected from project conditions that fall within the broad range of natural variability for this species. Therefore, uncertain concerns relate to the potential for above-normal sedimentation to result in loss of surfgrass and/or habitat functions. Similarly, adverse impacts would not be expected with temporary turbidity exposures; uncertain concerns relate to the potential for prolonged exposure to affect growth and/or density. Critical impact thresholds for sedimentation and turbidity are unknown.

Post-construction monitoring has been required for some beach nourishment projects when there was uncertainty regarding the potential for impacts. For example, monitoring was required for two beach nourishment projects that placed volumes ranging from 90,000 to 225,000 cy in the vicinity of surfgrass beds. No significant impacts to surfgrass beds were documented after four years of monitoring for one project, and no persistent impacts were identified after the first year of monitoring for the other project, which is still ongoing.

Recovery of beneficial functions of surfgrass habitat could take several years if impacts resulted in habitat loss. The effectiveness of compensatory mitigation to restore habitat loss is unknown. Successful restoration of surfgrass beds is technically feasible, but has not been demonstrated beyond an experimental scale.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities to surfgrass habitat.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Protective conservatism	Protective conservatism	Protective conservatism	Protective conservatism
Critical Impact Thresholds	NA	Rhizomes removed	Habitat loss	Degrade habitat, habitat loss	Minimum irradiance saturation levels not met
Impact Responses	NA	Damage, mortality, habitat loss	No effect, loss of function, habitat loss	No effect, loss of function, habitat loss	Reduced growth, cover
Duration of Impacts	NA	Months-years	Months-years	Months-years	Hours-months
Potential for Restoration	NA	Feasible, but experimental	Feasible, but experimental	Feasible, but experimental	Unnecessary

NA = not applicable

3.3.8 Eelgrass Meadow

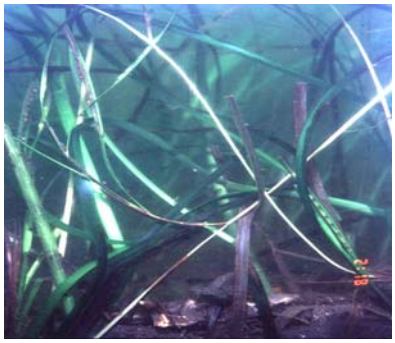


Photo by: SAIC

Species Scientific Name	***Zostera marina***

Regulatory Status:

CDFG Managed	X
Essential Fish Habitat	X

Eelgrass is a special aquatic site (SAS) (i.e., vegetated shallows) under Section 404(b)(1) of the federal Clean Water Act of 1972, as amended (http://www.usace.army.mil/inet/functions/ cw/cecwo/reg/40cfr230.htm#230.40). Eelgrass meadows are Essential Fish Habitat for managed fishery species. California's fishing regulations prohibit cutting or disturbing of eelgrass (CDFG 2005a). Eelgrass also is referred to as a type of submerged aquatic vegetation (SAV).

Description and Distribution:

Eelgrass is a species and a marine-estuarine habitat. Eelgrass is a marine vascular plant consisting of subsurface rhizomes and above ground leaves (also referred to as blades, shoots). The leaves and roots originate at nodes along the rhizomes, which grow vegetatively into an intertwined subsurface mat that binds and holds sediment (Phillips 1984, NOAA 2001b). Similar to other seagrasses, eelgrass obtains nutrients from both the sediment and water column (*ibid*.). Leaves contain air spaces, lacunae, which aid in buoyancy. Eelgrass forms submerged beds, also termed meadows.

Eelgrass habitat occurs in the eastern Pacific from Alaska to Baja California, Mexico (Phillips 1984). This habitat is found throughout California in bays, estuaries, and coastal lagoons and along some protected coastlines of the mainland and Channel Islands (Phillips and Esheverria 1990, Ware 1993, CINMS 2000). The most widely distributed species is *Zostera marina*, which ranges from low intertidal to subtidal depths up to 100 ft (30 m). Two variants of *Z. marina* occur with a narrow-leaved form having a broader depth distribution across intertidal and subtidal depths and a wide-leaved form restricted to subtidal depths (Ware 1993).

Life Stage or Function	California			On Land	Inter-tidal	Near-shore < 30 ft	Off-shore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Primary Habitat	X	X	X		X	X	X	P

A second species *Z. asiatica*, also wide-leaved, may occur off the coast from Tomales Bay to Santa Monica Bay at depths between 16 and 56 ft (5 and 17 m). Because the characteristics of the wide-blade form of *Z. marina* and *Z. asiatica* intergrade, some historical offshore records of *Z. marina* may include *Z. asiatica* (Ware 1993).

Eelgrass distribution is affected by several variables including light, salinity, temperature, wave/current energy, sediment, nutrients, and exposure to air (Williams and McRoy 1982,

Phillips 1984, Dennison and Alberte 1986, Dennison 1987, Fonseca and Kenworthy 1987, Thom and Albrete 1990, Thom and Albright 1990, Zimmerman et al. 1990, van Lent and Verschuure 1994a,b, Thom et al. 2001).

Depth limits are primarily controlled by exposure and dessication stress in the intertidal and by light in the subtidal (Phillips 1984). The lower depth limit is set by the compensation depth below which photosynthesis cannot meet metabolic demands for growth (Phillips 1984, Dennison 1987*).* The compensation depth for seagrasses is higher than the 1% light level used to define the euphotic zone for phytoplankton (Fonseca et al. 1992). Average Secchi disk depth (approximately 10% light level) has been considered a general indicator of eelgrass compensation depth (Dennison 1987, Fonseca 1989). Maximum biomass occurs at depths associated with 20 to 50% of surface light intensity during the growth period (Phillips 1984, CDFG 2001). In areas of chronic turbidity, eelgrass may be limited to depths less than < 5 ft (1.5 m) (Phillips 1984, Zimmerman et al. 1991). Temperature extremes may affect photosynthesis and respiration, with optimal temperatures for growth between 50 and 68°F (10 to 20°C), and decay and/or mortality when ≥ 86°F (30°C) (Phillips 1984, Marsh et al. 1986).

Eelgrass grows in a variety of sediments (mixed sand-cobble to mud), but appears to do best in medium to fine sands with some silts, organics, and nutrients (Phillips 1984, Short 1987, Ware 1993, Thom et al. 2001, Bradley and Stolt 2006). Eelgrass rhizomes are buried from 1.2 to 8 inches (3 to 20 cm), depending on sediment consistency, with rhizomes usually deeper in muddy versus sandy sediments (Phillips 1984).

Eelgrass occurs in areas with little water motion to moderate wave action and currents. Current velocities > 80 cm/sec may erode eelgrass patches (Thom et al. 2001), although the maximum current velocity where eelgrass has been observed is between 120 and 150 cm/sec (Fonseca et al. 1983, Fonseca and Kenworthy 1987). Growth may be optimized in areas with currents ranging 30 to 40 cm/sec (Conover 1958 cited in Phillips 1984). Eelgrass does not occur in areas with strong waves (Phillips 1984).

Potential Functions:

Eelgrass is considered one of the most productive of coastal habitats supporting nearly twice the number of species than adjacent soft substrate sediments (Hoffman 1986, Ware 1993). Significant higher densities of large and small organisms were found within interior and edge areas of eelgrass beds, respectively, than unvegetated beds (Bolgna 2005). Comparative field studies showed significantly more fish species and generally higher fish density and biomass in eelgrass meadows than areas where beds had vanished due to disturbance (Lief et al. 2006).

More than 20 fish species and more than 200 invertebrate species have been collected from eelgrass meadows in southern California (Hoffman 1986, Ware 1993). Eelgrass meadows support a variety of ecological functions for invertebrates and fish, including structural refuge, shelter, foraging habitat, and reproductive habitat.

Eelgrass meadows are used as spawning and/or nursery areas for many commercially and recreational important finfish and shellfish species, including California halibut, California spiny lobster, Dungeness crab, Pacific herring, rockfish, juvenile salmon, sand bass (barred, spotted), shiner surfperch, and steelhead (Hoffman 1986, Ware 1993, MEC 2000b, LFR

2004). Eelgrass meadows also are used as nursery areas for small forage fish (anchovies, silversides), which are favored prey of the endangered California least tern.

Eelgrass supports trophic transfer across nearshore ecosystems, contributing primary production, vegetative and detrital food sources, and secondary production of epiphytic plants and animals (Phillips 1984, Fonseca et al. 1992). The production of detritus (decaying plant matter) from dead leaves and plants supports a variety of invertebrates, which are eaten by fish and birds. Eelgrass leaves often are covered with a nutritious "brown felt" composed of epiphytes (e.g., bacteria, diatoms, algae, bryozoans, serpulid worms, young scallops) that support a number of grazers (e.g., amphipods, isopods, limpets, snails), which in turn provide forage for fish and a number of migratory birds (Penhale 1977, Phillips 1984, Williams and Ruckelhaus 1993, MEC 2000).

Other important functions provided by eelgrass beds include nutrient cycling, oxygen generation, water quality enhancement, sediment stabilization, and dampening of waves and current velocities (Fonseca and Kenworthy 1987, Phillips 1984, Fonseca and Cahalan 1992). The leaves trap sediments (sands and muds) carried by currents, aiding the process of sedimentation and helping to keep waters clear (Phillips and Meñez 1988 cited in NOAA 2001b). The sediment binding effect of eelgrass and other seagrasses may help prevent shoreline erosion (NOAA 2001b).

Eelgrass is recognized as a good indicator of environmental health because it is sensitive to poor water quality (e.g., nutrient enrichment, turbidity). It has been selected as an indicator species on which improvements in water quality conditions in the Chesapeake Bay and coastal lagoon systems are assessed (Moore and Orth 1997). Use of the ratio of leaf nitrogen to leaf mass has been proposed as an indicator of early eutrophication (Lee et al. 2004).

Associated Species	Primary Habitat	Forage Habitat	Reproductive Habitat	Fisheries Habitat		Forage /Prey
				Commercial	Sport	
Vegetation	X		X			X
Invertebrates	X	X	X	X	X	X
Fish	X	X	X	X	X	X
Birds		X				
T&E Species		X				

Life History Facts:

Eelgrass produces seed from sexual reproduction and/or propagates through vegetative growth of rhizomes (Phillips 1984). Eelgrass plants are monoecious with male and female flowers on the same plant. There is one rhizome node produced for each new leaf, and the same meristem produces a new internode for the elongating branch (Phillips 1984). Sexual reproduction and seed production provide a mechanism for dispersal, but experimental studies suggest that seed dispersal is limited with most seeds dispersing only a few feet (meters) (Orth et al. 1994), although longer distance dispersal may occur via floating reproductive fragments with seeds (Harwell and Orth 2002 cited in Orth et al. 2006).

Eelgrass forms perennial stands, but populations at the margins of their geographic range and/or under stress conditions may function as annuals with heavy production of seeds

(Phillips et al. 1983, Phillips 1984, van Lent and Verschuure 1994a). For example, several eelgrass beds in San Francisco Bay function as annuals (Hughes 2005).

Eelgrass displays seasonality in growth, generally characterized by rapid growth and expansion in spring-summer and slowed growth and/or die back in winter; however, expansions and declines are variable and reflect local differences in environmental conditions (Phillips 1984, Ware 1993, MEC 2000b, Cabello-Pasini 2002). In the Pacific Northwest, which extends between Canada and Humboldt Bay, California, eelgrass displays seasonal regularity with new and active growth of long leaves in spring-summer, seed production and dispersal in summer, and production of shorter winter leaves in November (Phillips 1984). In southern California, eelgrass may grow year round, although beds exhibit some die back (bed thinning) in winter with reduced leaf density, slowed growth, and distribution may shallow across the depth range (Ware 1993, MEC 2000b).

Eelgrass leaves generally are shorter in the intertidal and longer at subtidal depths, ranging from several inches to 6.6 to 10 ft (< 2 to 3 m) in the Pacific Northwest, and ranging from several inches to generally > 3 ft (> 1 m) in southern California (Phillips 1984, Ware 1993). During active growth (e.g., spring through summer), eelgrass may rapidly expand with vegetative growth rates up to 8 cm^2/day for leaves and 1.2 cm/day for rhizomes (Merkel unpublished cited in MEC 2000b).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Flower/Seed Vegetative	Spring-Summer (flowering)	March-October	Slowed growth and/or die back in late fall-winter	NA	Perennial, Annual when extreme stress	Sedentary

NA = not applicable

Adaptations and/or Behaviors to Disturbance:

Eelgrass has morphological and physiological adaptations to stress and disturbance associated with life in the coastal zone that contribute to its resilience. The morphological adaptation of long, buoyant leaves facilitates photosynthesis under naturally varying light conditions. Storage of carbohydrate reserves in leaves, rhizomes, and roots during periods of active growth supports metabolism during periods of light limitation (Zimmerman et al. 1995, Burke et al. 1996). Reduction of above-ground biomass in response to light limitation also reduces metabolic demand over winter (Phillips 1984).

Phillips (1984) stated that there appears to be a direct relationship between amount of physical disturbance and dependence on sexual reproduction, with intertidal populations dependant on annual seed production and seedling survival, and subtidal populations dependent on vegetative growth to maintain populations. Recovery of subtidal populations from disturbance also may be from seedlings. For example, Cabello-Pasini (2002) reported that open coast subtidal populations growing at depths of 16 to 23 ft (5 to 7 m) off Baja California, Mexico recovered from seeds after all above-ground leaves were lost from storm-generated turbidity lasting three weeks.

Life Stage	Physical Adaptation			High Reproductive Output and/or Growth
	Long Blades, Fronds	Protective Sheath	Rhizomes	
Adult	X		X	X
Juvenile	X		X	X
Seed				X

Adaptations and limitations associated with light are reviewed in more detail below because of particular relevance to sediment management activities that may result in increased turbidity. Following that are brief summaries of eelgrass response to other physical and to biological disturbance factors.

Seasonal accumulation of carbohydrates in leaves and rhizomes during favorable growth periods provide reserves that maintain plants during periods of light limitation (Zimmerman 1995, Burke et al. 1996). Eelgrass survival depends on the amount of time in a day that light levels are above a critical intensity, or the photosaturation period (Dennison 1987, Zimmerman et al. 1990). Zimmerman et al. (1990) estimated that the period of irradiance-saturated photosynthesis required to balance respiration may vary from 3 to 12 hours per day.

In San Francisco Bay, eelgrass required 3 to 5 hours per day of irradiance-saturated photosynthesis (H_{sat}) for whole plant maintenance and growth (Zimmerman et al. 1991). Thom et al. (2001) reported that at least 3 hours of light at saturating levels (300 μM quanta $m^{-2}s^{-1}$per day) in spring and summer was required for eelgrass to build up sufficient carbohydrate reserves to survive through the winter in Puget Sound. Experimental studies showed that eelgrass limited to 2 hours of saturated irradiance (200 micro mols (μM) quanta m^{-2} s^{-1}) per day died after 30 days, whereas, plants exposed to 7 hours of saturated irradiance per day (similar to wintertime conditions in Monterey Bay, California) survived the 45 day experiment but had a negative carbon balance insufficient for growth (Alcoverro et al. 1999). Plants exposed to 2 hours of saturated irradiance per day for periods of 10 to 14 days survived, but carbohydrate levels were 57% of those of plants exposed to 12 hours of saturated irradiance per day (Kraemer and Alberte 1995). Zimmerman et al. (1991) stated that while carbon concentrations may be met with short daily H_{sat} periods, it was not clear whether the roots are capable of tolerating long daily periods of anoxia (> 15 hours) for weeks at a time.

Some researchers have determined light compensation levels (minimum required to balance respiration) (H_{comp}) of eelgrass under various environmental and experimental conditions. Compensation values of daily quantum fllux of photosynthetically active radiation (PAR) range from 1.5 to 2.7 mols m^{-2} day^{-1} (Olesan and Sand-Jensen 1993, Moore et al. 1997, Hosakawa and Nakamura 2005).

Burke et al. (1996) found that seasonal peaks in rhizome carbohydrate reserves paralleled growth patterns of eelgrass in Chincoteague Bay, Maryland/Virginia, and suggested that light limitation during spring could affect subsequent survival. Experimental shading of eelgrass by 80% of incident irradiance for 3 weeks was found to reduce growth and survival rates. Burke et al. (1996) suggested that turbidity during the springtime “window of

opportunity" may jeopardize subsequent survival as a result of inadequate carbohydrate reserves to maintain a positive carbon balance during the rest of the year.

Backman and Barilotti (1976) measured a 76% decrease in eelgrass density within 18 days of shading plants to approximately 12% of surface insolation, and found density was only 5% of that in control areas at the end of the 9-month experiment. Eelgrass transplants in the York River tributary of Chesapeake Bay did not survive a one-month period of light limitation (<10% of solar PAR or < 15% as scalar PAR) associated with a season turbidity pulse (up to 56 mg/L TSS) (Moore et al. 1996, 1997). Mean scalar irradiance of 9% of solar PAR was verified as limiting during experimental shading experiments (Moore and Wetzel. 1999).

Cabello-Pasini et al. (2002) found 3 weeks of light limitation (near zero) a critical threshold for open coast populations in Baja California, Mexico. Open coast populations started experiencing leaf damage after 2 weeks and mortality after 3 weeks of light limitation (approximately 1% of surface irradiance); laboratory experiments confirmed that carbohydrate reserves were only sufficient to maintain metabolic activity for 3 weeks. In contrast, lagoon populations withstood storm-related light reductions of 9 to 18% of surface irradiance (the authors noted that values were uncorrected for light reflection at the air/water interface and were actually lower).

Zimmerman et al. (1991) stated that eelgrass plants in favorable light environments have adequate carbon reserves to withstand at least 30 days of light limitation, but it was doubtful that plants growing near the edge of depth distributions were capable of accumulating large carbon reserves. Merkel (personal communication 2005) noted eelgrass was able to tolerate for 3 months what may have been a more variable light reduction from a red tide (plankton bloom) before widespread loss was observed in Agua Hedionda Lagoon, San Diego County.

Eelgrass may be adversely impacted by sedimentation. Eelgrass distribution in Morro Bay has been substantially reduced by sedimentation from watershed inputs (MBNEP 2000, 2004). Inputs may be exacerbated from substantial reainfall associated with El Niño events. During the 1994-1995 winter season, El Niño storms washed substantial sediment into Morro Bay, central California, that buried and smothered substantial portions of the bay's eelgrass beds; eelgrass beds have exhibited recovery but acreage in 2004 was still lower than 1994 estimates (MBNEP 2004).

Substrate characteristics as well as blade length may influence response to sedimentation. Onuf and Quammen (1983) reported that eelgrass blade length varied from short to long between shallow water (8 in, 20 cm at low water) and deeper water (2.6 ft, 80 cm at low water) in Mugu Lagoon. A sedimentation depth of 4 in (10 cm) was reported to result in loss of the short-blade eelgrass. At a deeper water site, eelgrass survived with 6 in (15 cm) of sedimentation from the first storm, but substantially deteriorated and did not recover over the next four years, a period when there was additional accretion of 6 in (15 cm). At both those sites bottom type changed from approximately 90% sands to <40% sands. In addition, water depths at the sites shallowed by 40 to 75% over the course of the study. In contrast, eelgrass experienced a 20-fold increase at a site that experienced only temporary storm effects (i.e., a 10-fold increase in silt/clay did not persist more than 3 months) and bottom type (sandy) and water depths remained stable (1 ft, 30 cm at low water). From a lagoon-wide perspective, eelgrass showed a gradual recovery after the first major storm, but

had not recovered to pre-storm levels over the subsequent four years of the study. Because of the substantial changes in sediment type and water depth associated with this sedimentation example, it is possible that other factors besides sedimentation thickness may have differentially affected eelgrass in this shallow embayment. (e.g., change in sediment properties, continued accretion disturbance, greater sediment resuspension and turbidity associated with increased fines and shallower depths, depth of the anaerobic layer, increased thermal stress).

Generally, eelgrass occurs outside the surf zone and active area of littoral transport, although the inshore portions of beds may experience storm-related inundation (K. Merkel, personal communication 2005). Eelgrass is known to persist (although density varies) in some shallower subtidal areas such as south of Zuniga jetty (Los Angeles County), which experience periodic sand inundation (*ibid.*).

Substantial disturbance to eelgrass meadows has been associated with El Niño Southern Oscillation Events, including light limitation from sea level rise, sedimentation, and above-normal grazing pressure. Oceanographic conditions associated with the 1997 El Niño Southern Oscillation event were linked to widespread reductions of eelgrass in San Diego Bay and Mission Bay, San Diego County, which fully recovered via seedling recruitment and vegetative growth by 1999 (Merkel & Associates 2000 cited in MEC 2000). Some of that loss is suspected to have been caused by sea level rise essentially reducing the light-depth limits in the water body and decreasing the depth range of eelgrass (K. Merkel, personal communication 2005).

During the 1982-1984 El Niño, eelgrass meadows were eliminated at Anacapa Island, California by white sea urchins (*Lytechinus anamesus*), which formed feeding fronts in response to food limitation; eelgrass beds did not recover and restoration is currently being conducted at Anacapa Island (http://www.sbck.org/issues/ eelgrass.htm). Overgrazing and defoliation of seagrass also was reported long the coast of Florida in 1997 (NOAA 2001b).

Eelgrass also may be damaged and/or limited by other biological factors. Prolonged red tide conditions (several weeks) in 2005 resulted in substantial turbidity and widespread loss of eelgrass meadows in southern California embayments at Agua Hedionda Lagoon, San Diego County, and Newport Bay, Orange County (K. Merkel, and N. Davis, 2006 personal communications).

Other biological disturbances may include light reduction from epiphytes (Sand-Jensen 1977, Howard and Short 1986), benthic algae canopies, eutrophication, and effects of invasive species (Giesen et al. 1990, CDFG 2001, Cardoso et al. 2004, Hauxwell et al. 2006). During the 1930's widespread reduction (approximately 90%) of eelgrass occurred along the north Atlantic of the United States and Europe from a "wasting disease" (Rasmussen 1977 cited in NOAA 2001b, den Hartog 1987). It has been conjectured that elevated temperatures and stimulation of a normally occurring marine slime mold, *Labyrinthula zosterae,* were associated with the wasting disease; however, the cause has never been proven (NOAA 2001b, Orth et al. 2006). Recurrence of the disease with only local effects was reported on the east coast in the 1980s (Short et al. 1988).

Impacts to eelgrass may have substantial effects on associated animals. Several species of waterfowl (e.g., black brant, bufflehead, canvasback, Canada goose, redhead duck) feed directly on eelgrass and/or associated invertebrates; some waterfowl species (especially

black brant) had to shift migratory patterns and diets in response to the widespread loss of eelgrass habitat associated with wasting disease in the 1930s (NOAA 2001b).

Bell and Westoby (1986a) experimentally manipulated eelgrass (*Z. capricorni*) and *Posidonia autralis* height and density to one-third normal and found variable response among examined animals, with several decreasing in abundance when leaf height and density were reduced and fewer species increasing in abundance when leaves were shortened. When the author's compared leaf height and density in seagrass beds at a wider scale there was little relationship with fish and decapod abundances suggesting that other factors such as patchy settlement patterns and redistribution within beds to select favorable microsites were influential.

Jackson et al. (2006) found that discontinuous occurrence of seagrass beds supported lower numbers of fish species than more homogeneous seagrass landscapes; however, relationship tended to breakdown at night when there was more movement between seagrass and adjacent habitats to forage.

Potential Impacts from Sediment Management Activities:

Sediment management activities involving dredging and deposit extracting have been identified as contributing factors to the loss of seagrass in the United States and elsewhere in the world (Phillips 1984, Giesen et al. 1990, Short and Wyllie-Echeverria 1996 cited in Sobal et al. 2005, NOAA 2001b). Stated concerns have included eelgrass removal, burial of adjacent plants, turbidity during dredging, increased erosion and turbidity due to loss of sediment stabilizing function of eelgrass, alteration of velocity and/or direction of currents, and altered nutrient flow mechanics of the ecosystem (Phillips 1984, NOAA 2001b).

Eelgrass habitat and associated functions have the potential to be affected, if present near areas of sediment management activities involving beach nourishment. Impact concerns during construction include damage and/or removal of eelgrass by equipment (dredges, anchors, chains, pipelines, vessel propellers), burial during nearshore or profile placement, and turbidity during dredging and/or sediment placement. Potential post construction concerns include sand transport sedimentation, erosion, and/or turbidity.

Types of sediment management activities and potential impact factors to eelgrass habitat include:

- Maintenance dredging of embayments – equipment, sedimentation, turbidity.
- Offshore borrow site dredging – not applicable.
- Nearshore placement – equipment, burial, sedimentation, turbidity.
- Profile placement – equipment, burial, sedimentation, turbidity.
- Beach placement – equipment, sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging	A	A	A	A	A	
Growth			P	A, P	A, P	A, P
Habitat			P	P	P	P
Reproduction /Recruitment			A, P	A, P	A	A, P
Respiration					A	

A = associated animals, P = plant

Equipment

Eelgrass has the potential to be impacted by dredges, support vessels, and equipment during maintenance dredging, offshore borrow site dredging, nearshore placement, and/or profile placement if present within the footprint of the sediment management project. Dredge equipment and/or anchors used by vessels in embayments or offshore could damage and/or remove eelgrass if present. Damage from pipelines (used to deliver sediments to receiver sites) may result if placed through an eelgrass area. Damage and/or removal of plants by propellers may occur if vessels transit shallow waters in embayments where eelgrass occurs, but would not be expected in deeper waters of embayments or offshore.

Dredging, discharge, and/or fill have been leading causes of eelgrass loss and/or reduced density in many embayments in the United States (Phillips 1984, Zieman and Zieman 1989 cited in Onuf 1994, Fonseca et al. 1992, NOAA 2001b). Dredging results in long-term loss of eelgrass either from slow recovery rates and/or change in the suitability of the habitat. Fonseca et al. (1992) noted that dredging typically create depths with insufficient light for seagrass. Hoffman (1990) reported that dredging to provide sediments for beach restoration at six sites in Mission Bay, California in 1981 resulted in eelgrass habitat loss, which took two to seven years to recover depending on site (Hoffman 1990). Eelgrass removed during dredging an anchorage area in Morro Bay, California did not recover after 3 years (Nitsos 1990).

Sabol et al (2005) documented eelgrass removal during dredging an anchorage and channel in a small boat harbor in Massachusetts. Eeelgrass did not recolonize after two years; light limitation associated with dredge depths being deeper (-2.4 to -3 m MLLW) than pre-dredge depths (-1.5 m MLLW) and potential physical disturbance from boat moorings and vessel shading were considered potential contributing factors.

Moore and Orth (1997) documented loss of eelgrass in Chincoteague Bay, Virginia, from clam dredging, which left circular “scars” in eelgrass habitat ranging in diameter from 95 ft (29 m) to 396 ft (120 m); no recovery and increased dredge sets were observed over a two-year mapping period and recovery rates were predicted to exceed 5 years. Subsequently, regulations were enacted in Maryland and Virginia to protect seagrass beds (Orth et al. 2006).

Other equipment such as boat moorings, mooring chains, and propellers also may result in persistent eelgrass losses. Moore and Orth (1997) estimated recovery of eelgrass beds from 1-m wide boat propeller cuts at 3 to 5 years. Propeller damage has resulted in fragmentation and substantial damage to seagrass beds in Florida with recovery estimated at several years, if at all (NOAA 2001b).

Several maintenance dredging projects in California were reviewed and found to use a combination of measures and monitoring to protect eelgrass habitat and/or functions. Prescribed dredge limits are used to protect eelgrass during maintenance dredging of Agua Hedionda Lagoon in San Diego County; maps of eelgrass distribution and density are required before and after dredging and impacts to eelgrass outside dredge limits require mitigation (USACE permit 200100328-SKB). No work zones, restriction of propellers in no work zones, and restriction of use of aggregates (sand, gravel, concrete, etc.) to cushion or cover sand delivery pipelines in eelgrass areas were specified for maintenance dredging in Morro Bay (USACE 2001).

Burial/Sedimentation

Nearshore and/or profile sand placement has the potential to directly bury eelgrass, if present within the project area. Indirect sedimentation of eelgrass meadows has the potential to occur from beach nourishment (beach, nearshore, and/or profile placement) associated with sand transport from the receiver site.

Limited available information indicates complete burial results in loss of eelgrass, but plants may tolerate partial sedimentation (Onuf and Quammen 1983). Harrison (1990) reviewed two separate cases where burial of eelgrass occurred in British Columbia, Canada. One case involved sediments that were targeted for discharge to fill erosion channels instead landing on adjacent eelgrass. The other case involved fine sediment being washed from behind a retaining wall during storms and being transported by currents into an eelgrass meadow. Field observations over a two year period revealed that eelgrass plants were able to survive partial burial where rhizomes were buried 4 to 6 in (10-15 cm) deeper than normal and some leafy material remained above the sediment surface. Over three months to a year, the buried portion of the leaf bundle transformed into a rhizome a few centimeters below the sediment surface (normal position). Harrison (1990) conducted laboratory experiments to test field findings, including burial of rhizomes with 1 to 6 in (2 to 15 cm) of sand and trimming leaves so that 2 to 12 in (5 to 30 cm) remained exposed above the sand surface. He reported that field observations were confirmed and demonstrated that plants survived with as little as 2 in (5 cm) of the leaf bundle above the sediment.

Harrison (1990) suspected that the nature of sediment introduction may be influential; he contrasted his study involving slower sedimentation from currents carrying released sediments through the water column with that of Blois et al. (1961), who found that eelgrass beds can be destroyed by the deposition of as little as 4 in (10 cm) of sediment if thre is a rapid shift laterally and covers all the leaves. Fonseca et al. (1992) pointed out that seagrasses almost never are buried in an upright position from dredging operations, but rather bend over with the typically rapid addition of sediments and become completely buried even with the addition of only a few inches (centimeters of sediment.

Also influential may be the sediment characteristics associated with sedimentation. For example, Onuf and Quammen (1983) reported substantial adverse impact to eelgrass both in areas where sedimentation resulted in immediate burial and where plants were not buried but experienced up to 6 in (15 cm) of fine sedimentation that changed the bottom type from <10% to >60% silt/clay. Sedimentation also resulted in shallowing of the impacted areas by 40 to 75%.

Sediment smothering of seagrass, accumulation of sediment and the consequent shallowing of the water, increased turbidity associated with sedimentation, and possibly fine particulate coatings from suspended sediment preventing photosynthesis has been associated with declines of multi-species seagrass meadows in Australia, including losses of different species of Zostera and *Heterozostera* (Kirkman 1997).

Increased silt/clay content of bottom type from sedimentation has been identified as detrimental to other seagrasses. Terrados et al.. (1998) compared patterns of change in species richness and biomass of Southeast Asian seagrass communities along siltation gradients in the Philippines and Thailand and found that seagrass species richness and community leaf biomass declined sharply when the silt and clay content of the sediment exceeded 15%.

Wilber et al. (2005) recently reviewed that other seagrasses have the ability to withstand limited burial depending on species-specific growth form, depth of burial, and properties of the sediment (particularly depth of the anaerobic layer), and indicated that mortality may result if plant elongation and growth rates are insufficient to surpass sediment accretion rates. Reviewed species included *Halodule wrightii* (tolerance decreased with increase in percent burial), *Cymodoce nodas* (buried seedling survival was higher when not artificially illuminated), and *Thalassia testudinum* (burial by 10 cm of sediment killed leaves, but not rhizomes, and re-growth occurred after currents carried away sediment) (Duarte et al. 1997, Thorhaug et al. 1973 and Fonseca et al. 1998 cited in Wilber et al. 2005).

Little information is available regarding potential impacts to eelgrass as a result of sand transport sedimentation from beach nourishment sites. Potential sedimentation from sand transport would occur at the rate of coastal processes and would not result in a rapid vertical rain of sediment as may be experienced with dredge/disposal projects.

A recent implemented beach restoration project in the vicinity of eelgrass habitat included the BEACON Goleta Beach Nourishment Demonstration Project. This project involved placement of 97,600 cy of sand onto the beach from three sources between 2003 and 2004. Part of the material (58,937 cy) was dredged from Santa Barbara Harbor and pumped as a slurry through a temporary submerged pipeline to the beach behind a temporary constructed swale used to limit turbidity, the remainder was trucked to the beach. Diver transects were established at distances of approximately 1,642 to 3,284 ft (500 to 1,000 m) in eelgrass habitat directly offshore and downcurrentt of the placement location. Monitoring was conducted before, within one month, and one-year after project implementation, and is still ongoing. Chambers Group (2004) reported seasonal die-back and recovery of eelgrass was normal and eelgrass density and cover one year after the project was similar or greater than the pre-project condition. Moffatt & Nichol (2004) reported that the lack of effect on eelgrass was expected because the eelgrass transects were in deeper water than the closure depth for this section of the coastline, and most of the time the turbidity plume observed during

beach nourishment operations did not extend beyond the surf zone and was never observed to extend as far offshore as the eelgrass beds.

Beach nourishment projects in California may require monitoring to address uncertainty associated with potential for sedimentation if eelgrass is in the vicinity. The BEACON South Central Coast Beach Enhancement Program, which is currently in the permitting phase, seeks to opportunistically use beach-quality material at six beach fill sites; one of which has offshore eelgrass habitat in the vicinity; that program specifies that monitoring of eelgrass would be used to guide future use of the site and/or to implement additional mitigation if necessary (M&N 2001).

Turbidity

Numerous experimental and field studies have demonstrated the importance of light on eelgrass distribution, growth, and viability. Eelgrass may be affected by variable light levels with periodic extreme turbidities (Zimmerman et al. 1991) as well as chronic light limitation due to eutrophication (Cardoso et al. 2004, Hauxwell et al. 2006) and/or eutrophication and dredging activities (Giesen et al. 1990). Eelgrass has been impacted in estuaries and along the open coast when pulses of turbidity lasted 3 to 4 weeks and stored carbohydrate reserves were expended (Burke et al. 1996, Moore et al. 1997, Cabello-Pasini et al. 2002). Shorter-term light limitation may have little consequence provided that sufficient carbohydrate reserves are available for eelgrass to draw upon (Zimmerman et al. 1991).

As mentioned above under sedimentation, the 2003 Goleta Beach Nourishment Demonstration Project resulted in limited turbidity that was confined to the surf zone; the sand slurry was pumped over a 25-day period behind a temporary swale on the beach where sands settled and water was discharged via three pipes to the ocean (Moffatt & Nichol 2004). The location of the ends of the discharge pipes varied from directly in the surfline at high tide to onto the dry beach at low tide. No adverse impact to eelgrass habitat was observed at distances ranging from approximately 1,642 to 3,284 ft (500 to 1,000 m) from the beach within the first year of monitoring (Chambers Group 2004).

Analysis of impact of a beach replenishment made with terrigenous sediments on another species of seagrass (*Posidonia oceanica*) showed a 20% reduction in leaf production immediately after the project, but was considered a pulse disturbance since leaf production appeared to recover over a relatively short-time scale (approximately 2 to 3 years) and no change in rhizome growth rates was detected (Guidetti 2001). A “beyond BACI” analysis was conducted that compared the impact site to two controls and dating methods were used to reconstruct 12 years of before data for the three sites.

Sabol et al (2005) reported substantial loss (65 percent) of eelgrass in an undredged anchorage basin adjacent to dredged areas of a small harbor in Massachusetts (also see impacts under equipment). Dredging spanned 5 months and removed 260,292 cy of sediment. Sabol et al. (2005) suggested that loss of eelgrass may have been sediment related. Dredged sediments were predominantly silt that were more likely to have increased turbidity. Turbidity and light levels were not monitored during the study. Silt curtains were deployed to reduce turbidity and sedimentation; however, high tidal flows resulted in breakage of anchor lines, seams ruptured in the curtains, and insufficient record keeping of deployments and performance by the contractor prevented evaluation of the efficacy of the silt curtains (*ibid.*). Eelgrass in the undredged anchorage exhibited substantial recovery

(45%) within 17 months despite regional reductions in eelgrass that were monitored in another water body over the same time period. Sabol et al. (2005) concluded that indirect impacts in areas where the dredged sediments are coarse may be minimal and indirect impacts are more likely to be present in areas where the dredged sediments are fine-grained and easily resuspended. They also cautioned that normal inter-annual variability observed in the absence of dredging was substantial and dredging impact studies should take this into consideration.

Cutterhead maintenance dredging of the outer basin of Agua Hedionda Lagoon has been conducted for several years without apparent losses to eelgrass due to turbidity based on before and after mapping surveys (MEC 1997, 2002).

Long et al. (1995) documented that dredging of access channel in Deception Bay, Australia had no effect on a different species of eelgrass (*Zostera capricorni*) when tested with a Before/After, Control/Impact Repeated measures (BACIR) sampling design. Sampling both before and at a control area documented a high degree of background variability that was not statistically different from that observed after dredging.

Turbidity associated with hydraulic placement and resuspension of dredged sediment in a shallow water embayment (Laguna Madre) in Texas is suspected as the most likely cause of loss of shoalgrass (*Halodule wrightii*) (Onuf 1994). Subsequent monitoring of shoalgrass, benthic invertebrates, and fish indicated slow recovery of habitat and community functions trends in impact areas (4 to 8 years) (Sheridan 2004).

Resource agency consultations and work windows have been used to protect spawning and/or foraging functions of eelgrass meadows by sensitive species from turbidity and sedimentation impacts during dredging. Dredging and disposal activities in San Francisco Bay are conducted in accordance with the Long-Term Management Strategy (USACE et al. 2001), which requires resource agency consultation for projects where there are eelgrass beds to avoid direct impacts to special interest species such as Pacific herring (*Clupea pallasi*) that use eelgrass beds as spawning areas and/or California least terns that forage in this habitat. Pacific herring eggs appear to require virtual absence of fine sediment layers to allow attachment to the substratum (reviewed by Germano and and Cary 2005). Work windows (August-September) have been used for maintenance dredging in Crescent City Harbor to avoid impacts to rockfish that use eelgrass as spawning habitat (USACE 1998C).

Recovery from Disturbance:

Eelgrass beds are slow to recover from physical impacts that results in disruption of sediment, removal of rhizomes, and removal of seed bank. Colonization by vegetative reproduction is very slow, and limited seed dispersal can affect natural recovery rates when there is substantial habitat loss (Orth et al. 1994, Orth et al. 2006). Eelgrass removed during dredging an anchorage area in Morro Bay, California did not recover after 3 years, and required transplant mitigation (Nitsos 1990). Eelgrass did not recover within 17 months of dredging a bay in Massachusetts (Sabol et al. 2005). Recovery of eelgrass beds after dredging in Mission Bay, California took 2 to 7 years depending on site conditions (Hoffman 1990). Eelgrass recovery estimates range on the order of years from propeller damage (3 to 5 years) and/or hydraulic clam dredging (> 5 years) (Moore and Orth 1997).

Recovery appears to be faster if plant loss affects above ground leaves, but does not affect rhizomes or the seed bank. Experimental studies indicate eelgrass and other seagrasses may tolerate partial burial; however recovery from indirect sedimentation is not well understood. Substantial recovery of eelgrass indirectly impacted from dredging-related turbidity occurred within 17 months but had not yet reached pre-impact levels (Sabol et al. 2005). A coastal eelgrass population that lost all shoots due to storm-related turbidity reestablished from seedlings, which appeared within two months of loss of shoots; eelgrass achieved pre-disturbance densities within seven months (Cabello-Pasini et al. 2002). Recovery also occurred primarily from seedlings the following season after anoxia resulted in widespread loss of shoots in a Danish estuary; the relatively rapid recovery was attributed to stabilizing effect of remaining rhizomes, presence of large seed bank, and surviving shoots (4% survivorship) (Greve et al. 2005). Similarly, recovery occurred within 9 months following anoxia in a lagoon in France (Plus et al. 2003). Recovery was noted within one growing season of substantial red tides in southern California embayments (K. Merkel and N. Davis, 2006 personal communications).

	Recovery Rates				
Impact	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment			X		
Burial				X	
Sedimentation				X	
Turbidity	X			X	
Habitat Loss			X		

Critical Impact Thresholds:

Eelgrass distribution and growth are largely controlled by light availability. A light level of approximately 10% of surface irradiance (roughly the Secchi disk depth) is considered a general indicator of eelgrass compensation depth (Dennison 1987). Light levels below 20% surface irradiance may reduce growth and survival (Backman and Barilotti 1976, Burke et al. 1996).

Eelgrass apparently has different minimum light thresholds depending on the environmental conditions where it occurs, ranging from 3 to 12 hours of photosynthetic-saturating irradiance per day (Dennison and Alberte 1985, Zimmerman 1990, Dennison et al. 1993, Orth et al. 2006). Therefore, critical thresholds may vary with location.

Tolerance of eelgrass to below threshold light levels associated with pulses of turbidity may span 3 to 4 weeks if there are sufficient stored carbohydrate reserves. However, it would be inappropriate to use this time span as a critical impact threshold without specific information of the dynamic relationship between eelgrass and existing light conditions of the water body and time of year considerations (e.g., reserves expected to differ between active growth and seasonal declining periods).

Complete burial of eelgrass leaves can result in habitat loss. Critical impact thresholds have not been established for partial burial and/or sedimentation. Available studies suggest that thresholds may differ depending on sediment characteristics (e.g., lower for silty sediments, higher for sands) and method of sedimentation (lower for deposition, higher for change in bottom elevation).

Equipment removal, sedimentation, and/or turbidity that resulted in habitat loss would be significant.

Data Gaps:

Limited information is available regarding impact responses and recovery rates from turbidity and sedimentation associated with sediment management activities.

Restoration:

In the southern part of the state, historic losses of eelgrass from development activities led to the development of the Southern California Eelgrass Mitigation Policy (revision 11), which is regulated by the NMFS, USFWS, and CDFG (NMFS et al. 2005, www.http://swr.nmfs.noaa.gov/hcd/policies/EEPO). This policy is use as a guidance document for central and northern California on a case-by-case basis (K. Merkel, personal communication 2006).

Eelgrass has been mitigated and/or restored using transplants comprised of shoots/rhizome sprigs harvested from existing beds (donor site) (Fonseca 1989; Merkel 1990, 1991, Davis and Short 1997, Short et al. 2002) and broadcast seeding in propagule limited areas (Pickerell et al. 2005, Orth et al. 2006). Use of "seed buoys" is another method being tried in San Francisco Bay that involves harvesting flowering reproductive shoots from a donor bed and placing the into mesh bags, which are attached to buoys and anchored at the target site, and as seeds mature, they fall through the mesh and scatter over the soft bottom (Hughes 2005).

Preparing eelgrass transplant sprigs
Photo by: SAIC

Eelgrass bed creation and/or replacement mitigation have been conducted in California to compensate for port and harbor development and/or dredging (e.g., Oakland Harbor, Los Angeles Harbor, Mission Bay, Newport Bay, San Diego Bay). Dredged material has been used as beneficial reuse sediment for several mitigation projects (Merkel and Hoffman 1990). Eelgrass restoration to replace historical losses also has been conducted (e.g., Morro Bay) (MNEP 2004).

Success of mitigation sites as fully functional eelgrass meadows has been demonstrated in California and elsewhere. Generally, success rates have increased over time as techniques have improved (Thayer et al. 1986, Fonseca 1989; Merkel 1990, 1991; Curtis 1991; Ware 1993, Hoffman 2000, Thom et al. 2001, Short et al. 2002). Research has shown reduced genetic diversity in transplant beds relative to natural beds, with concern raised regarding long-term resilience of transplants to disturbance (Williams and Davis 1996). The California

Eelgrass Mitigation Policy requires several safe guards to protect donor beds and enhance success of transplant efforts. These include specification that no more than 10% of an existing bed can be harvested to provide donor stock, and recommendations that plants be harvested from the area of direct impact whenever possible, and from a minimum of two

additional distinct sites to better ensure genetic diversity of transplanted areas. All eelgrass mitigation projects require coordination with the NMFS and CDFG.
Project design and understanding of environmental conditions are critical to mitigation success. The site should be given the same design consideration as provided to natural beds, including considerations such as potential shading of the site, depth range, current regimes, dampening of wave energies, sediments, slopes, turbidity, and timing of construction (Fonseca 1989, Merkel 1991a, 1991b).

The time required before transplanted eelgrass beds become fully functional varies. Fertilizer has been experimentally shown to enhance vegetative reproduction of transplants (Kenworthy and Fonseca 1991). Fonseca et al. (1990) reported a time interval of 1.9 years before a transplanted bed was indistinguishable from a mature natural eelgrass bed. Hoffman (1991) reported that fishery utilization of a transplanted bed in Mission Bay, California resembled a control site after one year.

The Southern California Eelgrass Mitigation Policy reviews that eelgrass beds require approximately three years to achieve full fishery utilization. That policy requires mitigation at a ratio of 1.2 to 1 when mitigation is conducted concurrent to projects > 100 square meters to compensate for lower production within the first couple of years after transplanting. A ratio of 1 to 1 is allowed for smaller impacts and/or when mitigation is completed three years in advance of the project.

Summary:

Eelgrass meadows are Essential Fish Habitat and Special Aquatic Sites under Section 404(b)(1) of the Clean Water Act. This habitat occurs in association with unconsolidated substrates in embayments and protected coastal areas in California. Eelgrass occurs from low intertidal to subtidal depths up to 100 ft (30 m). Eelgrass meadows are ecologically sensitive, supporting habitat functions for a variety of invertebrates, fish, and birds, and nursery habitat for commercial and recreational fishery species.

Sediment management activities have the potential to impact eelgrass meadows and functional values for associated species depending on proximity to impact. The basis of concern has been documented in embayments where there have been direct impacts to eelgrass and other seagrasses associated with equipment damage, dredge material removal, dredge material discharge, and/or fill. No impacts to eelgrass from beach nourishment were identified from the literature review.

The basis of concern for indirect turbidity and sedimentation impacts ranges from documented to protective conservatism grounded with relevant field and/or laboratory studies of vulnerability and tolerance of eelgrass to these types of impacts. For example, eelgrass is tolerant of partial sedimentation, with buried shoots capable of producing roots; i.e., plants may adjust to changes in sediment height when leaves extending above the sediment surface are not light limited. Eelgrass distribution along the open coast of California generally is in deeper subtidal areas protected from waves and most littoral sand transport, which reduces risk to sand transport sedimentation from beach nourishment projects, although nearshore edges of habitat may remain vulnerable.

Eelgrass is light limited when time requirements for saturated irradiance are not met. Eelgrass may tolerate light limitation (e.g., from turbidity) on the order of days to weeks by

drawing upon carbohydrate reserves to meet metabolic demands. However, the availability of reserves is likely to vary seasonally and in response to natural environmental, biological, and anthropogenic stresses. Therefore, there may be uncertainty associated with potential impacts from turbidity and sedimentation (including sand transport sedimentation) depending on project specific factors such as project size, duration, proximity to eelgrass habitat, condition of eelgrass, and environmental conditions at the time of project implementation.

Eelgrass is a clonal species that forms perennial beds through vegetative propagation of rhizomes, but also produces a high output of seeds and may functionally act as an annual in response to environmental stress. These adaptive reproductive strategies contribute to natural resilience of the species. Similar to surfgrass (Section 3.3.7), eelgrass recovers from disturbance by vegetative propagation and/or by seedlings depending on scale of disturbance. Recovery from direct removal and/or damage losses that result in loss of rhizome mat takes several years, if at all. Recovery may occur within one or two growing seasons when disturbance only affects above-ground leaves.

Direct impact concerns (from equipment, burial) have been avoided with recent beach nourishment projects in California during the design phase and in some cases was and/or will be reinforced with pre-construction surveys to refine vessel/pipeline routes and/or project footprints based on up-to-date existing conditions (e.g., 2003 Goleta Beach Nourishment Demonstration Project, South Central Coast Beach Enhancement Program). Post-construction monitoring has been required for some beach nourishment projects when eelgrass was in the vicinity to address uncertainty regarding potential indirect impacts.

Environmental work windows (timeframes vary) have been used in the San Francisco Corps District to minimize potential dredging-related turbidity and sedimentation impacts to important eelgrass habitat functions as spawning/nursery habitat for fishery species and/or foraging habitat for California least terns (http://el.erdc.usace.army.mil/tessp/prfile). Environmental work windows for eelgrass have not been established in California.

Eelgrass naturally thins above-ground growth in late fall to reduce metabolic demand over winter; the degree of die back may range from bed thinning to entire above-ground loss depending on environmental conditions. Eelgrass is sustained over winter by photosynthesis equaling the reduced metabolic demand and/or by use of stored carbohydrate reserves. Therefore, winter may represent a period when eelgrass is naturally less vulnerable to indirect turbidity impacts. However, prolonged exposures that exceed critical thresholds could result in loss of above ground leaves.

Impact losses of eelgrass habitat require replacement mitigation, which is guided by the Southern California Eelgrass Mitigation Policy. Success rates of eelgrass mitigation projects have increased over time as techniques have improved, and restoration of eelgrass functions and values has been demonstrated.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities to eelgrass habitat.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	Unnecessary	Documented	Documented	Documented	Documented
Critical Impact Thresholds	NA	Rhizomes removed	Habitat loss	Degrade habitat, habitat loss	Minimum irradiance-saturation requirements not met
Impact Responses	Improved light regime	Damage, mortality, habitat loss	No effect, loss of function and/or habitat	No effect, loss of function and/or habitat	No effect, reduced growth, habitat loss
Duration of Impacts	Potentially Years	Days-years	Months-years	Months-years	Hours-months
Potential for Restoration	NA	Yes	Unnecessary unless persistent	Unnecessary unless persistent	Unnecessary unless persistent

NA = not applicable

3.3.9 Shallow-Inlet Embayments

San Dieguito Lagoon inlet

Photo credit: Hany Elwany from Coastal Frontiers 2004, with permission

Regulatory Status:

Essential Fish Habitat	X
Other Designations that may Apply	Ecological Reserves, Preserves, Wildlfie Refuges

All coastal embayments are Essential Fish Habitat and include wetlands. Some shallow inlet embayments have additional status as ecological reserves, preserves, and/or wildlife refuges (e.g., Elkhorn Slough National Estuarine Research Reserve, Salinas River National Wildlife Refuge, Seal Beach National Wildlife Refuge, Bolsa Chica Ecological Reserve, Tijuana Slough National Wildlife Refuge, Tijuana River National Estuarine Research Reserve). Wetlands, sanctuaries and refuges are considered special aquatic sites under Section 404(b)(1) of the federal Clean Water Act of 1972, as amended (http://www.usace.army.mil/inet/functions/cw/cecwo/reg/40cfr230.htm#230.40).

Description and Distribution:

Shallow-inlet embayments as defined in this document as shallow inlet estuaries and lagoons. These systems include river mouth estuaries (ocean inlets associated with creeks, rivers, streams), canyon mouth estuaries, coastal dune estuary, and lagoons (Schaffer 2003), and include waterbodies identified as esteros and sloughs. Over 75 shallow-inlet embayments occur throughout California (refer to Table 3.1-1).

Several of the shallow-inlet embayments are in the vicinity of historical and/or potential future beach nourishment locations (Table 3.3-1). Some are subject to dredging or excavation to maintain open inlet status, tidal functions, or flood control capacity and historically some of the removed sediments have been beneficially reused on local beaches (e.g., San Lorenzo River, Agua Hedionda Lagoon, Batiquitos Lagoon). Other shallow-inlet embayments have been identified for enhancement and/or restoration to improve tidal circulation, which may present sediment beneficial reuse opportunities (e.g., Bolinas Lagoon, Malibu Lagoon, Ballona Wetlands, Bolsa Chica Ecological Reserve, Buena Vista Lagoon, San Elijo Lagoon, San Dieguito Lagoon). Others are located in the vicinity of potential future maintenance dredging in larger deepwater-inlet embayments and have the potential to be affected by sediment management activities (e.g., Elk Creek, Elk River, Eureka Slough, Noyo River, Elkhorn Slough, Seal Beach National Wildlife Refuge).

Life Stage or Function	California			On Land	Inter-tidal	Near-shore < 30 ft	Off-shore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Primary Habitat	X	X	X					P

Table 3.3-1. List of shallow-inlet embayments in the vicinity of historical and/or future beach nourishment sites and/or sediment management activities.

County	Shallow Inlet Embayment	Historical and/or Potential Future Beach Nourishment Sites	Historical and/or Potential Future Dredging in Vicinity
Del Norte	Elk Creek		Crescent City Harbor maintenance dredging
Humboldt	Elk River, Eureka Slough		Humboldt Bay maintenance dredging
Mendocino	Noyo River		Noyo Harbor maintenance
Marin	Bolinas Lagoon	Stinson Beach	Lagoon restoration
Santa Cruz	San Lorenzo River	Twin Lakes State Beach	San Lorenzo River Maintenance
San Luis Obispo	Cayucos Creek, Little Cayucos Creek, Willow Creek,	Cayucos Beach	
	Toro Creek, Morro Creek	Morro Strand Beach	Morro Bay Harbor maintenance dredging, Morro Bay restoration
	Pismo Creek	Price Street Pocket Beach	
Santa Barbara	Goleta Creek, Goleta Slough,	Goleta Beach County Park, Isla Vista	Goleta Slouth
	Carpinteria Creek/Marsh,	Carpinteria State and City Beaches	
Ventura	Los Sauces Creek	La Conchita Beach, Hobson County State Park Beach, Oil Piers Beach	
	Ventura River	Emma Wood State Beach, Surfers Point Park, Pierpoint Beach	
	Santa Clara River	McGrath State Beach	Ventura Harbor
Los Angeles	Malibu Creek/Lagoon		Lagoon restoration
	Ballona Wetlands		Wetlands restoration
	Los Angeles River		Maintenance dredging
Orange	Santa Ana River	Huntington Beach, Newport Beach	Santa Ana River flood control maintenance
San Diego	San Luis Rey River, Loma Alta Creek	Harbor Beach, Oceanside City Beach	Oceanside sand bypass
	Buena Vista Lagoon	South Oceanside Beach, Carlsbad City Beach	Lagoon restoration
	Agua Hedionda Lagoon	Carlsbad State Beach	Maintenance dredging
	Batiquitos Lagoon	South Carlsbad State Beach, Batiquitos Beach	Maintenance dredging
	San Elijo Lagoon	Cardiff State Beach	Inlet maintenance, Lagoon restoration
	San Dieguito Lagoon	Solana Beach, Del Mar	Inlet maintenance, lagoon restoration
	Los Penasquitos Lagoon	Torrey Pines	
	Tijuana River	Imperial Beach	

Potential Functions – Associated Species:

Shallow bays, esteros, lagoons, and sloughs s upport a variety of habitats including some combination of open water, channels, mudflats, coastal salt marsh, and salt flats. Creeks and rivers provide long corridors of open water, stream banks, transition from salt to freshwater marsh in areas along their banks, and often include adjacent riparian (freshwater influenced shrubs and trees) habitats. Due to their diversity of habitats, shallow-inlet embayments represent sensitive wetland areas and support primary living, foraging, and reproductive habitat for hundreds of species of invertebrates, fish, birds, and plants (CCC 1987). Inventories of wetland characteristics and biological resources have been compiled for many of California's coastal wetlands (see box inset).

Useful links to California wetlands information.

- http://www.wrpinfo.scc.ca.gov/
- http://www.ceres.ca.gov/wetlands/inventories/inventories.htm
- http://ucjeps.berkeley.edu/wetlands/titlepag.html

Sensitive eelgrass meadows occur in many of the shallow embayments along the coast. Eelgrass meadows, open water, and channels provide important nursery habitat for several commercial/recreation species, including Pacific herring, California halibut, and Dungeness crab (CCC 1987, CDFG 2001). Shellfish mariculture occurs in some lagoons and shallow bays (e.g., Agua Hedionda Lagoon). Anadronomous fish use creeks, esteros, and rivers for immigration and emigration between riverine and ocean habitats. Endangered tidewater goby occur in some coastal creeks and lagoons. The diversity of habitats supports a variety of shorebirds, wading birds, and waterfowl, including numerous state species of concern. Endangered California least tern and threatened snowy plover nest at several coastal wetlands in the state (CCC 1987).

Associated Species	Primary Habitat	Forage Habitat	Reproductive Habitat	Resting/ Roosting Habitat	Fisheries Habitat		Forage /Prey
					Commercial	Sport	
Vegetation	X		X				X
Invertebrates	X	X	X		X	X	X
Fish	X	X	X			X	X
Birds		X	X	X			
Vegetation							
Mammals		X					
T&E Species	X	X	X				

Life History Facts - Associated Species

Virtually all life history strategies may be represented by the flora and fauna associated with the variety of habitats represented at shallow inlet embayments. Marine and estuarine invertebrates, fish, and several special interest birds are described in further detail in Sections 4.2.3, 4.2.7, 4.3.2, and 4.4, respectively. Eelgrass life history characteristics are described in Section 3.3.8.

Migratory and/or seasonal use periods at coastal wetlands are of particular relevance to sediment management activities due to the sensitivity of many of the species that use shallow-inlet embayments as migratory stopover, breeding, spawning, and/or nursery locations. Dungeness crabs concentrate in shallows to mate (February – July) and use nearshore shallows and estuaries as nursery grounds (Section 4.2.3). Several species of fish migrate between embayment and ocean through the tidal inlet. Some fish migrate into bays and estuaries to spawn (e.g., Pacific herring, November-March) and others enter as juveniles and use embayments as nursery grounds (e.g., California halibut). Eelgrass meadows, which are important nursery grounds for Dungeness crab and many fish species, has seasonal growth (spring-fall) and die-back (late fall-winter) periods.

Anadronomous fish migrate up coastal streams to spawn and generally migrate back to the ocean as juveniles or young adults. Migratory runs vary by species, with chinook salmon displaying several sesasonal runs, coho salmon with fall-winter immigration and spring emigration runs, and steelhead with winter and summer "races". Additionally, several groups of birds exhibit overlapping seasonal occurrence periods at California wetlands; e.g., gulls (October-March), shorebirds (July-April), waterfowl (September-March), California least tern (September-April), and western snowy plover (September-February). Birds may feed on lagoon resources and/or move between wetland and ocean to forage.

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Nest Egg/Spawn Flower/Seed Planktonic Vegetative	Year round	Year round across species	Eelgrass late fall-winter	Yes, depending on species	Depends on species, annual to >20 years	Sedentary to mobile

Adaptations and/or Behaviors to Disturbance – Associated Species:

A variety of adaptations and behaviors are displayed by the species associated with shallow-inlet embayments. Eelgrass is adapted to variable light levels (Sections 3.3.8). Invertebrates display a variety of life history strategies (Section 4.2.7). Fish, birds, and marine mammals generally move from disturbance (Sections 4.3, 4.4, 4.5, respectively).

Species that live and/or frequent shallow-inlet embayments are adapted to the various physical/chemical gradients that characterize these areas. The inlet area is a dynamic environment, which may undergo seasonal change in position and volume of exchange with the ocean. Some inlets are intermittent, only being open during the winter-spring storm season.

Other embayments have persistent inlets with or without structural stabilization (e.g., jetties). Based on disturbance gradients (e.g., wave energy, sedimentation, variable salinity), opportunistic species (pioneer, rapid turnover rates) and/or mobile species characterize inlet areas. Generally, dynamic inlet areas may be expected to be inhabited by few invertebrate species, fish migrating between the ocean and open water and/or upriver portions of the embayment, and birds that may opportunistically forage in this area.

Water characteristics in shallow embayments may undergo substantial seasonal variability. Salinities may fluctuate due to storm water stream inflows, urban runoff, and tidal exchange differences associated with inlet status. Temperatures may vary substantially between

winter and summer due to shallow depths, and dissolved oxygen concentrations may fluctuate widely during summer associated with biostimulation of aquatic plants from nutrient inputs. Embayments with fluctuating physical/chemical water characteristics are inhabited by hardy estuarine invertebrate and fish species with broad environmental tolerance ranges. Environmental fluctuations are modulated in embayments with good tidal exchange, and open inlet embayments support a greater variety of marine and estuarine species.

Life Stage	Physical Adaptation			Avoidance Behavior			Habitat	High Reproductive Output and/or Growth
	Long Blades, Fronds	Protective Sheath	Rhizome	Burrow	Fly	Swim Walk		
Adult	X		X	X	X	X		
Juvenile			X	X	X	X	X	X
Egg/ Seed							X	

Potential Impacts from Sediment Management Activities:

Sediment management activities may impact shallow-inlet embayments during maintenance dredging/excavation to open inlets and/or to remove sedimentation to improve tidal circulation. Dredged sediments may provide beneficial reuse as source material for beach nourishment (Table 3.3-1), and is addressed herein. Activities associated with transport and disposal of dredged sediments at in-bay aquatic disposal sites and/or upland landfills are not addressed further in this document since they do not relate to beach nourishment.

Beach nourishment has the potential to impact shallow-inlet embayments if sediment transport sedimentation results in accelerated infilling and//or inlet closure. Impact concerns mainly relate to the potential disturbance and/or damage to sensitive biological resources. Potential impacts to sensitive species are considered in more detail in Section 4.

Types of sediment management activities and potential impacts to shallow-inlet embayments include:

- Maintenance dredging of embayments – equipment, sedimentation, turbidity.
- Offshore borrow site dredging – not applicable.
- Nearshore placement – sedimentation.
- Profile placement – sedimentation.
- Beach placement – sedimentation.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging	A	A	A		A	
Growth			P		A, P	P
Habitat			P		P	P
Reproduction			A, P		A	A, P
Respiration					A	
Resting/Roosting	A	A				

A = associated animals, P = plant

Equipment

Maintenance dredging and/or excavation may be conducted to remove excess sedimentation from inlets, channels, and/or basins of shallow-inlet embayments to sustain tidal exchange of wetland habitats. Removed sediments may include sands that provide opportunity for beneficial reuse to nourish local beaches (Table 3.3-1). Generally, complete mortality is assumed for dredge removed and/or entrained organisms, although some small percentage may survive depending on discharge location. Examination of core samples from dredged sediments pumped to a beach verified no live organisms (Parr et al. 1978).

Dredging has the potential to entrain early life stages and/or small organisms as a result of near bottom water being withdrawn by suction dredges (LaSalle et al. 1991). Studies examining dredge entrainment effects report that overall entrainment rates are generally low, but mortality rates may range from 56 to 100 percent depending on species and their size (LaSalle et al. 1991, Reine and Clarke 1998). Dredge entrainment may be of concern during seasonal periods when early life stages are more prevalent and activities occur in more confined areas (e.g., narrow channels, confined basins) where mobile organisms may not be able to avoid the dredge and/or passive organisms concentrate.

Removal of excess sedimentation may require work in and/or adjacent to sensitive eelgrass habitat. Dredge area restrictions may be used to minimize potential equipment impacts to this habitat (see Section 3.3.8).

Burial/Sedimentation

Maintenance dredging/excavation may result in sedimentation of adjacent habitat from sediment resuspension and settling as a result of short-term turbidity impacts (LaSalle et al. 1991). Dredge-related sedimentation is a potential concern for eelgrass habitat and/or early life stages using eelgrass as spawning habitat (Section 3.3.8).

A documented concern of beach nourishment projects is the potential for sediment transport of placed materials to accelerate the infilling of downcurrent navigational channels, which could increase dredging frequency to maintain the channels (NRC 1995). Shallow-inlet embayments may be vulnerable to sedimentation as a result of beach nourishment involving

nearshore, beach, or profile placement. The degree of vulnerability will depend on a number of factors including, but not limited to: proximity to sediment management activity, volume of placed sands, prevailing current direction, outflow characteristics (including tidal prism as appropriate) of water body, and inlet stability. Historic records of inlet closures and/or maintenance dredging requirements generally provide relevant information regarding potential vulnerability to sedimentation effects.

Concern for beach nourishment to increase the risk for inlet closure and/or acceleration of sedimentation in downcurrent shallow-inlet embayments was identified for the San Diego Regional Beach Sand Project, Goleta Beach Pilot Demonstration Project, and BEACON South Central Coast Beach Enhancement Program (SANDAG and USDN 2000; Chambers 2000b, 2001; Moffatt & Nichol 2005a). Monitoring of inlet status and/or sediment profiles has been conducted to address uncertainty associated with potential impacts. Monitoring of inlet status and/or sediment profiles to document sand transport was required with the above-mentioned projects. Mitigation measures requiring removal of excess sedimentation and/or paying costs associated with removal of excess sedimentation were specified in environmental documents and/or permit conditions for each of the above projects.

Monitoring during and after construction of the Goleta Beach Nourishment Pilot Demonstration Project (79,000 cy) did not document inlet closure and/or sedimentation problems at Goleta Slough (Moffatt & Nichol 2005c). Coastal Frontiers (2004) reported that the two jetty-stabilized lagoon entrances, Agua Hedionda and Batiquitos, remained open to the full range of tidal exchange with only minor variations in water depth and a post-project dredge rate 10% lower than pre-project. Of the three unstabilized entrances, there was a variation in closure frequency with the San Elijo entrance channel remaining open for a greater percentage of time (91% vs. 43% historically), the San Dieguito channel remaining open for a lesser percentage of time (51% vs. 77% historically), and the Los Peñasquitos channel remaining open for a comparable percentage of the time (86% vs. 93% historically).

The BEACON South Central Coast Beach Enhancement Program, specifies as a mitigation measure the monitoring of downcurrent inlets (e.g., Carpinteria Creek and Marsh, Goleta Slough, and Ventura River) during, immediately after construction, and for six months after construction and removal of excess sedimentation until inlets are stabilized, if necessary (Moffatt & Nichol 2005a).

<u>Turbidity</u>

Maintenance dredging/excavation of shallow coastal embayments will result in temporary turbidity impacts. The duration of the impact may be on the order of days to weeks depending on project volume. Elevated turbidity associated with removal of sandy sediments generally is limited to the construction period and dissipates rapidly after cessation of dredging (hours) (LaSalle et al. 1991). Relevant reports indicate that substantial turbidity and/or sedimentation in confined water bodies may result in decline in eelgrass (Section 3.3.8).

Turbidity impacts associated with wetlands restoration projects have the potential to be more pronounced than maintenance projects because some of the removed sediments may contain a higher silt/clay fraction associated with historic watershed runoff sedimentation. For example, the Batiquitos Lagoon Enhancement Project and lagoon-wide dredging of Agua Hedionda Lagoon resulted in removal of both sandy material suitable for beach nourishment and siltier material that was discharged into in-bay disposal sites, which were

then capped with sandy material. Turbidity impacts were minimized during those projects by use of silt curtains, plume monitoring, and controlled dredge/discharge rates (B. Dyson, dredge operator, personal communication 2005).

Potential turbidity impacts may include displacement of motile animals, avoidance by fish-eating birds (e.g., California least tern), disturbance (reduced foraging, respiration) of sedentary animals, and/or reduced light levels for aquatic plants (e.g., eelgrass), if present.

Recovery from Disturbance:

Sediment management activities would not result in habitat loss in shallow-inlet embayments. Maintenance activities consist of dredging/excavation to maintain open inlets, tidal function, and/or flood control capacity. Wetlands enhancement/restoration is not a management activity, although such activities may provide source sands compatible for beneficial reuse in beach nourishment.

Disturbance factors during maintenance dredging/excavation concern turbidity, sedimentation, and equipment disturbance during removal of sedimentation. Most of these disturbance factors would be expected to be limited to the construction period and consequently would be of short duration. Sedimentation impacts could span months to a year or more depending on the frequency required for maintaining the inlet of the embayment in an open condition.

Reported recovery rates of benthic invertebrates after dredging shallow water embayments are limited, but range < 1 year. Kaplan et al. (1975) reported recovery within 11 months after dredging Goose Creek, Long Island, New York. Recovery also was reported as being less than 1 year after dredging in the Dawho River, South Carolina (Van Dolah et al. 1984). Recovery rates of benthic invertebrates after inlet maintenance are unknown, but are expected to be relatively rapid because the dynamic and energetic nature of this environment would favor colonization by opportunistic species with rapid turnover rates (Section 4.2.7). Slower recover rates may occur from dredging in areas with infrequent sediment management activities. Sedimentation impacts could span months to a year or more depending on deposition volume and near bottom currents.

The risk of inlet closure due to sedimentation from a beach nourishment site would depend on proximity, prevailing current direction, and project volume. Potential impacts, if they occurred, could include increased infill volume without change to frequency of inlet maintenance or acceleration of infill volume and increased frequency of required inlet maintenance. Both these impacts would have the potential for sedimentation of benthic communities and sensitive habitats such as eelgrass, if present. Significant reduction in eelgrass from sedimentation would not be expected because inlet maintenance would be expected to be needed before infill volumes in more inland areas of the embayment reached critical levels.

However, infill sedimentation could have different consequences on recovery rates of invertebrates in the area requiring dredge/excavation maintenance. Increased volume without change to inlet maintenance frequency should have little to no effect on recovery rates. However, increased volume requiring more frequent maintenance could result in prolonged disturbance and delayed recovery rates in the area where maintenance

dredging/excavation occurred. No reports of increased inlet maintenance frequency associated with beach nourishment were found during the literature review.

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	X			X	
Burial					X
Sedimentation				X	
Turbidity	X				
Habitat Loss					X

Critical Impact Thresholds:

Sedimentation that resulted in inlet closure and//or increased the frequency of inlet closure would be a significant impact. Equipment removal, sedimentation, and/or turbidity that resulted in loss of eelgrass habitat would be significant. Critical thresholds with respect to species are reviewed in Section 4.

Data Gaps:

Limited information is available with respect to differences in sand transport rates and potential shoaling risk under different wave climates. Such information could be useful for project design.

Restoration:

Dredging and/or excavation to remove excess sedimentation resulting from beach nourishment projects in the vicinity may be necessary to maintain open inlets and/or tidal circulation. Some shallow embayments have routine sediment maintenance to maintain tidal functions (e.g., San Elijo Lagoon). Funding of additional sedimentation volume removal and/or frequency of inlet maintenance has been specified as a protective mitigation measure, if needed, for several beach nourishment projects in California. Dredging and/or excavation to restore inlet function are demonstrated successful technologies.

Several ecosystem enhancement and/or restoration projects have been conducted in shallow-inlet embayments in California to remove excessive sedimentation from watershed inputs and/or trapping of littoral sands. Often use of suitable removed sediments for beach nourishment (beach placement, nearshore placement) are featured elements of these projects. For example, dredging was used in Agua Hedionda Lagoon to remove sand bars that impeded tidal circulation and excess watershed derived sedimentation that resulted in turbidity and light limitation of eelgrass habitat; in-bay disposal and beach nourishment were elements of lagoon-wide restoration dredging of as-built project depths (MEC 1997b). In addition, dredging and other beneficial uses such as beach nourishment and/or bird nest site improvements have been key design components of several planned and/or implemented enhancement and/or ecosystem restoration projects at Batiquitos Lagoon, Bolinas Lagoon, Bolsa Chica Lowlands, San Elijo Lagoon, and San Dieguito Lagoon (Chambers Group 2000a, M&A 2001, USACE 2002, http://www.batiquitos.org; http://bolsachica.fws.org; http://www.marinopenspace.org/os_bolinaslagoonmgtplan.asp; http://www.sce.com/PowerandEnvironment/PowerGeneration/MarineMitigation/SanDieguitoLagoonRestoration.html).

Summary:

Shallow inlet embayments include highly productive estuarine wetland habitats. Creeks, rivers, and streams represent important wildlife corridors and connection between the land and ocean. Tidal exchange through the ocean inlet to these water bodies is critical to their ecological values. Sedimentation resulting from trapping of littoral sands and/or watershed runoff is a maintenance issue for many embayments. Dredging and/or excavation may be periodically conducted to maintain open inlet connections and tidal circulation in shallow-inlet embayments. Dredging also may be associated with ecosystem enhancement and/or restoration projects in embayments. Dredged and/or excavated material that is "clean" and sandy may provide opportunity for beneficial reuse for beach nourishment.

The distance between a beach nourishment location and the tidal inlet may be an important consideration depending on current direction and placed volume. Of particular concern is the potential for sand transport from a receiver site to exacerbate sediment maintenance problems in a shallow embayment. This concern also applies to beach nourishment projects using other source materials. Placing beach receiver sites downcurrent from tidal inlets and/or at a sufficient distance that inlet sedimentation is negligible may be the most effective measure to avoid impact concerns. Providing funding to to remove excess sedimentation may or may not be an effective mitigation measure depending on implementation feasibility (e.g., access, equipment availability).

Shallow inlet embayments are ecologically important ecosystems that may serve as nursery habitats for marine and esturarine species, include sensitive SAV habitat (eelgrass), provide connection to streams used by anadronomous fish, serve as important stopover and/or nesting areas for migratory birds, and/or provide nesting and foraging areas for endangered and/or threatened species. Conducting sediment management activities in these areas often requires implementation of mitigation measures to avoid and/or minimize impacts to sensitive resources (Section 6).

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities to shallow inlet embayment habitat.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Documented	NA	Documented	Relevant reports
Critical Impact Thresholds	NA	Loss of eelgrass, substantial entrainment	NA	Inlet closure, increase dredge volume and/or dredge frequency	Loss of eelgrass habitat
Impact Responses	NA	Damage, entrainment, mortality	NA	Shoaling, degrade habitat	Reduce foraging, Impair feeding, respiration,
Duration of Impacts	NA	Months-years	NA	Days-months	Hours-months
Potential for Restoration	NA	Eelgrass feasible	NA	Mechanically open inlet feasible	Eelgrass feasible

NA = not applicable

3.3.10 Deepwater Inlet Embayment

Photo permission: Ralph Appy
Port of Los Angeles

Regulatory Status:

Essential Fish Habitat	X
Other Designations that may Apply	Ecological Reserves, National Estuary, Preserves, Wildlfie Refuges, Wildlife Sanctuaries

All coastal embayments are EFH. Some of the larger embayments are bay-estuaries with portions designated as ecological reserves, refuges, and/or wildlife sanctuaries (e.g., Arcata Marsh and Wildlife Sanctuary, Humboldt Bay National Wildlife Refuge, San Francisco Bay National Wildlife Refuge, San Francisco Bay National Estuary, San Pablo Bay National Wildlife Refuge, Morro Bay National Estuary, Upper Newport Bay Ecological Reserve, Sweetwater Marsh National Wildlife Refuge).

Sanctuaries and refuges are considered special aquatic sites (SAS) under Section 404(b)(1) of the federal Clean Water Act of 1972, as amended (http://www.usace.army.mil/inet/functions/cw/cecwo/reg/40cfr230.htm#230.40).

Description and Distribution:

Deepwater inlet embayments, as defined in this study, include marine bays, large bay-estuaries, ports, harbors, and associated marinas. Over 25 deepwater inlet embayments occur throughout California (Table 3.3-2). Most of these require periodic dredging to maintain navigable channels. Disposal options for dredge materials are based on sediment grain size and chemical contaminant levels. Alternatives may include in-bay disposal sites, offshore Ocean Dredge Material Disposal Sites (ODMDSs), and/or upland sites for finer-grained sediments with acceptable contaminant levels. Upland landfills and/or contained aquatic disposal (CAD) sites may be used for contaminated sediments. Beneficial reuse of dredged materials may include fill for port expansion and/or use of “clean” sandy sediments for beach nourishment.

Potential beach nourishment placement locations for “clean” sandy sediments dredged from deepwater inlet embayments were listed on Table 3.3-2 based on review of historical placement locations and identified future projects (refer to Section 2.1). In cases where historical and/or future beach nourishment locations were not identified during document review and online searches, this was noted on the table.

	California			On Land	Inter-tidal	Near-shore < 30 ft	Off-shore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Habitat	X	X	X					P

Table 3.3-2. List of deepwater inlet embayments and associated historical and potential future beach nourishment sites in California.

County	Deepwater inlet Bays, Harbors, Ports with Sediment Management Dredging Needs	Historical and/or Identified Potential Beach and/or Nearshore Placement (Beach Nourishment) Sites
Del Norte	Crescent City Harbor	Crescent City Beach, Whaler Island
Humboldt	Trinidad Harbor	Not identified
Humboldt	Humboldt Bay-Arcata Bay	Disposal at offshore ODMDS
Mendocino	Noyo Harbor	Upland disposal
Sonoma	Bodega Bay and Harbor	Nearshore, Doran Regional Park Beach
San Francisco	San Francisco Bay	Ocean Beach
Multiple	San Francisco Bay, San Pablo Bay, Suisan Bay, Richardson Bay	In-bay disposal
Alameda	San Francisco Bay	Crown Beach
San Mateo	San Francisco Bay	Coyote Point
	Pillar Point Harbor	Princeton Beach
Santa Cruz	Santa Cruz Harbor	Twin Lakes State Beach
Monterey	Moss Landing Harbor	Moss Landing State Beach, South Sandspit, Aquatic SF-12, SF-14
Monterey	Monterey Marina	Upland (negligible)
	Elkhorn Slough	
San Luis Obispo	Morro Bay Harbor	Morro Strand State Beach, Morro Bay State Park Sand Spit, Montana Del Oro State Park,
	Port San Luis	West Bluff Beach, Price Street Pocket Beach
Santa Barbara	Santa Barbara Harbor	East Beach
Ventu ra	Ventura Harbor,	McGrath State Beach
	Channel Islands Harbor,	Silver Strand
	Port Hueneme	Hueneme Beach
Los Angeles	Marina Del Rey Harbor	Venice Beach, Dockweiler Beach,
	King Harbor	Redondo State Beach
	Los Angeles Harbor	Cabrillo Beach*
	Long Beach Harbor	Long Beach
	Alamitos Bay	Alamitos Peninsula Beach
Orange	Anaheim Bay	Surfside-Sunset Beach
	Sunset Aquatic Regional Park	Not identified
	Huntington Harbor	Not identified
	Newport Bay, Upper Newport Bay Ecological Reserve	West Newport Beach
	Dana Point Harbor	San Juan Capistrano Beach, Baby Beach
San Diego	Oceanside Harbor	Oceanside
	Mission Bay	Not identified
	San Diego Bay	Coronado, Silver Strand, Imperial Beach

Note: Alternative disposal sites may be used depending on physical/chemical characteristics of dredged material.

Note: Some embayments have shallow depths, but were listed here because of a deepwater inlet connection to the ocean. For example, relatively shallow Sunset Aquatic Regional Park and Huntington Harbor are under the influence of the deepwater inlet at Anaheim Bay.

*Sands were historically placed at Cabrillo Beach; however, no near future beach nourishment projects were identified (R. Appy, personal communication).

Potential Functions Supported:

Deepwater inlet embayments generally serve multi-use purposes as commercial, recreational, and/or military ports, harbors, and marinas. Embayments may support commercial mariculture (abalone, oysters, mussels). Recreational fishing and boating generally occur.

Deepwater inlet embayments provide protected habitats for hundreds of species of invertebrates, fish, aquatic vegetation, and birds (e.g., CCC 1987, Allen 1999, MEC 2000b, Thompson et al. 2000). Substantial resident populations of invertebrates and fish inhabit embayments; however, there also is considerable transient movement of fish and some invertebrates between the ocean and embayments for spawning and foraging purposes. Anadronomous fish may migrate through embayments on their way to and from the ocean and upstream rivers. Marine mammals, including seals, sea lions, sea otters, dolphins and whales on occasion may be observed in large embayments (MEC 2000b, USACE 2001).

Vegetated habitats (e.g., eelgrass, kelp beds) occur in many deepwater inlet embayments, which provide important nursery habitat for several commercial/recreation species, including Pacific herring, California halibut, rockfish, and Dungeness crab (CCC 1987, USACE 1998, MEC 2000B, CDFG 2001, USACE et al. 2001). Endangered California least tern nest forage at several of the large embayments along the coast; e.g., San Francisco Bay, Los Angeles Harbor, Mission Bay, and San Diego Bay (Section 4.4.2).

Associated Species	Primary Habitat	Forage Habitat	Reproductive Habitat	Resting/ Roosting Habitat	Fisheries Habitat		Forage /Prey
					Commercial	Sport	
Vegetation	X		X				X
Invertebrates	X	X	X		X	X	X
Fish	X	X	X			X	X
Birds		X	X	X			
Mammals		X					
T&E Species	X	X	X				

Life History Facts – Associated Species:

Similar to shallow inlet embayments (Section 3.3.9), a wide range of life history strategies are represented by the flora and fauna associated with deepwater inlet embayments. Additionally, seasonal occurrence and/or migrations that were briefly summarized for shallow inlet embayments also apply to deepwater embayments. Additional descriptions of kelp and eelgrass resources are given in Sections 3.3.6 and 3.3.8, respectively. Invertebrates, fish, birds, and marine mammals are described in further detail in Sections 4.2,7, 4.3, 4.4, and 4.5 respectively.

Anadronomous fish make seasonal runs through some embayments to adjacent tributaries (LFR 2004). Additionally, several groups of birds exhibit overlapping seasonal occurrence periods at California wetlands; e.g., gulls (October-March), shorebirds (July-April), waterfowl (September-March), California least tern (September-April), and western snowy plover (September-February). Birds may feed on lagoon resources and/or move between wetland and ocean to forage.

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Nest Egg/Spawn Flower/Seed Planktonic Vegetative	Year round	Year round across species	Eelgrass slowed growth and/or die back late fall-winter	Yes, depending on species	Depends on species, annual to >20 years	Sedentary to mobile

Adaptations and/or Behaviors to Disturbance:

A variety of adaptations and behaviors are displayed by the species that are associated with deepwater inlet embayments. Kelp and eelgrass are adapted to variable light levels (Sections 3.2.6, 3.2.8). Invertebrates encompass a variety of life history strategies ranging from opportunists to more equilibrium species (Section 4.2.7). Fish, birds, and marine mammals are mobile and generally move from areas of disturbance (Section 4.3, 4.4, 4.5, respectively).

Species that live and/or frequent deepwater inlet embayments are adapted to the various physical/chemical and disturbance gradients that characterize these areas. Entrance channels are used by a variety of species that migrate between the open ocean and more protected areas of embayments. Anadronomous fish may migrate through embayments on their way to and from the ocean and upstream rivers. Substantial transient movement of fish, some invertebrates, and marine mammals also occur between the ocean and embayments for spawning and/or foraging purposes.

Navigable channels and other areas subject to routine maintenance dredging may have altered benthic communities depending on frequency of disturbance. Areas that have more variable physical/chemical water characteristics due to shallow depths, proximity to freshwater inflows, and/or reduced tidal circulation from port/harbor development also may have altered communities; generally, characterized by hardy estuarine invertebrate and fish species with broad environmental tolerance ranges (MEC 2000b)

Life Stage	Physical Adaptation			Avoidance Behavior			Habitat	High Reproductive Output and/or Growth
	Long Blades, Fronds	Protective Sheath	Rhizome	Burrow	Fly	Swim Walk		
Adult	X		X	X	X	X		
Juvenile	X		X	X	X	X	X	
Egg/seed							X	X

Contaminated sediments represent a sediment management challenge for many of California's ports and harbors. Benthic communities may be substantially altered in contaminated sediments; e.g., dominated by pollution tolerant invertebrate species that when eaten transfer contamination up the food chain. Passage of environmental laws in the 1970s and subsequent improvements in environmental discharge practices have reduced contaminant effects in most ports. For example, widespread areas with few to no benthic invertebrates were observed in severely polluted Los Angeles and Long Beach Harbors in the 1950s; whereas, polluted and semi-healthy areas were not as widespread and over 400

benthic invertebrate species were recorded in 2000 (MEC 2000b). Different strategies for reducing contaminated sediments are implemented in California's ports and harbors, including excavation and disposal in CAD sites, capping to sequester contaminated sediments and provide clean sediment surface and/or removal to upland landfill sites. Contaminated sediments are not permitted for use as beach nourishment materials.

Potential Impacts from Sediment Management Activities:

Sediment management activities may impact deepwater-inlet embayments during dredging to maintain navigable channels and dredged material disposal. Sediments dredged from deepwater-inlet embayments may provide beneficial reuse as source material for beach nourishment. Beach nourishment has the potential to impact deepwater-inlet embayments if sediment transport sedimentation from the receiver sites results in accelerated infilling of the embayment. Although inlet closure may not be an issue, an increased frequency of maintenance dredging would be of potential concern. Dredging and discharge related to beach nourishment are addressed herein.

Activities associated with transport and disposal of dredged sediments at in-bay aquatic disposal sites, ODMDSs, port development locations, and/or upland landfills are not addressed further in this document since they do not relate to beach nourishment.

Types of sediment management activities and potential impact factors to deepwater-inlet embayments include:

- Maintenance dredging of embayments – equipment, sedimentation, turbidity.
- Offshore borrow site dredging – not applicable.
- Nearshore placement – sedimentation.
- Profile placement – sedimentation.
- Beach placement – sedimentation.
- Dune placement – not applicable.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging	A	A	A		A	
Growth			A, P		A, P	P
Habitat			A, P		P	P
Reproduction			A, P		A	A, P
Respiration					A	
Resting/Roosting	A	A				

A = associated animals, P = plant

Equipment

Maintenance dredging may be required to remove sedimentation from deepwater inlet embayments to maintain navigable channels. Dredging results in removal of benthic habitat, mortality of benthic invertebrates, and disturbance displacement of fish, birds, and marine mammals. Most removed benthic invertebates do not survive dredging (Section 3.3.9). Removed sediments may include sands that provide opportunity for beneficial reuse to nourish local beaches (Table 3.3-2).

Dredge entrainment generally is at low rates, but may range higher in more confined areas at certain times of year (LaSalle et al. 1991, Reine and Clarke 1998). Environmental windows have been used to minimize potential impacts to spawning areas for Dungeness crabs (Section 4.2.3) and Pacific herring (Section 4.3.2).

Removal of excess sedimentation may require work in and/or adjacent to sensitive eelgrass habitat. Dredge area restrictions may be used to minimize potential equipment impacts to this habitat (see Section 3.3.8).

Burial/Sedimentation

Maintenance dredging of deepwater-inlet embayments may result in sedimentation of adjacent habitat from sediment resuspension and settling as a result of short-term turbidity impacts (LaSalle et al. 1991). Dredge-related sedimentation is a concern for sensitive habitats and spawning areas in embayments. Dredge area restrictions and environmental windows have been used to minimize potential sedimentation/turbidity impacts on species using eelgrass habitats as nursery areas in some deepwater embayments in California such as Crescent City Harbor (USACE 1998c) and San Francisco Bay (USACE et al. 2001).

A documented concern of beach nourishment projects is the potential for sediment transport of placed materials to accelerate the infilling of downcurrent navigational channels, which could increase dredging frequency to maintain the channels (NRC 1995). The degree of vulnerability depends on a number of factors including, but not limited to: proximity to sediment management activity, volume of placed sands, and prevailing current direction.

Turbidity

Maintenance dredging/excavation of embayments will result in short-term turbidity impacts. The duration of the impact may be on the order of days to months depending on project volume. Elevated turbidity associated with removal of sandy sediments generally is limited to the construction period and dissipates rapidly after cessation of dredging (hours) (LaSalle et al. 1991).

Potential turbidity impacts may include displacement of motile animals, avoidance by fish-eating birds (e.g., California least tern), disturbance (reduced foraging, respiration) of sedentary animals, and/or reduced light levels for aquatic plants (e.g., eelgrass, kelp), if present. Sabol et al (2005) reported substantial loss (65 percent) of eelgrass in an undredged anchorage basin adjacent to dredged areas of a small harbor in Massachusetts (Section 3.3.8).

Recovery from Disturbance:

Sediment management activities would not result in habitat loss in deepwater inlet embayments. Disturbance factors during maintenance dredging concern equipment damage, turbidity, and sedimentation. Turbidity disturbance would be expected to be limited to the period of maintenance dredging and consequently would be of temporary and or short duration. Recovery rates of benthic invertebrates from dredging deepwater-inlet embayments have been reported as being rapid (e.g., 1 to 6 months) in navigation channels of Coos Bay, Oregon and Mobile Bay, Alabama (McCauley et al 1977, Clarke et al. 1999 cited in Newell et al. 1998) (Section 4.2.7). Slower recover rates would be expected if dredging occurred in areas with infrequent sediment management activities. Sedimentation impacts could span months to a year or more depending on deposition volume and near bottom currents.

	Recovery Rates				
Impact	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	X	X			
Burial					X
Sedimentation	X	X			
Turbidity	X				
Habitat Loss					X

Critical Impact Thresholds:

Sedimentation that resulted in substantial increase in the frequency and/or volume of maintenance dredging would be a significant impact. Critical thresholds with respect to species are reviewed in Section 4.

Data Gaps:

Cumulative impacts from sediment management activities in combination with multiple uses, watershed runoff, and point and nonpoint source discharges in coastal harbors are not well understood.

Restoration:

Beach nourishment has the potential to increase maintenance dredging requirements if conducted in the vicinity of deepwater inlet embayments (NRC 1995). Several maintenance dredging programs in California include location of beach nourishment sites downcurrent of breakwater entrance channels to restore eroded beaches resulting from the structural interruption of littoral transport (e.g., Channel Islands Harbor, Port Hueneme Harbor, Santa Barbara Harbor, USACE 1994a, 1998a).

Deepwater embayments, particularly more inland aquatic areas with shallows, may experience habitat degradation due to excessive sedimentation resulting from watershed inputs and/or littoral transport. Dredging was a key design component of planned and/or implemented enhancement and/or ecosystem restoration projects at Morro Bay and Upper Newport Bay (USACE and County of Orange 2000, USACE 2003, http://www.mbnep.org; http://www.city.newport-beach.ca.us/ UpperBayProject.html).

Summary:

Deepwater-inlet embayments support a variety of marine and estuarine species, may include sensitive SAV habitat (eelgrass), represent important nursery habitat for a number of fisheries species, and may have potential occurrence of endangered and/or threatened species. Conducting sediment management activities in these areas often includes implementation of mitigation measures to avoid and/or minimize impacts to sensitive resources (Section 6).

Sedimentation resulting from trapping of littoral sands and/or watershed runoff is a maintenance issue for many embayments. Dredged materials that are "clean" and sandy provide may provide beneficial reuse opportunity depending on availability of suitable receiver sites.

Similar to shallow inlet embayments, the distance between a beach nourishment location and the tidal inlet may be an important consideration depending on current direction and placed volume. Of particular concern is the potential for sand transport from a receiver site to exacerbate sediment maintenance problems in the entrance channel of a deep water embayment. Placing beach receiver sites downcurrent from tidal inlets and/or at a sufficient distance that inlet sedimentation is negligible may be the most effective measure to avoid impact concerns. Providing funding to augment dredge maintenance budgets has been required for some California beach nourishment projects. However, determination of whether sedimentation results from beach nourishment or natural processes can be challenging.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities to deepwater inlet embayment habitat.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Documented	NA	Documented	Documented
Critical Impact Thresholds	NA	Loss of eelgrass habitat, substantial entrainment of fishery species	NA	Loss of eelgrass habitat	Loss of eelgrass habitat
Impact Responses	NA	Displacement, mortality	NA	Shoaling, degrade spawning areas	Reduced foraging, avoidance
Duration of Impacts	NA	Days to years	NA	Days to years	Days to months
Potential for Restoration	NA	Eelgrass feasible	NA	Unnecessary unless persistent loss of eelgrass	Unnecessary unless persistent loss of eelgrass

NA = not applicable

4.0 REVIEW OF SPECIES POTENTIALLY AFFECTED BY SEDIMENT MANAGEMENT ACTIVITIES

This report section is a companion to the review of habitats in Section 3, providing more detailed summaries of the animals associated with the reviewed habitats. Similar to the review of habitats, a standardized format (see Section 3.3) is used to summarize the following types of information: regulatory status, distribution, potential functions provided by the species, life history characteristics, adaptations and/or behavior to disturbance, potential impacts from sediment management activities, recovery from disturbance, critical impact thresholds, data gaps, restoration considerations, and summary.

Section Topics:

4.1 Overview of Species and Impact Concerns
4.2 Review of Invertebrates and Impact Responses
4.3 Review of Fish and Impact Responses
4.4 Review of Birds and Impact Responses
4.5 Review of Marine Mammals and Impact Responses

Section 4.1 provides an overview of types of species where sediment management activities may occur. Relevant ecological background information and impact responses are reviewed for sensitive species and species groups for invertebrates, fish, birds, and marine mammals in Sections 4.2 through 4.5, respectively. Keystone species ov vegetation associated with coastal SAV habitats are reviewed in Section 3. Integrated summaries of sediment management impacts on habitats and associated species are presented in Section 5.

4.1 Overview of Species and Sediment Management Impact Concerns

Sediment management activities have the potential to impact both aquatic and terrestrial species. The following question of interest to the CSMW is addressed in this section:

- *What are the types of species and threatened and/or endangered species that may be potentially impacted by sediment management activities, especially beach nourishment, along the entire California coast?*

Species reviewed in this section were selected in coordination with a technical advisory committee, which included representatives from resource and regulatory agencies (Section 10). Species include several threatened and/or endangered species, managed fishery species, and species groups associated with coastal sandy substrate and/or rocky substrate habitats. The sensitive species and species groups occur in the sandy substrate, rocky, SAV, and embayment habitats reviewed in Section 3. Detailed reviews of terrestrial species other than birds are not addressed because most sediment management activities, with the possible exception of dune placement have little to no potential to affect those species. An overview of terrestrial species is provided as part of the review of the coastal dune and/or strand habitat in Section 3.2.1 .

Table 4.1-1. List of sensitive species and types of species in areas where sediment management activities may occur.

Species	Threatened and/or Endangered	Commercial and/or Recreational Importance	Associated Habitat
Invertebrates			
Abalone	White abalone	Red abalone	Rocky Intertidal, Rocky Subtidal
California Spiny Lobster		X	Rocky Subtidal, Surfgrass Beds, Kelp Forests and Beds
Dungeness Crab		X	Sandy Subtidal, Eelgrass Meadows, Embayments
Pismo Clam		X	Sandy Beach, Sandy Subtidal
Sea Urchins		X	Rocky Subtidal, Kelp Forests and Beds
Sandy Beach Invertebrates		Bait	Sandy Beach
Sandy Subtidal Invertebrates		Sea cucumbers, Prawns/Shrimp	Sandy Subtidal
Rocky Intertidal Invertebrates			Rocky Intertidal
Rocky Subtidal Invertebrates		Wavy Turban Snail, Rock Crabs, Rock Scallop, Sea cucumbers	Rocky Subtidal
Fish			
California Grunion		X	Sandy Beach, Neritic
Pacific Herring		X	Neritic, Eelgrass Meadows, Embayments
Salmonids	X	X	Neritic, Embayments
Bottom-Dwelling Fish		Corbina, Flatfish, Sand Bass	Subtidal Sands, Eelgrass Meadows, Embayments
Water Column Fish		Croakers, Seabass, Silversides, Surfperch	Neritic, Embayments
Subtidal Reef Fish		Cabezon, Greenling, Rockfish, Scorpionfish, Sheephead	Rocky Subtidal, Kelp Forests and Beds
Tidepool Fish		Monkeyface Prickleback	Rocky Intertidal, Rocky Subtidal
Birds			
California Brown Pelican	X		Neritic, Sandy Beach, Rocky Intertidal, Embayments
California Least Tern	X		Neritic Coastal Dunes and/or Strand, Sandy Beach, Embayments
Western Snowy Plover	X		Coastal Dunes and/or Strand, Sandy Beach, Embayments
Gulls and Terns			Neritic, Coastal Dunes and/or Strand, Sandy Beach, Rocky Intertidal, Embayments
Shorebirds			Coastal Dunes and/or Strand, Sandy Beach, Embayments
Wading Birds			Rocky Intertidal, Embayments
Waterfowl			Neritic, Rocky Intertidal, Embayments
Marine Mammals			
Sea Otter	X		Neritic, Kelp Forests, Embayments
Pinnipeds	Guadalupe fur seal, Stellar sea lion		Neritic, Sandy Beaches, Rocky Intertidal, Rocky Subtidal, Kelp Forests and Beds, Embayments
Cetaceans	Whales		Neritic, Kelp Forests and Beds

The reviewed information provides the basis for addressing the following questions of interest to the CSMW:

- *What are the direct and indirect ways species may be impacted by sediment management activities, particularly beach nourishment?*
- *Are documented concerns based on scientific data, uncertainty based conservatism, or other information?*

Similar to Section 3, the following species reviews consider impacts from equipment, burial/sedimentation, and turbidity effects associated with the range of sediment management activities involving dredging and beneficial use of sediments for beach nourishment and/or obtaining other source sands for beach nourishment. The activities may include maintenance dredging/excavation in embayments; offshore borrow site dredging; and nearshore, profile, beach, and/or dune placement. Direct and indirect impacts during construction and indirect impacts after construction (later in time) are considered.

The following types of impact concerns have been identified in reviews of dredging and/or beach nourishment (Hirsch et al. 1978, Wright 1978, Naqvi and Pulllen 1983, LaSalle et al. 1991, NRC 1995, Greene 2002).

- Equipment (dredges, pipelines vehicles, vessels) involved with removal, transport, and/or placement of sands in coastal habitats has the potential to result in direct mortality and/or indirect disturbance (e.g., displacement, reduced foraging, reduced nesting success) of aquatic and terrestrial species during the construction phase.
- Construction related turbidity has the potential to affect foraging, respiration, recruitment, and/or reproduction of aquatic animals, and reduced photosynthetic activity of plants (see Section 3). Turbidity has the potential to result in displacement disturbance of mobile animals. An additional concern with turbidity is the potential to affect foraging activities of birds that feed on aquatic species.
- Sands placed in subaerial (beach) or sublittoral (subtidal) habitats may result in direct burial impacts of species with limited mobility and/or cause indirect disturbance displacement of mobile species.
- Indirect displacement and/or mortality impacts also are of concern after construction from sedimentation associated with the natural winnowing and transport of placed sands by coastal processes.

4.2 Review of Invertebrates and Impact Responses to Natural Disturbance and Sediment Management Activities

4.2.1 Abalone

Species Scientific Name	***Haliotis* spp.**

Regulatory Status:

Endangered	White abalone
Threatened	
CDFG Managed	X
Other	Black abalone candidate species

Black abalone
Photo credit: http://www.marine.gov

Abalone found in California waters.

Red abalone (*Haliotis rufescens)*
Pink abalone (*H. corrugata)*
Green abalone (*H. fulgens)*
Black abalone (*H. cracherodii)*
White abalone (*H. sorenseni)*
Threaded abalone (*H. assimilis**)
Pinto abalone (*H. kamtschatkana)*
Flat abalone (*H. walallensis)*

* Considered a subspecies of the Pinto abalone. Several hybrid crosses of abalone have been reported from California waters.

Source: McBride and Conte 1996

Seven species of abalones occur offshore California. The previously recognized threaded abalone is considered a southern subspecies of the pinto abalone (McBride and Conte 1996, CDFG 2001). Hybrid abalones are not uncommon in areas where several species occur together; the most common hybrids are among red and white abalone with pink abalone (http://www.fishtech.com/facts.html).

White abalone was proposed for listing as endangered under the federal Endangered Species Act in 2000 and was listed as endangered in 2001 (NMFS-NOAA 2001); it was added to the List of Endangered and Threatened Wildlife in 2005 with the applicable date of listing given as 2001 (USFWS 2005). Black abalone is a candidate species for listing under the federal Endangered Species Act (http://www.CDFG ca.gov/ mrd/forum2004.html#abalone).

Most species of abalone are considered depleted off California due to impacts from commercial and sport fishing, expansion of the sea otter population, disease, pollution, loss of kelp populations associated with ENSO events, and inadequate wild stock management (CDFG 2001). The abalone fishery, which began in the early 1900s, started with the red and then alternated to pink, green, white, and black as stocks became serially depleted. Over 4.4 million pounds of abalone were taken between 1950 and 1970 by commercial divers, all in southern California, and by 1996 less than ten percent of the usual take could be harvested (http://www.biosbcc.net/ocean/marinesci/06future/abhist.htm). In 1997 the Thompson bill (AB 663), also known as the Abalone Bill, went into effect. This bill closed both the recreational and commercial harvesting of all species of abalone from state waters south of San Francisco. Recreational fishing for red abalone continues to be allowed north of San Francisco County, but is restricted to breath-hold divers and shore pickers (CDFG 2001). No more than 3 red abalones may be taken at any time, and no no more than 24 abalones may be taken during a calendar year (CDFG 2005a).

The Abalone Recovery and Management Plan (ARMP) was recently finalized (CDFG 2005b). This plan outlines restoration strategies for depleted abalone stocks in central and southern California and describes the management approach to be used for northern California red abalone and eventually for other recovered abalone species.

Description and Distribution:

Abalones are associated with rocky coasts, kelp beds, and surfgrass beds. The distributions of the different species vary geographically and by water depth (Cox 1962, CDFG 2001), as follows: red and black abalones extend from Oregon to Baja California and range from intertidal to subtidal depths. Green, pink, and white abalones, and the southern subspecies of pinto abalone range from Point Conception south into Baja California. Green abalones mainly are found between 10 and 20 ft (3 and 6 m), often associated with surfgrass beds, but may occur as deep as 60 ft (18 m). Pink abalones range from the lower intertidal to nearly 200 ft (60 m), but mostly occur from 20 to 80 ft (6 to 24 m). White abalones range from 60 to 200 ft (18 to 60 m). Flat and pinto abalones are rare south of Point Conception; flat abalones occur subtidally to depths greater than 70 ft (21 m) and most pinto abalones in California occur between 30 and 50 ft (9 and 15 m).

The occurrence of abalones has been reduced to hard-to-find crevice dwelling individuals in many areas of the state as a result of substantial depletion.

Life Stage or Function	California			On Land	Inter-tidal	Near-shore < 30 ft	Off-shore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X		X	X	X	E
Juvenile	X	X	X		X	X	X	E
Egg	X	X	X		X	X	X	E
Primary Habitat	X	X	X		X	X	X	E
Foraging Habitat	X	X	X		X	X	X	E
Nesting/Spawning Habitat	X	X	X		X	X	X	E

Potential Functions:

Abalones are eaten by a variety of invertebrates, fish, and sea otters. Abalone eggs and larvae are eaten by filter-feeding animals. Crabs, lobsters, octopuses, starfish, fish, and predatory snails prey on juvenile abalones. Large abalones are taken by fish (e.g., bat ray, cabezon) and threatened sea otters. The federally threatened sea otter is considered the most effective natural predator (http://www.fishtech.com/facts.html). As previously noted, a substantial commercial fishery used to occur off California, but only a limited recreational fishery is currently allowed in northern California.

Associated Species	Forage/ Prey	Eaten By
Invertebrates		X
Fish		X
Birds		
Vegetation	X	
Marine Mammals		X
Terrestrial Animals		
Humans		X

Abalone aquaculture has developed to serve domestic and international seafood markets and to enhance wild stocks. Abalone farms began producing abalone in the 1980s (McBride

and Conte 1996). Some of these farms used grow-out chambers located in the ocean and others used land-based, flow through tanks. The red abalone, and to a lesser extent pink and green abalones, have been the principal species grown in California aquaculture facilities for commercial operations. White abalone are being raised in hatcheries (UCSB under Dr. Morse, Proteus SeaFarms International) in an effort to increase native population stocks; the first release was scheduled in 2005 (http://www.biosbcc.net/ocean/marinesci/06future/abhist.htm).

Life History Facts:

Abalones are synchronous broadcast spawners, with the females and males releasing eggs and sperm at the same time (CDFG 2001). Individuals must be fairly close to support reproduction; distances greater than 3 to 4 feet (1 to 1.2 m) may be insufficient for fertilization (*ibid.*). Because of reduced stocks, abalone may not recruit annually.

Fertilized eggs hatch into a microscopic, free living trochophore larvae, which spends several days to a week in the plankton depending on species and temperature, and then settle to the bottom and begin to develop the adult shell form. Laboratory studies indicate that white abalone have a larval period of 9 to 10 days, which may result in greater dispersal of this species relative to other abalone species (Hodbay and Tegner 2000 cited in NMFS-NOAA 2001). Reproductive output increases from thousands to millions of eggs with increasing size.

Abalones are motile animals, but normally are sedentary. Abalones generally establish a particular homesite (home scar) that juveniles forage around and return to daily, and that adults seldom leave because of their reliance on drift algae and plants that lodge near them (Abbott and Haderlie 1980). However, abalones may move about somewhat to aggregate for spawning and/or in response to environmental factors. Red abalones have been shown to move distances up to 0.4 mile (0.5 km) (CDFG 2001).

Abalones are long lived. Sexual maturity is reached between 3 and 7 years depending on species. Black, green, pink, and red abalones live 20 years or more, and the white abalone has been estimated to live 35 to 40 years (Abbott and Haderlie 1980, CDFG 2001).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Spawn Planktonic	Black (spring-summer, fall); Green (summer-early fall); Pink (year round); Red (year round in southern California, April – July in northern California); White (winter).	Year round	None	None	> 3 Years	Motile

Abalones are herbivorous. Juvenile abalones graze on rock-encrusted coralline algae, diatoms, and bacterial films. Adult abalones feed on loose pieces of drift kelp and/or algae. Some species exhibit clear distinction between juvenile and adult habitat. For example, red abalone juveniles live in small spaces between rocks and under boulders, and move into larger crevices when they switch to feeding on drift kelp (CDFG 2001).

Seawater temperature and/or food supply influence abalone growth and reproduction. Warm water associated with El Niños in the 1980s and 1990s decreased kelp beds, which had a devastating effect on populations of abalone, especially in southern California where the El Niño effect was greater than in northern California (CDFG 2001).

Warm water conditions may increase disease symptoms from bacteria. Abalone populations have been substantially impacted by the withering syndrome, which is caused by a rickettsia-like procaryote that results in weight loss due to bacteria-induced starvation (e.g., abalone unable to digest its food), pedal atrophy, weakness, lethargy, and death (Alstatt et al. 1996, CDFG 2001). Because the shell stays the same size, abalone are vulnerable to predation when the animal is too weak to hold the shell against rock substrate. Although the bacteria may be normally present, it is during warmer water conditions that disease symptoms result in abalone mortality.

Mass mortality of black abalone populations from withering syndrome began to be documented in 1985 at the Channel Islands in southern California and was found to have spread into central California in the 1990s (Alstatt et al. 1996). Black abalone mortality due to withering syndrome has been documented as far north as Pacifica, San Mateo County (CDFG 2001). Withering syndrome also has been reported, to a much lesser degree, to affect green, pink, red, and white abalones (FR 2001).

An invasive species of sabellid worm (from South Africa) was accidentally introduced to mariculture farms in the late 1980s. This worm causes the shell of the abalone to deform, but does not hurt the abalone's body. CDFG learned of infestations at some aquaculture facilities in 1994; thereafter initiating corrective measures to eradicate the exotic species. These measures have included testing and inspection of stock at aquaculture facilities, obtaining permission from CDFG before transfer of sabellid-free stock between aquaculture facilities, a ban on wild-planting from mariculture farms, and testing and certification of sabellid-free abalone stock before outplanting (http://www.CDFG.ca.gov/news/news98/98087.html).

Adaptations and/or Behaviors to Disturbance:

Abalones naturally reduce their exposure to predation by living between small rocks and under boulders as juveniles and in crevices as adults. They clamp their shell down against the rock surface with their powerful foot to avoid dislodgement. They also exhibit escape response to contact by sea stars, including retreat movement, shell rotation, and movement of their foot in a manner that dislodges starfish tube feet (MacGinitie and MacGinitie 1968, Abbott and Haderlie 1980).

Giant sea star (*Pisaster giganteus*)
Photo by: D. Heilprin, SAIC

Abalones that become dislodged during storms may reorient themselves if they land against rocks and/or right side up. However, they are highly vulnerable to predation if they land upside down since they are unable to right themselves. Partial or temporary burial in sand apparently does not affect abalones (Cox 1962). Abalones clinging to the bases of rocks set in sand frequently have only a small part of their shell and body exposed above the sand. However, when sand completely covers a rock or reef where abalones are established, they must move and find hard substrate. Red abalones have been reported to move from sanded-in reefs (CDFG 2001).

In most localities, abalones and sea urchins are not intermixed due to competition for food and living space. Sea urchins are intensive algae grazers and may crop rocks almost completely bare. When this occurs, the abalones are forced to move to another area to find food (Cox 1962). Populations are maintained through broadcast spawning and planktonic larvae; however, the short-lived planktonic stage limits dispersal of most species.

Life Stage	Behavior			Protective Shell	Habitat	High Reproductive Output and/or Growth
	Crawl	Clamp onto rock	Short larval stage			
Adult	X	X		X	X	
Juvenile	X	X		X	X	
Egg/larvae			X			X

Potential Impacts from Sediment Management Activities:

Concerns regarding potential impacts to abalone relate to the depleted nature of populations and planned restoration and management of stocks in California. Abalones have the potential to be directly or indirectly impacted during construction and/or sedimentation after construction, if present in the vicinity of sediment management activities.

Types of sediment management activities and potential impacts to abalone may include:

- Maintenance dredging of embayments – not applicable.
- Offshore borrow site dredging – equipment, turbidity.
- Nearshore placement – equipment, sedimentation, turbidity.
- Profile placement – equipment, sedimentation, turbidity.
- Beach placement – sedimentation, turbidity.
- Dune placement – Sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Mortality			X	X	X	X
Foraging					X	X
Growth					X	X
Habitat			X	X	X	X
Reproduction					X	X
Respiration					X	

Equipment

Anchoring associated with offshore dredging of sand borrow areas, nearshore discharge, and/or placement of pipelines to convey sands to the beach have the potential to overturn rocks and/or damage abalone living on intertidal and/or subtidal reefs, if present in the area of these activities. Equipment impacts, it they were to occur could include temporary dislodgement and/or damage, both which could lead to predation and mortality. Damage to abalones often is fatal since there is no mechanism to coagulate the blood (Cox 1962).

Pre-construction environmental surveys were used to finalize pipeline and vessel routes to avoid direct impacts to kelp canopies and sensitive rocky reef resources during the 2001 San Diego Regional Beach Sand Project (AMEC 2002) and 2003 Goleta Beach Demonstration Project (Chambers Group 2003, Moffatt & Nichol 2003). Pre-construction surveys to finalize pipeline and vessel routes in areas with intertidal and nearshore reefs have been recommended as a beach nourishment mitigation measure (Courtenay et al. 1972, Chambers Consultants and Planners 1992, Chambers Group 2000b, SANDAG and USDN 2000).

Burial/Sedimentation

Direct burial of sensitive hard bottom areas, such as those that support abalone, are unlikely to be permitted in California. Several California beach nourishment projects have been designed during project planning to avoid direct placement of sand in areas with persistent rocky intertidal, subtidal reefs, and/or kelp beds (e.g., potential abalone habitat) (Tekmarine and Analytic Planning Service 1990; Chambers 1992; USDN 1997a, b; SANDAG and USDN 2000; Moffatt & Nichol 2001). Burial of habitat occupied by abalones would be a significant impact.

Indirect sedimentation of reefs from post-construction sand transport from beach nourishment sites if of potential concern if abalones are present. Limited information indicates that abalones are capable of tolerating some partial and/or temporary burial, but may move from sanded-in reefs (Cox 1962, CDFG 2001). Larval settlement and/or small juvenile abalones may be more vulnerable to sedimentation effects because of their occurrence on the underside of rocks. Potential impacts would depend on the nature and duration of sedimentation of rocky reefs and presence of abalone.

Pre- and post-construction monitoring of reefs in the vicinity of beach nourishment projects have been recommended as a mitigation measure to document project impacts and ensure no significant impacts to sensitive resources. Black abalone were searched for but were absent at intertidal monitoring sites before and after the 2001 San Diego Regional Beach Sand Project; although abalones were not a target species during monitoring of subtidal rocky reefs and kelp beds, other species monitoring indicated no significant sedimentation impacts to those habitats (AMEC 2005).

Turbidity

No specific information on the response of abalones to suspended solids concentrations was found during the literature review. The shallow depth ranges of several California abalone species suggest adaptation to turbid waters. Abalones have two gills in the mantle cavity beneath the shell and holes on the shell allow water to enter and exit the mantle cavity (Abbott and Haderlie 1980). Substantial turbidity has the potential to interfere with

respiration. Turbidity effects generally are limited to the construction period, but actual exposure duration would vary depending on project- and site specific conditions. Prolonged exposure to elevated suspended sediment concentrations can reduce marine vegetation (Konar and Roberts 1996, Pondella et al. 1996, CRM 1997), which if occurred could affect abalone food supply. Abalone growth and reproduction may be reduced when food is limited (CDFG 2001).

Recovery from Disturbance:

Recovery rates of abalone may be rapid in the case of minor disturbance such as short-term turbidity and/or partial sedimentation of reefs. Recovery could take years if there was direct mortality, increased vulnerability to predation from indirect displacement, food supply reduction, and/or habitat loss associated with prolonged sedimentation. Turbidity effects would be limited to the construction period, but actual exposure duration would vary depending on project- and site specific conditions. Recovery of abalones is slow due to depressed population levels and unpredictable recruitment.

	Recovery Rates				
Impact	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	X	X	X		
Burial			X		
Sedimentation	X	X	X	X	
Turbidity	X			X	
Habitat Loss			X		

Critical Impact Thresholds:

Critical impact thresholds have not been established for California abalone species. Reproductive failure was reported for an Australian species when stocks were 40% of unaffected population biomass; most California populations are below a 40% level (CDFG 2001). Burial and/or sedimentation that resulted in habitat loss and/or prolonged turbidity that resulted in loss of algal food base would be of ecological concern.

Data Gaps:

Limited information is available on sedimentation and turbidity impacts to abalone.

Restoration:

Artificial reef construction is considered technically and economically feasible and has been specified as a potential mitigation measure in the event of significant impacts to rocky reefs for several California beach nourishment projects (e.g., 2001 San Diego Regional Beach Sand Project, 2003 Goleta Beach Demonstration Project). Restoration of abalone stocks remains uncertain and will be determined with implementation of the ARMP (CDFG 2005b).

Summary:

No beneficial or adverse impacts to abalones have been documented from sediment management activities. Direct impacts to rocky habitat supporting abalones are unlikely to

be permitted in California. Equipment impacts could range from dislodgement disturbance to mortality. Direct burial of reef habitat could result in displacement, increased vulnerability to predation, reduced recruitment, habitat loss, and/or direct mortality.

Documented impacts from natural sedimentation include no impact from temporary partial burial to displacement from sanded-in reefs. Although effects of turbidity on abalone have not been studied, species live in naturally turbid intertidal and nearshore areas. Of concern is the potential for prolonged turbidity and/or persistent sedimentation to reduce abalone food supply, habitat, and/or recruitment.

Critical impact thresholds for abalones are unknown, but considered low due to depressed population levels. Loss of abalone habitat due to persistent sedimentation would require restoration to avoid significant impact to Essential Fish Habitat. The feasibility of restoring abalone stocks to reefs is uncertain; information on feasibility will be forthcoming with implementation of the ARMP. Project design avoidance and/or pre-construction surveys to finalize pipeline and vessel routes have been used to avoid direct and minimize indirect impacts to sensitive reef habitats and are applicable to abalones.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on abalone.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Protective conservatism	Protective conservatism	Documented, protective conservatism	Protective conservatism
Critical Impact Thresholds	NA	Rocks overturned Mortality	Habitat loss	Habitat loss	Loss of algal food base
Impact Responses	NA	Disturbance, mortality	Displacement, reduced recruitment, habitat loss, mortality	Disturbance, displacement, reduced recruitment, habitat loss, mortality	Respiration interference, reduced growth, reproduction
Duration of Impacts	NA	Days-months	Months-years	Months-years	Days-months
Potential for Restoration	NA	Unnecessary to uncertain	Unnecessary to uncertain	Uncertain	Unnecessary to uncertain

NA = not applicable

4.2.2 California Spiny Lobster

Species Scientific Name	***Panulirus interruptus***

Regulatory Status:

Endangered	
Threatened	
CDFG Managed	X
Other	

Photo credit: SCE http://www.sce.com/PowerandEnvironment/PowerGeneration/MarineMitigation/KelpReefProject.htm

California spiny lobster is a valuable fishery species in southern California. Commercial fishermen use baited traps, which are set on the bottom in rocky areas ranging from nearshore areas close to shore to depths of 300 ft (91 m) (CDFG 2001).

The commercial fishery is regulated by season and permits with a formal commercial restricted access program, which limits permits based on prior participation in the lobster fishery. Lobsters also are prized by sport divers, who may use hoop nets or their hands but no other devices to capture no more than 7 lobsters per day. Both commercial and recreational lobster catch is size regulated with a minimum size of 3 ¼ inches (8.3 cm) carapace length. The open fishing season ranges from the Saturday preceding the first Wednesday in October through the first Wednesday after the 15th of March (CDFG 2005a).

Description and Distribution:

California spiny lobsters occur from Monterey Bay to Manzanillo, Mexico primarily in rocky areas ranging from the intertidal to approximately 240 ft (73 m) (CDFG 2001). Lobsters may occur along breakwaters and in association with riprap in coastal embayments (MEC 2000b). Commercial fishing is limited near any breakwater, jetty, pier, and/or wharf depending on ownership; i.e., within 750 ft (229 m) if publicly-owned or within 75 ft (23 m) if privately-owned (http://www.CDFG.ca.gov/licensing/pdffiles/fg1448.pdf).

Life Stage or Function	California			On Land	Inter-tidal	Near-shore < 30 ft	Off-shore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X			X	X	X	E, P
Juvenile	X	X			X	X	X	E, P
Egg	X	X				X	X	E, P
Primary Habitat	X	X			X	X	X	E, P
Foraging Habitat	X	X			X	X	X	E, P
Nursery/Spawning Habitat	X	X			X	X		E, P

Potential Functions:

Lobsters are eaten by fish (e.g., sheephead, cabezon, kelp bash, rockfish, sea bass), sharks (horn, leopard), moray eels, and octopuses (Shaw 1986). As noted above, the California spiny lobster is a valued commercial and recreational fisheries species. San Diego County

produces the highest landings followed by Los Angeles/Orange and Santa Barbara/Ventura counties (CDFG 2001).

Lobsters are omnivores with juveniles feeding on crustaceans, foraminiferans, tiny mollusks, fish eggs, coralline algae, and surfgrass, and adults feeding on a variety of algae, invertebrates (clams, snails, mussels, sea urchins), fish, and newly molted lobsters (Engle 1979, CDFG 2001).

Associated Species	Forage/ Prey	Eaten By
Invertebrates	X	X
Fish	X	X
Birds		
Vegetation	X	
Marine Mammals		X
Terrestrial Animals		
Humans		X

Life History Facts:

California spiny lobsters mate in waters 50 to 100 ft (15 to 30 m) from December through March, and the females move to shallower water (< 30 ft, 9 m) to release eggs approximately 9 to 10 weeks later (Shaw 1986). Larvae (phyllosome stage) are planktonic for 7 to 9 months and have wide dispersal capability. Larvae metamorphose to a presettling puerulus stage, which swims to nearshore waters from May through September, where it is associated with floating habitats consisting largely of surfgrass. The puerulus stage, which is structurally similar to the adult although the animal is transparent, lasts about 2.5 months. Once pueruli settle on the bottom they molt in 9 to 11 days and are fully pigmented juvenile lobsters.

Juveniles usually spend their first two years in surfgrass beds, although they also occur in rocky habitats with other algae (Engle 1979). Generally, adult lobsters live in rocky crevices or holes (dens) during the day and leave their dens at night to search for food. After approximately 2 years, lobsters undergo seasonal offshore (October to November) and onshore (late March to May) migrations (Engle 1979, CDFG 2001).

Lobsters grow by shedding their hard exoskeleton, termed molting, with several molts during its early life and annual molting as they age. California spiny lobsters become sexually mature after 3 to 6 years for males and 5 to 9 years for females (Engle 1979, Shaw 1986). Both sexes may reach legal harvestable size after 7 to 8 years (Engle 1979), but it may take 10 to 12 years depending on environmental conditions (CDFG 2001). Lobsters may live 20 to 30 years.

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Mate Egg Carrying Planktonic Settlement	Dec-Mar May-Jun 5-9 months Jun-Oct (peak Jul-Aug)	Year round	None	Offshore (Oct-Nov), Onshore (late Mar-May)	20-30 years	Motile

Adaptations and/or Behaviors to Disturbance:

Lobsters have several adaptations, behaviors, and life history traits that protect them from predation and natural disturbance. Their hard exoskeleton provides some protection from predation, and lobsters are highly mobile, able to walk and/or burst-swim from disturbance.

Juvenile lobsters have cryptic coloration (green) that match their surfgrass habitat. Sub-adults find shelter in shallow rocky crevices and/or mussel beds and adults live in rocky crevices or holes during the day. Multiple individuals (up to several hundred) may shelter

together facing the den entrance with their paired antennae facing outward in a defensive posture (Engle 1979). The antennae are used to physically keep predators at a distance (MacGinitie and MacGinitie 1968) and to create sound to deter predators (Patek 2001). In addition, local populations are maintained by high larval production and recruitment from widely dispersed planktonic larvae.

Life Stage	Behavior			Exo-Skeleton	Habitat (Shelter and Nursery)	High Reproductive Output and/or Growth
	Crawl/ walk	Swim	Antennae Defense			
Adult	X	X	X	X	X	
Juvenile	X	X	X	X	X	
Egg/larvae						X

Potential Impacts from Sediment Management Activities:

Limited information is available on the effects of sediment management activities on lobster. Commercial fishermen have expressed concern that sedimentation and turbidity associated with beach nourishment may result in loss and/or degradation of nearshore rocky reef and surfgrass habitats that could reduce recruitment and/or growth of lobster to harvestable size and/or result in movement of lobster from harvestable areas (SANDAG and USDN 2000). Construction impacts of concern include direct damage of habitat by equipment, sediment placement burial, and/or indirect disturbance from turbidity. Post construction concerns include the potential for indirect sedimentation of habitat.

Types of sediment management activities and potential impacts to abalone may include:

- Maintenance dredging of embayments – turbidity.
- Offshore borrow site dredging – equipment, turbidity.
- Nearshore placement – equipment damage, burial, sedimentation, turbidity.
- Profile placement – equipment damage, burial, sedimentation, turbidity.
- Beach placement – equipment damage, burial, sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging						
Growth						
Habitat			X	X		X
Reproduction						
Respiration					X	

Equipment

Anchoring associated with offshore dredging of sand borrow areas, nearshore discharge, and/or placement of pipelines to convey sands to the beach have the potential to damage and/or displace lobsters, if present. Inadvertent equipment impacts, it they were to occur, would be expected to be localized and could include damage and/or displacement to individual lobsters. Both could be fatal since displacement could lead to loss from predation. If sediment management activities included nighttime operations, California lobster could be vulnerable to damage in soft substrate areas within foraging distance from daytime rocky shelters and/or during seasonal onshore-offshore migration.

Pre-construction environmental surveys were used to finalize pipeline and vessel routes to avoid direct impacts to kelp canopies and sensitive rocky reef resources during the 2001 San Diego Regional Beach Sand Project (AMEC 2002) and 2003 Goleta Beach Demonstration Project (Chambers Group 2003, Moffatt & Nichol 2003). Pre-construction surveys to finalize pipeline and vessel routes in areas with intertidal and nearshore reefs have been recommended as a beach nourishment mitigation measure (Chambers 1992, 2000b).

Burial/Sedimentation

Because lobsters forage nocturnally across a range of habitats, vulnerability to burial/sedimentation impacts may be greater for day-time shelter and/or nursery habitats where lobsters are more sedentary.

Nearshore sand placement in areas with low relief reefs with limited resource development and/or on subtidal sands has the potential to indirectly impact foraging habitat of lobsters, if present. Occurrence of lobsters in nearshore waters varies seasonally and depends on a variety of factors including habitat characteristics (e.g., proximity to nursery and/or sheltering reef areas) and time of year (e.g., March to October). Impacts and recovery of subtidal sand and reef habitats are discussed in Section 4.2.7 and 4.2.9, respectively.

Limited information is available regarding response of lobsters to beach nourishment. Lobsters were monitored in nearshore subtidal reefs before and after the 2001 San Diego Regional Beach Sand Project. No strong correlations between lobster abundance and percent cover of sand, low-relief substrate, and high-relief substrate were observed during this project (AMEC 2005).

No reports on response of spiny lobster to sand inundation of reefs and/or surfgrass beds were found with the literature review. It is expected that impacts would depend on the nature and duration of sedimentation and presence of lobster. Post-construction sand transport from beach, nearshore, and/or profile placement sites could potentially result in sedimentation of rock shelters and/or nursery habitat resulting in lobster displacement, reduced recruitment, and/or increased vulnerability to predation. Consequently, sedimentation of reef areas is of potential concern for California spiny lobsters.

Relevant reports for other species indicate a general sensitivity to silty sedimentation. Post-pueruli larvae of spiny lobster (*Panulirus argus*) avoided settling in heavily silted algal beds (Herrnkind et al. 1988) and juvenile American lobster (*Homarus americanus*) avoided gravel shelters that were covered with silt/clay (Pottle and Elner 1982 cited in Wilber et al. 2005). Wilber et al. (2005) suggested that loss of habitat used as shelter by juvenile lobsers may

increase competition for remaining shelters, decrease growth rates as a result of crowding, and increase vulnerability to predation associated with additional time spent searching for non-silted areas.

Turbidity

No specific information on the response of California spiny lobster to suspended solids concentrations is available. The shallow depths at which the species may occur suggests adaptation to turbid waters. A laboratory study found no mortality, increased grooming of the gills, or stress-related walking behaviors by juvenile lobsters (*Jasus edwardii*) in New Zealand to exposure of suspended sediment concentrations ranging from 85 to 363 mg/L for four days (Perry 1997). No information is available on response of spiny lobsters to prolonged exposure to elevated turbidity.

Recovery from Disturbance:

Short term elevations in suspended sediment concentrations would not be expected to result in significant impacts given natural adaptations and behavioral characteristics of lobsters. Turbidity effects generally would be limited to the construction period, but actual exposure duration would vary depending on project- and site specific conditions. Recovery rates associated with burial and sedimentation also would depend on magnitude and duration of impact. Lobsters have the potential to be displaced from reefs with substantial sedimentation, and recovery could take years if burial or sedimentation resulted in loss of shelter and/or recruitment habitat.

	Recovery Rates				
Impact	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	X	X	X		
Burial	X	X	X		
Sedimentation	X	X	X		
Turbidity	X			X	
Habitat Loss			X		

Critical Impact Thresholds:

Impacts that resulted in substantial reduction of rocky subtidal habitat and/or surfgrass habitat where lobsters occur would be of ecological concern.

Data Gaps:

Limited information is available on the effects of sedimentation and turbidity on lobsters.

Restoration:

Restoration would not be necessary unless sediment management activities resulted in persistent sand inundation of rocky intertidal and/or subtidal reefs where sensitive and/or managed resources occurred, such as lobsters. Artificial reef construction is considered technically and economically feasible and has been specified as a potential mitigation measure in the event of significant impacts to rocky reefs for several California beach nourishment projects (e.g., 2001 San Diego Regional Beach Sand Project, 2003 Goleta

Beach Demonstration Project). Restoration of surfgrass beds while feasible has been experimental and no large-scale restoration has been demonstrated to date.

Summary:

The basis of concern of sediment management activities on lobster is uncertainty-based conservatism to protect the high biological and commercial resource value of this species. It is hypothesized that burial and/or substantial sedimentation could adversely affect lobster by reducing day time cover and larval settlement sites. Recovery of beneficial habitat functions could take several years if there is substantial burial and/or sedimentation. Localized impacts to lobster populations have the potential for long term impacts given that lobsters do not reach sexual maturity and harvestable size for several years.

Critical impact thresholds are unknown. Loss of sensitive reef habitat due to persistent burial would require restoration to avoid significant impact to Essential Fish Habitat. Reef construction is considered technically and economically feasible (Lewis and McKee 1989). Restoration of lobster nursery habitat (surfgrass) is technically feasible; however, no large-scale restoration of surfgrass habitat has been demonstrated to date. Project design avoidance and/or pre-construction surveys to finalize pipeline and vessel routes have been used to avoid impacts to sensitive reef habitats.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on California spiny lobster.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Protective conservatism	Protective conservatism	Protective conservatism	Relevant reports
Critical Impact Thresholds	NA	Rocks overturned Mortality	Habitat loss	Habitat loss	Impair recruitment, decrease surfgrass nursery habitat
Impact Responses	NA	Disturbance, mortality	Displacement, mortality	Displacement, reduced recruitment	impaired recruitment, displacement
Duration of Impacts	NA	Minutes-months	Months-years	Months-years	Minutes-months
Potential for Restoration	NA	Unnecessary if no habitat loss	Yes for artificial reefs; surfgrass beds feasible but experimental	Yes for artificial reefs; surfgrass beds feasible but experimental	Unnecessary if no habitat loss

4.2.3 Dungeness Crab

Species Scientific Name	***Cancer magister***

Regulatory Status:

Endangered	
Threatened	
CDFG Managed	Yes
Other	

Dungeness crabs mating
Photo credit: http://www.noaa.gov

Dungeness crabs are a managed fishery in central and northern California. Commercial traps are generally fished from 1 to 10-day periods at water depths ranging from 60 to 240 ft (18 to 73 m), although some may be fished in shallower and deeper waters (Wild and Tasto 1983, CDFG 2001). Crabs are fished in northern (Oregon border to Fort Bragg) and central (Bodega Bay to Avila) California. The northern California fishery is centered between Eureka and Crescent City. San Francisco is the center of the central California fishery. The fishery is controlled through limited entry permits.

The commercial fishery is managed on the basis of sex, season, and size (CDFG 2001). Only male crabs may be retained. The fishing season generally is open in northern California from December 1 through July 15, and in central California from the second Tuesday of November until June 30. However, opening of the season may be delayed by the CDFG based on condition of crabs. The summer-fall closed fishing periods are intended to prevent fishing when the males are soft-shelled. The minimum size limit is 6.25 in (15.9 cm) across the back. Dungeness crabs are commercially collected by trap.

A limited sport fishery also occurs with limits of 10 crabs of either sex with a size of 5.75 in (14.6 cm) across the back. Dungeness crab may not be taken or possessed in San Francisco Bay and San Pablo Bay, plus all their tidal bays, sloughs and estuaries between the Golden Gate Bridge and Carquinez Bridge (CDFG 2005a).

Description and Distribution:

Dungeness crab ranges from approximately Alaska to Santa Barbara, although it is rare south of Point Conception (CDFG 2001). This crab occurs from the intertidal to deep subtidal depths in excess of several hundred feet. They may be found on any bottom type, but prefer sandy to sandy-mud substrate and eelgrass beds in intertidal areas to depths of 90 ft (27 m) (http://blueocean.org/seafood/species/112.html).

Life Stage or Function	California			On Land	Inter-tidal	Near-shore < 30 ft	Off-shore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	Rare	X	X		X	X	X	E, P
Juvenile	Rare	X	X		X	X	X	E, P
Plankton Stage	Rare	X	X			X	X	E, P
Primary Habitat	Rare	X	X		X	X	X	E, P
Foraging Habitat	Rare	X	X		X	X	X	E, P
Spawning Habitat	Rare	X	X		X	X	X	E, P

Potential Functions:

Dungeness crabs feed on a variety of resources, including other crustaceans (amphipods, isopods), clams, fish, and also prey on each other (CDFG 2001). Many species of fish (e.g., cabezon, flatfish, Pacific herring, rockfish, salmon), larger crabs, octopuses, the threatened sea otter, seals and sea lions prey on Dungeness crabs. As noted above, Dungeness crabs support commercial and sport fisheries.

Associated Species	Forage/ Prey	Eaten By
Invertebrates	X	X
Fish	X	X
Birds		
Vegetation		
Marine Mammals		X
Terrestrial Animals		
Humans		X

Life History Facts:

Dungeness crabs become sexually mature at the end of their second year, and live to an age of 6 to 8 years (CDFG 2001). Commercial landings have been highly variable, suggesting wide fluctuations in year-class recruitment that are not well understood (CDFG 2001). Warm water periods (e.g., ENSO) have been linked to reduced Dungeness crab populations (Wild and Tasto 1983). Temperatures of about 58 to 59°F (16 to 17°C) may represent an upper lethal limit for developing Dungeness crab eggs (Wild and Tasto 1983.).

Dungeness crabs shed their hard exoskeleton (molt) as they grow. Females may molt between February and July, and mating occurs when females are soft-shelled; males molt in summer-fall (USACE 1998c, CDFG 2001). Most Dungeness crab mating in California occurs in the spring from about March through June (Wild and Tasto 1983). Adult Dungeness crabs concentrate in shallows to mate (USACE 1998c).

Fertilization of eggs takes place when eggs are extruded on the female crab's abdomen; females must be partially buried for the egg mass to form (Wild and Tasto 1983). Reported time of egg extrustion in California populations varies. For example, extrusion may occur between September and November (Wild and Tasto 1983) or October and December (CDFG 2001). Female Dungeness crabs may carry as many as 500,000 to 2 million eggs, depending on size, and may store viable sperm for at least 2.5 years (CDFG 2001).

Egg hatching generally occurs from late December to early February in central California and January to early March in northern California (Wild and Tasto 1983). CDFG (2001) reports egg hatching as occurring between November and February. Larvae are planktonic for approximately 3 to 4 months, depending on water temperature. Larvae undergo daily vertical migration, being more abundant at the surface by night and at depths of 49 to 82 ft (15 to 25m) by day.

Advanced larval stage megalopae are transported to nearshore waters, with most settlement occurring at depths < 82 ft (25 m) between April and June (Wild and Tasto 1983). Dungness crabs may use embayments as nursery areas, and have been reported in eelgrass beds (Section 3.3.8). Humboldt Bay and San Francisco Bay are important nursery areas, but most rearing is believed to occur in nearshore waters (CDFG 2001). Juveniles remain in shallow inshore areas for approximately 1.5 years, generally moving offshore in September the following year after settlement (Wild and Tasto 1983).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Mate/Molt, Brood Eggs/Hatch to Plankton	Mate Feb-Jul, Peak Mar-Jun; Berried Sep-Dec; Hatch Nov-Mar; Metamorphosis Apr-Jun	Year Round	None	Settle in nearshore Apr-Jun, move offshore following Sept	6-8 years	Mobile, limited mobility when soft-shell or berried

Adaptations and/or Behaviors to Disturbance:

Dungeness crabs are vulnerable to predation while soft-shelled, which may last up to 2 to 3 months (http://whatcom-mrc.wsu.edu/Fact_Sheets/dungeness_crab.htm). Dungeness crabs bury themselves almost completely in sand or mud for protection. Physiological adaptations to burial include ventilatory reversals that clear the branchial chambers of sediment and cardiovascular modulation similar to that of sand dwelling crabs (McGaw 2003).

Dungeness crabs are highly mobile and change depths in response to local conditions such as storm surge (USACE 1998c). When necessary, Dungeness crabs can move quite quickly. Dungeness crabs commonly move within a 10 mile range, although individual tagged males have been noted to travel up to 100 miles (CDFG 2001). Movement studies of Dungeness crabs tagged with sonic transmitters have demonstrated that egg bearing females move less frequently and slower than males or nonovigerous females (O'Clair et al. 1990 cited in Taggert et al. 2004).

Life Stage	Behavior			Exo-Skeleton	Nursery Habitat	High Reproductive Output and/or Growth
	Burrow	Crawl/ Walk	Claws defense			
Adult	X	X	X	X		
Juvenile	X	X	X	X	X	
Egg/larvae					X	X

Potential Impacts from Sediment Management Activities:

Impacts to Dungeness crabs from sediment management activities have received some attention due to the important commercial status of the species. Laboratory experiments have examined responses to suspended sediment concentrations, and field studies have examined dredging equipment entrainment (LaSalle et al. 1991). Commercial fishermen have expressed concern regarding the potential for impacts to Dungeness crabs with nearshore placement of dredged materials (K. Berresford, USACE, San Francisco District, personal communication 2005).

Types of sediment management activities and potential impacts to Dungeness crab may include:

- Maintenance dredging of embayments – equipment damage, turbidity.

- Offshore borrow site dredging – equipment damage, turbidity.
- Nearshore placement – equipment damage, burial, sedimentation, turbidity.
- Profile placement – equipment damage, burial, sedimentation, turbidity.
- Beach placement – equipment damage, burial, sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Mortality			X	X		
Foraging					X	
Growth					X	
Habitat			X	X		X
Reproduction						X
Respiration					X	

Equipment

Dredging, anchoring, and/or pipeline placement have the potential to kill individual crabs and impact nursery grounds should they occur in the vicinity of sediment management activities. The USACE (1998c) scheduled dredging of Crescent City Harbor, California (late August to late September) to minimize disturbance to adult Dungeness crabs (and other sensitive species), although potential mortality to the crabs was considered insignificant due to their mobility and small project footprint.

Demersal and pelagic eggs, larvae, and young juvenile Dungeness crabs were found to be susceptible to dredge entrainment due to their limited mobility. Entrainment rates for Dungeness crab ranged from 0.00017 to 0.518 organisms per cubic yard of dredged material, with overall mortality rates of 56 to 73 percent for hopper dredge and 100 percent for pipeline dredge in Grays Harbor, Washington (Stevens 1981, Armstrong et al. 1982 cited in LaSalle et al. 1991). Entrainment rate was correlated with shellfish abundance. The primary authors (Stevens 1981, Armstrong et al. 1982) suggested seasonal restrictions be imposed on dredging in Grays Harbor (March-August) as a way to reduce mortality of Dungeness crab. LaSalle et al. (1991) summarized that a seasonal restriction seems justified in areas known to have highly concentrated numbers a given area on a seasonal basis, and that special consideration should be given to restricted bodies of water (e.g., narrow channels) where organism avoidance may be less concentrated.

The USACE, San Francisco District uses environmental windows (May 1 to June 30) to schedule dredging in San Francisco Bay/Delta Esturary and San Pablo Bays to avoid entrainment impacts to early juvenile stages of Dungeness crabs (http://el.erdc.usace.

army.mil/tessp/). Environmental windows also are used by the USACE, Portland and Seattle Districts to minimize entrainment and physical impacts to the species.

The Oregon Department of Environmental Quality (2003) required the following special conditions of the USACE (Portland District) for maintenance dredging in the Columbia River: (1) additional study of crab entrainment to assess seasonal variations and salinity influence on entrainment rates, (2) continuation of their efforts to develop a crab distribution and salinity model as a management tool for scheduling dredging and disposal, (3) development and adherence to a crab mitigation strategy designed to avoid and minimize entrainment of Dungeness crab, (4) dredging and disposal in known or suspected areas of overall high crab abundance to be conducted during seasons or river conditions of least crab abundance (http://www.deq.state.or.us/wq/401Cert/ ColumbiaRiver/WaterQualityCertification.pdf).

Commercial traps are set individually, weighted to sit on the bottom, and are buoyed to the surface. Vessel traffic, anchoring, and/or pipeline placement activities associated with sediment management activities have the potential to foul fishing gear if not avoided. No effects of offshore dredging activities on the Dungeness crab fishery have been reported for California.

In Europe, there has been a decline in brown crab (*Cancer pagurus*) stocks that have been associated with overfishing and indirectly with commercial dredging (Cooper 2005). This species is considered vulnerable to hydraulic dredging during their overwintering phase when females remain partially buried while incubating eggs. Cooper (2005) reviewed the effects of marine aggregate extraction in an area east of the Isle of Wight, noting changes in topography associated with dredge furrows and fining of sediments and exposure of boulders. The study focused on effects of commercial dredging activities on the brown crab fishery and local fishermen, which reported avoidance of licensed mining areas due to changes in the seabed and potential for gear damage. Avoidance of fishing in certain areas has increased fishing pressure in alternate fishing grounds already heavily exploited. Cumulative impact concerns to the fishing industry in areas where there are concentrations of marine extraction licenses were reported. The cumulative effects reported in that study were associated with high intensity commercial activities. While not directly applicable to sediment management activities involving infrequent offshore borrow site dredging, the results are relevant to management considerations of dredging frequency in areas with important shellfish fishing grounds.

Burial/Sedimentation

Burial of Dungeness crabs has the potential to occur with beach, nearshore, or profile placement. Potential impacts may be significant during the mating season (March through June) when crabs concentrate. Sedentary, berried females also may be more at risk (Sepember through December).

Because of their mobility and soft substrate habitat preference, post-construction sand transport sedimentation may have little influence on Dungeness crabs. However, sedimentation has the potential to affect static recruitment sites. Yellow shore crabs out-competed Dungeness crabs, aggressively excluding them from shelter and adversely affecting their recruitment when sedimentation and turbulence reduced the three-dimensionality of a mitigation oyster-shell reef (Visser et al. 2004).

Beach nourishment may potentially benefit Dungeness crabs by providing habitat in erosive areas where intertidal sand habitat is seasonally limited.

Turbidity

Turbidity may interfere with respiration of Dungeness crabs. Turbidity has been reported to affect respiration of a related species, *Cancer pagurus* (Howard 1982 cited in Cooper 2005.

Laboratory studies suggest Dungeness crabs are tolerant of relatively high suspended sediment concentrations. Abnormalities were observed at concentrations between 1,800 and 4,300 mg/L (Peddicord and MacFarland 1978 cited in LaSalle et al. 1991). Juveniles exhibited 38% mortality when exposed to 9,200 mg/L after 25 days. Adult crabs are more tolerant than juveniles. Adult Dungeness crabs had a 10% lethal concentration (LC_{10}) of 3,500 mg/L after 21 days. Adults were able to tolerate short-term exposure (8 days) to very high concentrations of kaolin clay, with a LC_{50} at approximately 35,000 mg/L (Peddicord et al. 1975 cited in O'Connor 1991).

Recovery from Disturbance:

Construction related equipment disturbance from dredging, anchoring, and/or pipeline placement generally would be expected to have only localized, minor impact to populations due to the high degree of mobility of Dungeness crabs. However, population-scale impacts are unknown, but considered possible when early life stages are vulnerable to entrainment (April-June) and/or adults are more vulnerable to physical disturbance (e.g., when females are soft-shelled and adults concentrate for mating; March to July). Similarly, the potential for burial impacts would be greater during spring-summer when mating occurs and early life stages settle. Otherwise Dungeness crabs are not considered particularly sensitive to sedimentation because of their habit of burrowing into sandy and muddy sediment.

Turbidity effects would be limited to the construction period, but actual exposure duration would vary depending on project- and site specific conditions. Habitat loss from dredging generally is temporary due to the similarity of underlying sediments and/or filling in of dredged channels, and would not be expected to have population-scale impacts, except as noted above during sensitive periods when early life stages settle.

	Recovery Rates				
Impact	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	X			X	
Burial	X			X	
Sedimentation	X				
Turbidity	X				
Habitat Loss	X			X	

Critical Impact Thresholds:

Laboratory tests indicate abnormalities in juveniles may develop with prolonged exposure (25 days) of high turbidity concentrations (≥ 1,800 mg/L); however, upper and lower limit thresholds have not been established. Dungeness crabs concentrate for breeding and may be abundant in nursery areas in shallow embayment and nearshore areas. Substantial loss

of local populations would be of ecological concern. Loss of nursery or shelter habitat from burial and/sedimentation

Data Gaps:

No information is available on the significance of dredging (entrainment, disturbance) impacts on populations of Dungeness crabs. In addition, the effects of prolonged turbidity (e.g., > 25 days) on Dungeness crabs are unknown.

Restoration:

Not applicable.

Summary:

Dungeness crab is a commercially and recreationaly importantl shellfish species in California. Construction impacts of concern may include direct damage of nursery habitat, breeding population, and/or entrainment of early life stages by equipment during dredging. Direct burial impacts have the potential to occur from beach nourishment and could be locally significant if activities affected substantial numbers of sedentary, berried females. The potential for impacts from post construction sand transport sedimentation may be limited based on the affinity of the species to soft substrate habitat and mobility. However, sedimentation that reduced habitat quality of nursery habitats or recruitment sites would be of ecological concern. Dungeness crabs appear to be tolerant of short-term exposure to elevated turbidity, but may be adversely impacted from prolonged exposures. Turbidty impacts that resulted in loss of eelgrass nursery habitat would be of concern.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on Dungeness crab.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	None	Documented	Protective conservatism	Protective conservatism	Documented
Critical Impact Thresholds	NA	Loss of eelgrass nursery habitat, substantial entrainment	Substantial loss of local population	Incompatible substrate that degrades habitat	Impair recruitment, decrease eelgrass nursery habitat
Impact Responses	Habitat	Disturbance, entrainment, mortality	Displacement, mortality	Disturbance	Respiration interference, abnormalities, mortality
Duration of Impacts	NA	Days-months	Months-years	Months-years	Days-months
Potential for Restoration	NA	Unnecessary	Unnecessary	Unnecessary	Unnecessary

NA = not applicable

4.2.4 Pismo Clam

Species Scientific Name	***Tivela stultorum***

Regulatory Status:

Endangered	
Threatened	
CDFG Managed	X
None	

Photo by: Karen Green, SAIC

Commercial fishing for Pismo clams has been prohibited since 1947 due to overfishing pressure (CDFG 2001). Pismo clams may be taken by recreational fishermen any time of year, except in Santa Cruz and Monterey counties where the fishing season is restricted to September 1 through April 30 (CDFG 2005a). Fishing size limits differ north and south of the county line between San Luis Obispo and Monterey counties: i.e., 5 inches (12.7 cm) north and 4 ½ inches (11.4 cm) south. The daily bag limit is 10 clams.

Description and Distribution:

Historically, Pismo clams extended from Half Moon Bay (San Mateo County) south to Bahía Magdalena, Baja California (Morris et al. 1980). The current range of Pismo clams extends from approximately Monterey Bay south to Socorro Island, Baja California, Mexico (CDFG 2001). Clams occur from the intertidal to water depths of 80 ft (24 m) in sandy substrate along the mainland coast, occurs at two of the Channel Islands (Santa Cruz and Santa Rosa Islands), and occasionally is found in entrance channels to bays and estuaries. Pismo clams do not inhabit the more protected areas of embayments (Weymouth 1922).

Generally, pismo clam populations are greater in subtidal than intertidal waters due to historic commercial and continuing recreational fishing pressure (CDFG 2001). Pismo clams may occur in aggregations; i.e., Pismo clam bed.

Locations with developed populations appear to relate to beach morphodynamics. Pismo clams usually live on flat beaches of the open coast (Shaw and Hassler 1989). A beach must maintain a sandy low tide terrace throught the winter season (equilibrium beach) to support Pismo clam (Masters 2005). Pismo clams sometimes occur in entrances to bays, sloughs, and estuaries (Shaw and Hassler 1989).

Life Stage or Function	California			On Land	Inter-tidal	Near-shore < 30 ft	Off-shore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X			X	X	X	E
Juvenile	X	X			X	X	X	E
Egg	X	X				X	X	E
Primary Habitat	X	X			X	X	X	E
Foraging Habitat	X	X			X	X	X	E
Spawning Habitat	X	X			X	X	X	E

Potential Functions:

Associated Species	Forage/ Prey	Eaten By
Plankton	X	
Invertebrates		X
Fish		X
Birds		X
Vegetation		
Marine Mammals		X
Terrestrial Animals		
Humans		X

Pismo clams are eaten by a variety of invertebrates (moon snails, crabs), surf fish, sharks and rays, sea gulls, threatened sea otters, and humans (CDFG 2001). The commercial fishery of Pismo clam was prohibited in California in 1947 due to over fishing. The recreational fishery for Pismo clams continues, but may be substantially affected by oceanographic conditions and/or sea otter foraging on a widespread to local basis. Pismo clams were substantially depleted during the 1982-1983 El Niño storms, but exhibited substantial recruitment in 1990 along southern and central California beaches. In areas where sea otters forage, Pismo clams rarely survive to legal size, impacting recreational fishing for the species from Monterey to Morro Bay. Recruitment in the Pismo Beach and Morro Bay areas has been low since 1992 (CDFG 2001).

Life History Facts:

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Spawn, short planktonic stage	Year round, Most Jun-Dec, Peak Jun-Sep	Year round, greatest spring-fall	None	None	> 20 years	Motile

Pismo clams have a relatively thick, heavy shell. They may grow to more than 7 in (17.8 cm) in length and live more than 50 years, although the oldest reported in California was estimated at 23 years (CDFG 2001). Clams 4.5 to 5 in (11.3 to 12.7 cm), minimum legal size depending on location, may be 5 to 9 years old. Sexes are separate and fertilization occurs in the water when males and females spawn. The number of released eggs varies with female size, ranging from < 1 million in the smallest females to 10-20 million in legal-sized females. Spawning may occur year round, but most occurs between June and December, with peak spawning from June to September (Morris et al. 1980, Shaw and Hassler 1989, CDFG 2001).

Although early reports suggested a larval stage of 3 weeks (Coe 1947 cited in Shaw and Hassler 1989), more recent studies indicate a shorter timeframe. Shaw and Hassler (1989) reported that larvae have a high weight/volume ration and may remain on or near the bottom most of the time and move very little. In the laboratory, Pismo clam eggs were observed to hatch and settle to the bottom within 60 to 72 hours (CDFG 2001). It seems reasonable that the relatively short, demersal larval stage contributes to formation of Pismo clam beds.

Post larval clams attach to sand grains by means of byssal threads, which degenerate after a few months when clams are more able to maintain a buried position (Shaw and Hassler 1989). Clams are sexually mature at 1 year in southern California and within 2 years in central California. Settlement and recruitment are variable between years. Dugan et al. (2000) suggested that recruitment of populations on the northern Channel Islands may be infrequent, occurring at intervals of 10 years or more, based on population size structure.

Oceanographic conditions are influential, but little is known regarding conditions that optimize recruitment (CDFG 2001).

Pismo clam respiration and feeding occur through their siphons. The inhalent siphon has papillae, which exclude larger particles (Weymouth 1922). Water is drawn into the incurrent siphon and aerates the gills, which are covered by a mucus sheet that intercepts all particles (Fitch 1953). The food-laden mucus is carried in strings along the edges of the gills to the labial palps (fleshy appendages on each side of the mouth), which remove undesirable particles and allow the rest of the material to pass intact with the strings of mucus directly into the stomach. A 3-inch (7.6- cm) Pismo clam strains approximately 15 gallons (60 liters) of water a day (Morris et al. 1980, CDFG 2001). Detritus and planktonic organisms are the primary food items. Sediment also is ingested with the food; sand may account for up to half the stomach contents (CDFG 2001). Waste matter, the products of respiration, and the reproductive products are expelled into the water through the excurrent siphon.

Adaptations and/or Behaviors to Disturbance:

The relatively heavy shell of Pismo clams provides some protection from predation. Populations are maintained through high reproductive output (millions of eggs) and early maturation; however, the short-lived planktonic larval stage limits dispersal.

Pismo clams are adapted to live intertidal and shallow subtidal areas with shifting sands (Herrington 1929). The clam orients vertically and burrows into sandy substrate, generally within 6 in (15 cm) of the surface because of their short siphons, but may be found as deep as 12 in (30 cm) (CDFG 2001). During ordinary weather the clam is found buried in the sand at a depth roughly equal to the length of its own shell, but are usually found at a greater depth during stormy weather (Weymouth 1922). There have been cases reported of clams found so deeply buried by the shifting sand that they were apparently unable to dig out (Herrington 1929). A Pismo clam buries itself by jetting water from its shell while digging in with its foot, which aided by the shell weight, pulls the clam down through the loosened sand (Morris et al. 1980, CDFG 2001).

Die-offs of Pismo clam larvae have been reported during heavy runoffs from rivers after substantial storms (Fitch 1950 cited in Shaw and Hassler 1989). Red tide blooms, sudden changes in salinity, and extremely cold weather may kill young clams.

Life Stage	Behavior			Protective Shell	Byssal Thread Attachment	High Reproductive Output and/or Growth
	Burrow	Short larval stage				
Adult	X			X		
Juvenile	X			X		
Egg/larvae		X			X	X

Potential Impacts from Sediment Management Activities:

Areas where Pismo clams occur in substantial nearshore beds are of particular concern due to the limited dispersal capability of the species and substantial population declines that have resulted from over fishing and predation pressure from sea otters. Pismo clams are no longer prevalent in the intertidal as a result of over fishing, although low densities may

occur. Pismo clams have the potential to be directly impacted by equipment and sand placement, if present in the area of sediment management activities. Indirect impacts from turbidity and sedimentation also are possible. Potential impacts would be limited to the open coast, Pismo clams do not occur in embayments.

Types of sediment management activities and potential impacts to Pismo clams may include:

- Maintenance dredging of embayments – not applicable.
- Offshore borrow site dredging – equipment damage, turbidity.
- Nearshore placement – equipment damage, burial, sedimentation, turbidity.
- Profile placement – equipment damage, burial, sedimentation, turbidity.
- Beach placement – equipment damage, burial, sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging				X	X	
Growth				X		
Habitat			X	X		X
Reproduction /Recruitment				X	X	
Respiration				X	X	

Equipment

Offshore borrow site dredging, anchoring, and/or pipeline placement to convey sands to the beach have the potential to disturb and/or kill Pismo clams, if present. Anchoring and/or pipeline placement effects may affect individual clams, if present, but would not be expected to result in population level impacts. If offshore borrow site dredging removed a Pismo clam bed, the impact would be significant on the local population.

Pre-construction surveys have been used to characterize biological resources at offshore borrow sites. No Pismo clams were found during pre-construction surveys of borrow sites used for the 2001 San Diego Regional Sand Project (MEC 2000a).

Construction monitoring also has been used during beach nourishment to examine sands pumped from offshore borrow sites. No Pismo clams were listed from shell samples collected to assess presence of cultural resources (e.g., shell middens) in borrow site sediments during the 2001 Regional Beach Sand Project (Scripps and EDAW 2002).

Burial/Sedimentation

Beach nourishment has the potential to directly bury Pismo clams within the footprint of the receiver site. Pismo clams may be found buried up to 12 inches (30 cm), but would not be expected to survive overburden depths of several feet. Burial impacts may be of greater concern for nearshore placement than beach placement given the current distribution of the species; i.e., clam beds may occur in the nearshore, individual clams generally occur in low abundance in the intertidal.

Pismo clams are competent burrowers and are adapted to natural shifts of sand associated with seasonal accretion and erosion cycles. Therefore, sedimentation associated with sand transport from a receiver site would be expected to have little effect when associated with natural coastal processes and rates. However, sedimentation that resulted in a change in sediment characteristics from sandy to silty would be of concern. Sand-sized particles are attachment sites for larval clams (Shaw and Hassler 1989).

The average density of Pismo clams in the low intertidal significantly declined (from 1.2 to 0.14 per square meter) after the 1977 beach nourishment project at Imperial Beach, California; although the authors cautioned that the result was based on very few individuals (Parr et al. 1978).

Beach nourishment has the potential to benefit Pismo clams by providing habitat in erosive areas where intertidal sand habitat is seasonally limited. A juvenile Pismo clam was collected at a beach that changed from cobble to sand after receiving indirect sedimentation from beach nourishment in the City of Encinitas; however, population establishment was not documented by subsequent surveys (SAIC 2006).

Pre-construction surveys to determine presence of Pismo clam beds and, if present, implementation of protective measures have been recommended for some beach nourishment projects in California (Chambers 1992, USACE 1994a). Preconstruction surveys and development of an impact avoidance plan in the event of Pismo clam beds was recommended as a mitigation measure for the BEACON Beach Nourishment Demonstration Project (Chambers 1992). The USACE (1994a) stated that pre-construction surveys would be conducted (transects at 5-ft (1.5-m) widths between +3 and -5 ft (+1 and -1.5 m) MLLW) and Pismo clams, if present, would be collected and relocated either up- or downcoast of beach nourishment associated with maintenance dredging of Port Hueneme and Channel Islands Harbors. Experimental relocation of juvenile Pismo clams has been successful (J. Dugan, 2007 personal communication).

Placement method has been used to minimize impacts to Pismo clams during beach nourishment in California. During the 1995 Surfside-Sunset Beach Nourishment Project, the USACE (1995) specified that beach material would be placed on the upper portion of beach and allowed to slowly migrate seaward to minimize impacts to Pismo clams.

Turbidity

No specific information on the response of Pismo clams to suspended sediment concentrations was identified with the literature review. Pismo clams may be fairly tolerant given that their feeding system excludes large particles and strains small particles, and they are adapted to live in coastal waters subject to natural turbidity and shifting sands. Effects of prolonged turbidity are unknown, but could be detrimental given that they use siphons for

feeding, respiration, and spawning. Discharge of fluidized sediments would be of concern in the vicinity of Pismo clam beds. Die-offs of young clams have been reported from heavy runoff from rivers (Fitch 1950). Whether that was related more to salinity or sedimentation is uncertain.

An experimental study of the effect of suspsended sediment (attapulgite clay) on surf clam (*Spisula solidissma*) may be relevant to Pismo clam. Robinson et al. (1984) showed interference with feeding (increased pseudofecal production, decrease in algal food injestion) at concentrations > 100 mg/L over a 3-day exposure period, acclimation to 100 and 500 mg/L over 20-day exposures, but inability to acclimate at concentrations > 1,000 mg/l.

Recovery from Disturbance:

Recovery of Pismo clams may be rapid in the case of minor disturbance such as localized equipment disturbance, short-term turbidity, and/or indirect sedimentation. Sedimentation that resulted in a change in sediment characteristics from sandy to silty would be of concern. Recovery of a Pismo clam bed from direct burial or dredge removal could take several years to re-establish population age structure.

	Recovery Rates				
Impact	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	X			X	
Burial			X	X	
Sedimentation	X				
Turbidity	X			X	
Habitat Loss					X

Critical Impact Thresholds:

Pismo clam beds appear to be persistent areas maintained by limited larval dispersal and environmental conditons. Therefore, burial or dredge removal that resulted in loss of a clam bed would be significant.

Data Gaps:

Limited information is available on locations of subtidal Pismo clam beds. Critical thresholds to turbidity and substrate characteristics are unknown.

Restoration:

Restoration would not be necessary unless there was loss of a persistent Pismo clam bed. The potential to restore Pismo clams has not been well studied. A substantial number (10,000) of Pismo clams were transplanted to Huntington Beach in Orange County in 1989 to assist with post El Niño recovery in southern California (CDFG 2001). Clams were taken from Pismo Beach, which had experienced record recruitment in that year. Follow up surveys at Huntington Beach found very few clams and biologists were uncertain of the fate of the clams.

Summary:

Pismo clams have been seriously impacted by over fishing and sea otter predation in California, and populations are variable between years and geographic location. Pismo clams are long-lived, but become reproductive within one to two years. Early maturation and high reproductive output contributes to the natural resilience of the species.

No impacts to Pismo clams have been documented from sediment management activities. Protective conservatism is the primary basis of concern, and mainly pertains to where Pismo clams occur in substantial nearshore beds. Recovery of Pismo clam beds from substantial burial or dredge removal is uncertain due to limited larval dispersal capability and depressed population status in many areas along the coast. Pismo clams are competent burrowers and would be expected to tolerate indirect sedimentation unless there was a substantial change in substrate characteristics. Pismo clams do not occur in sility sediments. Relevant reports suggest Pismo clams may be tolerant of moderate turbidity over relatively short exposure durations (e.g., days to a couple of weeks); however, critical thresholds with respect to concentration and exposure duration are unknown. Limited information is available on locations of subtidal Pismo clam beds.

Pre-construction surveys have been recommended to finalize design and minimize potential impacts to Pismo clams from beach nourishment projects in California. This measure should be effective for avoiding direct impacts. A construction method involving sand placement on the upper portion of the beach to facilitate gradual sand migration has been used to minimize impacts to Pismo clams. Construction monitoring of discharged sediments (i.e., checking for presence of Pismo clam shells) also may be effective for verifying that dredging of offshore borrow sites avoid Pismo clam beds. Relocation of Pismo clams has been specified in some NEPA documents to minimize impacts. Although relocation of juvenile clams is technically feasible, that measure is not recommended due to the localized occurrence of beds and limited knowledge of environmental requirements of the species. Avoiding direct impacts to Pismo clam beds may be a more effective mitigation measure.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on Pismo clam.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	None	Protective conservatism	Protective conservatism	Unlikely	Protective conservatism
Critical Impact Thresholds	NA	Substantial loss of local population	Substantial loss of local population	Incompatible substrate that degrades habitat	Impair recruitment
Impact Responses	Habitat	Damage, Mortality	Disturbance, mortality	Disturbance	Impaired feeding, respiration, and recruitment; mortality
Duration of Impacts	NA	Days-months	Months-years	Months-years	Days-months
Potential for Restoration	NA	Unnecessary to Uncertain	Uncertain	Unnecessary	Unnecessary

4.2.5 Sea Urchins

Species Scientific Name	***Stronglyocentrotus, Lytechinus, Centrostephanus***

Regulatory Status:

Endangered	
Threatened	
CDFG Managed	*Stronglyocentrotus*
None	*Centrostephanus, Lytechinus*

Purple sea urchins and aggregating sea anemone
Photo credit: http://www.marine.gov/

Several species of sea urchins occur offshore California. Two species are harvested commercially, red sea urchins (*Stronglyocentrotus franciscanus*) and to a much lesser extent purple sea urchins (*S. purpuratus*). Gonads from the sea urchins (roe) primarily are sold for the Japanese export market.

The white sea urchin (*Lytechinus anamesus*) and diadematid sea urchin (*Centrostephanus coronatus*) also occur within the depth range of sediment management activities. Other species of sea urchins in California have restricted distributions and are uncommon.

Description and Distribution:

Red and purple sea urchins occur throughout California, ranging from Alaska or Canada to Baja California, respectively (Morris et al. 1980). Red sea urchins occur from very low intertidal to subtidal depths up to 200 ft (90 m). Purple sea urchins have a broader distribution, ranging from intertidal to subtidal depths up to 525 ft (160 m,). White sea urchins range from 6 to 985 ft (2 to 300 m) from southern California to Mexico. Diadematid sea urchins occur from low intertidal (protected coasts) to 361 ft (110 m) off southern California to Mexico.

Life Stage or Function	California			On Land	Inter-tidal	Near-shore < 30 ft	Off-shore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X		X	X	X	E
Juvenile	X	X	X		X	X	X	E
Egg/Plankton	X	X	X			X	X	E
Primary Habitat	X	X	X			X	X	E
Foraging Habitat	X	X	X			X	X	E
Spawning Habitat	X	X	X			X	X	E

Potential Functions:

Sea urchins are herbivores, feeding on brown and red algae. Giant kelp is a favored food (Morris et al. 1980). Red, purple , and white sea urchins may form dense aggregations of feeding “fronts” during periods of limited food supply and may completely strip areas of vegetation (sea urchin barrens) (Dean et al. 1984, 1988, 1989; Engle 1994). The

diadematid sea urchin feeds on kelp, but does not form dense aggregations (Foster and Shiel 1985, Engle 1994.).

Sea urchins are eaten by a variety of animals, including crabs, lobsters, starfish, other sea urchins, fish (particularly sheephead), and threatened sea otters (Durham et al. 1980, CDFG 2001) Birds (sea gulls, oyster catchers, crows) and raccoons also may prey on purple sea urchins in the intertidal zone CDFG 2001).

Associated Species	Forage/ Prey	Eaten By
Invertebrates		X
Fish		X
Birds		X
Vegetation	X	
Marine Mammals		X
Terrestrial Animals		X
Humans		X

A substantial commercial fishery for red sea urchin occurs in northern and southern California, but sea otter predation keeps sea urchin populations at densities too low to sustain a commercial fishery in central California (CDFG 2001). Southern California landings are highest from San Diego County and around the Channel Islands. Northern California landings are highest in the vicinity of Fort Bragg, Bodega Bay, Point Arena, Port Albion, and Crescent City. The fishery for purple sea urchins has been much more limited and experimental.

Life History Facts:

Red sea urchins become sexually mature in their second year and females spawn up to several million eggs. Spawning generally occurs during winter-spring in southern California and in spring and summer in northern California (Ebert et al. 1994). Larvae are planktonic for approximately five to eight weeks after which individuals settle to the bottom and metamorphose into juveniles (Ebert et al. 1994, CDFG 2001). Peak settlement periods tend to be spring and summer, although there is year to year variation in settlement timing and density (CDFG 2001). Red and purple sea urchins settle on rocks with an algal and bacterial film, but otherwise do not exhibit substrate selection (Cameron and Schroeter 1980).

Red sea urchins may reach ages in excess of 100 years; they range from 6 to 8 years old at minimum harvestable size (3.5 inches) (CDFG 2001, Stauth 2003). Red sea urchins move less when food is abundant (approximately 1 m/day), but are capable of rapid movement (up to 10 mph) (Mattison et al. 1977 and Rogers-Bennett et al. 1998 cited in Carter and VanBlaricom 2002). Adults are thought to move within a range of tens or hundreds of meters during a lifetime (CDFG 2001).

Purple sea urchins generally spawn during winter-spring in both northern and southern California. Fertilization rates of purple sea urchin eggs remain high (> 80%) under conditions of turbulent mixing associated with waves up to 6.5 ft (2 m) (Denny et al. 2002). Purple sea urchins become sexually mature in their second year (Morris et al. 1980). Larvae spend several weeks in the plankton before they settle and metamorphose, peak recruitment occurs in spring and early summer although there is considerable annual variability in settlement timing and density (CDFG 2001). After 5 years, purple sea urchins may range up to 2 inches (50 mm); large individuals rarely exceed 4 inches (100 mm) (Morris et al. 1980). Warm temperatures associated with El Niño conditions have been linked with physiological stress, disease, and periodic mass mortalities of purple sea urchins in southern California (CDFG 2001).

White sea urchins generally spawn from June to September (Morris et al. 1980). Larvae are planktonic for 1 to 2 months, and grow quickly after settlement. White sea urchins become sexually after about 4 to 5 months, before they are full grown; large individuals are approximately 1.5 inches (40 mm) in diameter. Individuals often live in large aggregations. Feeding fronts rarely eat adult plants, but graze on early developmental stages of algae (Dean et al. 1984). The feeding pattern of white sea urchins may affect algal recruitment and have substantial effect on community composition of subtidal reefs (Dean et al. 1988).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Planktonic	Red sea urchin winter-spring (S. CA), spring-summer (N. CA); Purple sea urchin winter-spring White sea urchin summer Diadematid sea urchin unknown	Year round	None	None	> 10 years	Motile

Diadematid sea urchins also are small with diameters up to approximately 2 inches (60 mm) (Morris et al. 1980). The density of their spines is twice that of *Strongylocentrotus* species.

Other invertebrates may influence the abundance and distribution of sea urchins. Tegner and Dayton (1981) reported lobster and sheephead influenced abundance of purple and red sea urchins. The distribution of white sea urchins may be controlled by predators such as the starfish *Patiria miniata* (Schroeter et al. 1983).

Sea urchins lack respiratory organs. Gas exchange in sea urchins occurs through podia that operate a countercurrent to facilitate transfer of oxygen and carbon dioxide between the coelomic fluid and overlying water (Brusca and Brusca 1990).

Adaptations and/or Behaviors to Disturbance:

The spine canopy and motility of sea urchins protects them from a variety of predators. Populations are maintained through broadcast spawning and planktonic larvae that may disperse over a wide range. Juvenile mortality can be high, and the spine canopy of adult urchins is considered important protected habitat for juveniles (Tegner and Dayton 1977, CDFG 2001).

Fishing pressure has substantially reduced red sea urchins of harvestable size in many areas of California and the consequence of this on future recruitment is of concern (CDFG 2001). Reduction in adults not only may limit larval supply, but also may result in decreased survivorship of juveniles in the absence of functional benefits provided by adults such as protection from predation and contributing an increased food source (reviewed in Carter and VanBlaricom 2002).

Sea urchins may form feeding aggregations during periods when drift algae forage is limited such as during kelp die back associated with storms, reduced recruitment, and/or El Niño events (Dean et al. 1984, Ebeling et al. 1985, Harrold and Reed 1985, Tegner and Dayton

1991, Engle 1994). Sea urchin aggregations also have been reported to form in response to predation pressure and as a consequence outstripped their local food supply (Tegner and Dayton 1981 cited in Dean et al. 1984). Leighton et al. (1971 cited in Ebeling et al. 1985) reported that recovery of kelp may be inhibited when red sea urchin density exceeds 1 per square meter and/or purple sea urchin density exceeds 10 per square meter; however, Dean et al. (1984) concluded that feeding behavior of sea urchins (i.e., stationary or aggregations) was more influential than density.

Surveys conducted in the vicinity of the Portuguese Bend landslide in southern California provide relevant information on tolerance of purple and red sea urchins to areas with chronic sedimentation and turbidity. Red and purple sea urchins were present at all survey areas, landslide affected (Portugese Bend), partially affected (Abalone Cove) and unaffected (Palos Verdes Point). However, there was a difference in sea urchin occurrence at Portuguese Bend with sea urchins absent along transects directly offshore the landslide area but present at less affected headland areas near the boundaries of the slide area. Their distribution appears to relate to food source. For example, kelp was absent directly offshore the landslide area and at one of the headland sites, but was present at other surveyed sites farther from landslide activity.

Life Stage	Behavior			Exo-Skeleton	Habitat	High Reproductive Output and/or Growth
	Crawl/ walk	Aggregate	Spine defense			
Adult	X	X	X	X	X	
Juvenile	X		X	X	X	X
Egg/larvae						X

Potential Impacts from Sediment Management Activities:

Limited information is available regarding impacts of sediment management on sea urchins. Commercial fishermen have expressed concern that sedimentation and turbidity associated with beach nourishment may impact sea urchin stocks (SANDAG and USDN 2000). Potential construction impacts include damage by equipment, sediment burial, and/or indirect disturbance from turbidity. Post-construction concerns include potential indirect sand transport from the receiver site resulting in sedimentation of sea urchin habitat.

Types of sediment management activities and potential impacts to sea urchins may include:

- Maintenance dredging of embayments – turbidity.
- Offshore borrow site dredging – equipment damage, sedimentation, turbidity.
- Nearshore placement – equipment damage, burial, sedimentation, turbidity.
- Profile placement – equipment damage, burial, sedimentation, turbidity.
- Beach placement –equipment damage, sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging				X	X	
Growth				X	X	
Habitat			X	X	X	X
Reproduction				X		
Respiration				X		

Equipment

Anchoring associated with offshore dredging of sand borrow areas, nearshore and profile placement, and/or placement of pipeline to convey sands onshore have the potential to disturb and/or damage sea urchins. Sea urchins generally are associated with rocky reefs and kelp beds. Direct disturbance of sensitive hard bottom and vegetated reefs are unlikely to be permitted in California. Inadvertent impacts if they were to occur would be expected to be localized and could result in mortality of individuals and/or aggregations of sea urchins.

Pre-construction environmental diving surveys have been used to finalize pipeline and vessel routes to avoid direct impacts to kelp canopies and rocky reef resources during recent beach nourishment projects in California (e.g., 2001 San Diego Regional Beach Sand Project, 2003 Goleta Beach Demonstration Project).

Burial/Sedimentation

Nearshore or profile placement potentially could bury sea urchins, if present. Direct burial of sensitive rocky reefs and/or kelp beds from nearshore or profile placement are unlikely to be permitted in California. However, sea urchins could be impacted if placement occurred on sand in the vicinity of hard bottom. Sea urchins are mobile and may be able to escape sedimentnation; however, complete burial would likely result in mortality.

Post-construction sand transport from the receiver site could potentially result in sedimentation of sea urchin habitat with any placement method. Sedimentation primarily would be limited within the beach depth of closure; thus, limiting potential impacts to the intertidal and shallow subtidal portion of the depth distribution range of sea urchins. Potential impacts would probably depend on the nature and duration of sedimentation and presence of sea urchins. Sea urchins would not be expected to be impacted by sedimentation due to their mobility; however, sedimentation could indirectly affect sea urchins by potentially reducing algal food supply and/or adversely impacting larval settlement locations. Studies in the vicinity of landslides indicate that sea urchins may be eliminated in areas with frequent and persistent sedimentation.

Few studies have examined sedimentation impacts to sea urchins associated with beach nourishment. Abundances of red and purple sea urchins were monitored in kelp beds before and after the 2001 San Diego Regional Beach Sand Project; no changes in abundance attributed to beach nourishment were reported (AMEC 2005).

Turbidity

No specific information on the response of sea urchins to suspended solids concentrations is available. Direct impact is unlikely due to the physiology of sea urchins; i.e., gas exchange occurs across podia. No significant impacts would be expected unless prolonged turbidity resulted in reduction in algal food supply of sea urchins.

Recovery from Disturbance:

Recovery rates may be rapid in the case of minor disturbance such as equipment damage and/or short term turbidity. Potential impacts from sand transport sedimentation and/or prolonged turbidity are not well understood. Recovery rates from sedimentation would probably relate to the nature and magnitude of sedimentation as well as occurrence of sea urchins. Turbidity effects generally would be limited to the construction period, but actual exposure duration would vary depending on project- and site specific conditions. Recovery rates from turbidity would begin when construction ended. No significant impacts would be expected unless prolonged turbidity resulted in reduction in algal food supply of sea urchins.

	Recovery Rates				
Impact	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	X				
Burial				X	
Sedimentation				X	
Turbidity	X				
Habitat Loss			X		

Critical Impact Thresholds:

No critical thresholds have been established for sea urchins.

Data Gaps:

Limited information is available on the effects of sedimentation and prolonged turbidity on sea urchins.

Restoration:

Restoration would not be necessary unless sediment management activities resulted in persistent sand inundation of rocky intertidal and/or subtidal reefs where sensitive and/or managed resources occurred, such as sea urchins. Artificial reef construction is considered technically and economically feasible and has been specified as a potential mitigation measure in the event of significant impacts to rocky reefs for several California beach nourishment projects (e.g., 2001 San Diego Regional Beach Sand Project, 2003 Goleta Beach Demonstration Project).

Summary:

No beneficial or adverse impacts to sea urchins have been documented from sediment management activities. The basis of concern primarily is uncertainty-based conservatism. Construction related damage to rocky reefs and/or turbidity have the potential to result in

short-term adverse impacts. Prolonged exposure to turbid waters may be of concern. Rlevant studies indicate prolonged turbidity may reduce plant diversity, with potential impacts to sea urchin food supply. Direct burial likely would result in mortality. Sedimentation has the potential to reduce forage, settlement sites, and/or displace sea urchins.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on sea urchins.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	None	Protective conservatism	Protective conservatism	Protective conservatism	Protective conservatism
Critical Impact Thresholds	NA	Rocks overturned Mortality	Habitat loss	Loss of algal food base	Loss of algal food base
Impact Responses	NA	Mortality, reduced settlement	Mortality, displacement, reduced Settlement	Displacement, reduced settlement	Reduced feeding
Duration of Impacts	NA	Days-months	Months-years	Months-years	Days-months
Potential for Restoration	NA	Unnecessary	Yes, Artificial Reef Construction if Significant Impact	Yes, Artificial Reef Construction if Significant Impact	Unnecessary

NA = Not applicable

4.2.6 Sandy Beach Invertebrates

Photo by: Karen Green

Species Scientific Name	

Regulatory Status:

Endangered	
Threatened	
CDFG Managed	X
None	X

Recreational fishing limits apply to Pismo clam (10), razor clam (20), other clams (50 in combination), and sand crabs (50) (CDFG 2005a). All sandy beach invertebrates reside within Essential Fish Habitat.

Description and Distribution:

Sandy beach invertebrates occur throughout California wherever habitat occurs. Invertebrate assemblages are broadly similar throughout the world. Invertebrates on the intertidal portion of the shore include relatively larger (visible) animals such as sand crabs, clams, and worms that live in the sediment (macroinvertebrate infauna) and very small (hard to see without microscope) organisms such as bacteria, protozoans, gastrotrichs, and very small worms that live in sediments between sand grains (meiofauna or interstitial fauna).

Both macroinvertebrate infauna and meiofauna occur in the upper 3 ft (1 m) of sediment, often occurring at depths < 2 ft (0.6 m) (McLachlan et al. 1981, Straughan 1981, SAIC 2006). Invertebrates (marine and terrestrial) also may occur in association with kelp and/or seagrass debris washed ashore (marcrophyte wrack) and/or on the upper backshore where coastal strand vegetation is present (also see Section 3.3.1).

Life Stage or Function	California			On Land	Inter-tidal	Near-shore < 30 ft	Off-shore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X		X			E, P
Juvenile	X	X	X		X			E, P
Egg/Larvae	X	X	X		X	X	X	E, P
Primary Habitat	X	X	X		X			E, P
Foraging Habitat	X	X	X		X			E, P
Reproductive Habitat	X	X	X		X			E, P

Intertidal macroinvertebrate infauna assemblages on California beaches include a variety of crustaceans (amphipods, anomuran mole crabs, cumaceans, isopods, mysids), clams, and worms. The most abundant macroinvertebrates on California sandy beaches include sand crabs (*Emerita analoga*), isopods (*Excirolana chiltoni, Tylos punctata*), talitrid beach hopper amphipods (e.g., *Megalorchestia* spp.), and polychaete worms of the families spionidae (*Scolelepis spp.*) and opheliid (*Euzonus* spp.) (Straughan 1982, Dugan et al. 2000, SAIC

2006). Bean clams (*Donax gouldii)* also may occur in very high abundance on southern California beaches (Morris et al. 1980, Dugan et al. 2000a, SAIC 2006).

Other commonly encountered intertidal macrofaunal species on California beaches, but generally in lower abundance, include other amphipods (e.g., *Eohaustorius* spp., *Ericthonius brasiliensis*), spiny mole crabs (*Blepharipoda occidentalis*), porcelain mole crabs (*Lepidopa californica*), mysids (e.g., *Archaeomysis grebnitzkii*), cumaceans (e.g., *Anchicolorous occidentalis*, *Diastylopsis tenuis*), Pismo clams (*Tivela stultorum*), Northern (Pacific) razor clam (*Siliqua patula*), olive snails (*Olivella biplicata*), polychaete worms (e.g., *Arabella spp., Dispio uncinata, Heimipodus borealis, Lumbrineris* spp., *Nephtys californiensis, Notomastus tenuis, Scoletoma* spp., *Scoloplos acmeceps*), nemertean worms (e.g., *Carinoma mutabilis*, *Cerebratulus* sp*., Paranemertes californica*), and oligochaetes (Straughan 1982, Oakden 1996, SAIC 2006) These species represent suspension, suspension-deposit, surface detritus/deposit, buried deposit, herbivore, carnivore, omnivore, and scavenger feeding types (Morris et al. 1980, SAIC 2006).

Distribution and abundance of macroinvertebrates varies vertically on the beach and horizontal patchiness also is common. Numbers of species generally are lowest in the upper beach and increase seaward, although the diversity along the upper drift line may be enhanced at beaches where macrophyte wrack occurs (Straughan 1981, Thompson et al. 1993, Dugan et al. 2000a). For many species, their location on the beach is predictable and relates to tide inundation and exposure (vertical zonation), although some species such as sand crabs actively move up and down the beach with the tidal swash. Talitrid beach hoppers are found in the upper intertidal (high tide) zone, although they may move down the beach at night to feed on stranded algae during low tides and retreat back up the beach with the incoming tide (Thompson et al. 1993). The first occurrence of talitrid burrowing on the beach has been used as an indicator of the boundary between foreshore and backshore (Dashgardt and Gringras 2005)). Bloodworms (*Euzonus*) and isopods may range from upper to high mid-intertidal (Oakden 1996, SAIC 2006). *Donax* bean clams occur in the middle intertidal (Morris et al. 1980, SAIC 2006), which during high recruitment years may lead to overcrowding that affects feeding and anchoring abilities (Morris et al. 1980). Worms generally range from mid to lower intertidal (SAIC 2006). Spiny and porcelain mole crabs, Pismo clams, northern razor clam, and other amphipods generally occur in the lower intertidal (Oakden 1996, SAIC 2006).

Interstitial, micro- and/or meiofauna (very small organisms) may include bacteria, protozoans, gastrotrichs, copepods, nematodes, platyhelmenthes, and small polychaete worms that feed on dissolved and particulate organics and serve as decomposers (McLachlan et al. 1981, Armonies and Reise 2000). Interstitial and meiofauna may outnumber macroinvertebrates by ratios up to 25:1 and generally reach highest abundance between the upper and middle intertidal zones (Armonies and Reise 2000). Distribution and abundance also may be influenced by sediment characteristics (particularly silts that fill interstitial spaces), sub-surface freshwater flows, depth of the anoxic layer (generally very deep on sand beaches), and organic content of the sand (Oakden 1996).

Macrophyte wrack assemblages may include a variety of herbivores, decomposers, and predators. The wrack usually is first colonized by talitrids and flies, followed by colonization by terrestrial isopods and beetles (Oakden 1996). On California beaches, the following types of species may be encountered in organic wrack debris: talitrid amphipods (*Megalorchestia* spp., *Traskorchestia traskiana*), isopods (e.g., *Alloniscus perconvexus, Tylos punctatus*), a variety of beetles (e.g., carabid, curculionids, histeriid, hydrophilid,

staphylinids, tenebrionids), flies (e.g., *Colopa vanduzeii, Fucellia costalis*), springtails (Collembola), bristletails (e.g., *Neomachilis halophila*), mites (e.g., *Neomolgus littoralis*), spiders, pseudoscorpions, and centipedes (Morris et al. 1980, Oakden 1996, Duggan et al. 2000a).

Potential Functions:

Invertebrates use sandy beaches as primary living, foraging, and reproductive habitat. Most sandy beach macroinvertebrates are suspension feeders on organic material (plankton, detritus) in the swash zone, herbivores and/or deposit feeders on organic matter on or within the sand, and predators/scavengers (McLachlan et al. 1981, Dexter 1992, Dugan et al. 2003, SAIC 2006). Meiofauna interstitial fauna generally function as decomposers. The macrofauna and meiofauna communities operate independently without significant energy exchange between them (McLachlan et al. 1981).

Major inputs of nutrients to the beach are particulate organic matter (detritus, plankton) from the sea and carrion (McLachlan et al. 1981). Washed ashore macrophytes (kelp, surfgrass, algae) represent an important organic source for beaches in California (Dugan et al. 2000, 2003). Wave energy transports energy and matter throughout the beach system by bringing in organic matter, pumping water and organics through sediment pores where decomposition occurs, and exporting nutrients back to the sea (McLachlan et al. 1981). It has been suggested that the intertidal and surf zone areas of the beach together act as an ecosystem with important nutrient feedback loops between these areas (McLachlan 1980, McLachlan et al. 1981).

Macroinvertebrates represent important forage for birds and fish (McLachlan et al. 1981, Baird 1993, Thompson et al. 1993, Dugan et al. 2000a, 2003). Small clams, worms, and crustaceans are eaten by a variety of shorebirds. Gulls opportunistically feed on bean clams, dead invertebrates, and scavenge trash for organic tidbits. Fish feed on invertebrates (particularly sand crabs, bean clams) in the very low intertidal and adjacent nearshore zone (Fitch and Lavenberg 1971 cited in Thompson 1993, Morris et al. 1980). Some marine invertebrates (e.g., clams, sand crabs) are taken by recreational fishermen for bait and/or food.

Associated Species	Forage/ Prey	Eaten By
Invertebrates	X	X
Fish		X
Birds		X
Vegetation	X	
Marine Mammals		
Terrestrial Animals		
Humans		X

The number of species (and feeding types) collected at a beach may reflect factors associated with beach morphodynamics, macrophyte wrack, disturbance, and/or sand depth and persistence (Dugan et al. 2000a, Brown and McLachlan 2002, SAIC 2006). Differences in sandy beach community composition and structure primarily relate to physical factors (e.g., wave energy, grain size, slope) (Straughan 1982, McLachlan and Hesp 1984, McLachlan 1990, McArdle and McLachlan 1992, Dexter 1992, McLachlan et al. 1993, Thompson et al. 1993, McLachlan 2001, Brown and McLachlan 2002).

Generally, higher diversity and abundance characterize flatter sloped beaches that dissipate wave energy (dissipative beaches) than steeper-sloped beaches that reflect wave energy (reflective) (McLachlan 1990, Nelson 1993, Brown and McLachlan 2002, Defeo and

McLachlan 2005, McLachlan and Dorvlo 2005). The number of invertebrate species associated with these three categories of beach types has been reported as 0-4 (reflective), 4-19 (intermediate), and 16-39 (dissipative) for beaches in Australia, Belgium, Chile, Oregon, and South Africa (McLachlan 1990, Brown and McLachlan 2002, and reviewed in Dugan et al. 2000a and 2003). Dexter (1992) reviewed data from 284 locations world wide and summarized a similar pattern based on exposure to wave action, with an average number of species of 8 for exposed beaches, 12 for semi-protected beaches, 16 for protected beaches, and 22 for very protected beaches.

Dugan et al. (2000a) reported a total of 11 to 37 species per survey at 36 intermediate and reflective beaches in southern California, but noted that a relatively high number of species (33) was found at one of the reflective beaches (perhaps related to a relatively low wave height of 1 ft (0.3 m) (also see Dugan et al. 2003). Numbers of species associated with intermediate and reflective beach types at many southern California beaches are relatively high compared to reports for other beaches in the world (Dugan et al. 2000a). However, general community patterns with respect to different morphodynamics appear to match those described elsewhere, but othr factors such as isolation, human disturbance, and input of macrophyte wrack may strongly influence California sandy beach communities (Dugan and Hubard 1996, Dugan et al. 2000a).

In addition to the general pattern of increased species richness with decreased wave exposure, Dexter (1992) noted a change in taxonomic composition of invertebrate communities, with dominance by crustaceans on exposed beaches and an increase in polychaetes as wave exposure decreased. Dugan and Hubbard (1996) demonstrated that the often numerically dominant *Emerita* sand crab is tolerant of a wide range of environmental conditions with occurrence generally independent of beach morphodynamics, suggesting differences in local distribution may relate more to variation in recruitment along the coastline. However, results indicated higher abundance (survivorship) of older sand crabs on beaches where sand is retained through winter months.

The number of invertebrate species and abundance vary seasonally associated with sand mobility (seasonal erosion and accretion) and storm disturbance. Seasonal differences in species number is less on beaches where sand mobility is limited, but can range widely from many more species during seasonal sand accretion and few to no invertebrate species on highly erosive beaches during seasonal erosion if the sand layer thins and rocky platform and/or cobble become dominant (MEC 2000a, Brown and McLachlan 2002, SAIC 2006).

Biological interactions also influence sandy beach communities. For example, density dependent competitive interactions were demonstrated between *Emerita* sand crabs and small clams (*Mesodesma*), both of which may be numeric dominants on sandy beaches in Chile (reviewed in Dugan et al. 2004). High densities of clams and sand crabs often were spatially separated on the beach, and in areas of overlap the burrowing rates of large sand crabs were affected and large sand crabs also physically displaced clams. Dugan et al. (2004) also reviewed observational notes and distributional patterns between sand crabs and *Donax* clams from other studies, suggesting that density-dependent competitive interactions likely occur between those species. Defeo and McLachlan (2005) reviewed that under the more benign dissipative beach characteristics, biological interactions may be more important than physical factors in structuring macroinfaunal communities.

Other factors affecting community development include macrophyte wrack, which imports organics to the upper beach and support invertebrates (e.g., talitrid amphipods, oniscid

isopods, beetles, flies, other insects) dependent on this resource, and provides secondary production for higher trophic levels (e.g., some shorebirds) (Brown and McLachlan 2002, reviewed in Dugan et al. 2003). Wrack burial was shown to enhance abundance of some macroinfaunal worms (e.g., capitellid, orbinid, nereid) on mudflats and intertidal sandflats in Botany Bay, Australia (Rossi and Underwood 2002).

Life History Facts:

A variety of reproductive strategies apply to the invertebrates that use sandy beach habitats. Most of the commonly occurring sandy beach invertebrates release eggs and/or larvae that undergo further development in the plankton, and then settle and metamorphose into their juvenile-adult morphology (Morris et al. 1980). However, the duration of the planktonic stage and/or larval behavior result in different dispersal capabilities depending on species.

Most crustaceans brood fertilized eggs; for example, sand crabs brood eggs and hatch larvae that are released to the plankton; however, amphipods (including beach hoppers) brood young until they are able to fend for themselves (Morris et al. 1980). Clams spawn gametes directly to the sea that develop into planktonic larvae with variable dispersal potential. For example, Pismo clams have limited dispersal because eggs settle to the bottom and hatch within 2 to 3 days of fertilization, and Northern razor clams also have limited larval dispersal because of brevity of swimming larval stage and tendency of larvae to remain in the sand (Lassuy and Simons 1989, CDFG 2001). Bean clams, which are common to southern California, have highly variable recruitment at irregular intervals from 2 to 14 years, apparently from larvae originating elsewhere (Morris et al. 1980). Olive snails lay eggs that when hatched, the larvae quickly settle to the bottom (Morris et al. 1980).

Although reproduction may occur throughout the year, most spawning occurs between spring and late summer or early fall (Morris et al. 1980, Lassuy and Simons 1989). Invertebrate abundance also is highest on the beach in spring through late summer-early fall coincident with recruitment and movement patterns of dominant species. Recruitment begins in spring and may continue through summer depending on species (Morris et al. 1980).

Most species that live on sandy beaches have relatively short life spans, one to three years, while a few are long lived such as the Pismo clam (up to 50 years) and northern razor clam (5 to > 10 years) (Morris et al. 1980, Lassuy and Simons 1989). Longer lived species occur on gentle slope, stable beaches (Lassuy and Simons 1989).

Sandy beach invertebrates generally are motile, adapted to burrowing in shifting sediments. Some are quite mobile such as sand crabs which move up and down the beach with the tides and may move to the shallow subtidal zone during high tides and seasonal periods of beach erosion (Dugan et. al 2000b, 2004). Others like the *Donax* bean clam and Pismo clam hold position by digging into the sand, and the shallow burrowing bean clam may also extend its foot and siphons to provide drag if exposed (Morris et al. 1980). The relatively stationary behavior of the California species *Donax gouldii* is similar to that of *D. serra*, which undergoes limited semilunar movements corresponding to spring-neap tide cycles to maintain position in a band of water-saturated sand, but different from other species of *Donax* common in other parts of the world that migrate with the swash (Donn et al. 1986).
Burrowing depths and rates vary among species. The sand crab (*Emerita analoga*) is a substrate generalist with similar burrowing rates (generally < 6 seconds) across a range of sediment types from fine sand (0.15 mm) to gravel (3.24 mm) for individuals ranging from 10

to 30 mm in size (Dugan et al. 2000b). Sand crabs also can swim if dislodged, but generally only move a short distance before rapidly burrowing into the sand (Morris et al. 1980, Dugan et al. 2000). The spiny mole crab (*Blepharipoda occidentalis*) and porcelain mole crab (*Lepidopa california*), which are common but patchy in distribution on California beaches, are rapid burrowers in fine to medium sands (≤ 6 seconds) but burrow slower in coarser sands (> 6 to 18 seconds) and take longer to orient and burrow after dislodgement in the swash zone (Dugan et al. 2000b) These species burrow deeper than *Emerita*, do not migrate up and down the beach with the tides, and may be more abundant subtidally than intertidally (Morris et al. 1980). It has been suggested that species that are rapid burrowers across a range of substrate types may inhabit a wider range of beach morphodynamic types and tidal zones than species that burrow slowly relative to swash period depending on sediment characteristics (Dugan et al. 2000b).

Burrowing rates of mollusks also vary. Some species of *Donax* have been reported as substrate sensitive with slower burrowing rates in coarse sediments (Alexander et al. 1993 cited in Dugan et al. 2000). Experiments with *Donax variabilis* showed similar burrowing times (approximately 10 seconds) in fine to coarse sands, but significantly slower (> 25 seconds) rates in sediment with coarse shell (Petersen et al. 2002).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/brood Egg/Spawn Planktonic	Spring-early Fall peak	Year round	No	No	1 to > 10 years	Motile to Mobile

Adaptations and/or Behaviors to Disturbance:

Mobility, morphology, and high recruitment are the primary adaptations of invertebrates living on dynamic intertidal beaches. Many of the invertebrates inhabiting sandy beaches have reproductive strategies characterized by high reproductive output and planktonic larvae with wide dispersal, which contributes to recruitment potential, and/or larvae with limited dispersal that favor recruitment to beaches with suitable habitat conditions. Most species are active burrowers and some are capable of swimming when dislodged from the sand. Sand crabs may be sensitive to vibration based on observation of their retreat when walkers are still several feet (meters) away (K. Green, personal observation).

Life Stage	Behavior			Protective Shell	Habitat	High Reproductive Output and/or Growth
	Burrow	Crawl/ Walk	Swim			
Adult	X	X	X	X	X	
Juvenile	X	X	X	X	X	
Egg/larvae						X

Species differ in tolerance and/or sensitivity to differences in wave exposure and interrelated variables such as beach slope and grain size, which account for the trend of increasing species richness across a continuum from reflective to dissipative beaches (McLachlan 1990, Dexter 1992, McLachlan 1993). Species common to dissipative beaches where environmental conditions are not as harsh likely have more specific habitat requirements.

Commonly occurring species, such as *Emerita* sand crabs, have been found to be habitat generalists, tolerant of a wide variety of beach morphodynamic types and sediment characteristics (Dugan and Hubbard 1996, Dugan et al. 2000b). High mobility may contribute to the broad environmental tolerance range of *Emerita* sand crabs. For example, sand crabs are highly mobile, moving up and down the beach with the swash. In addition, sand crabs may move subtidally to escape disturbance during periods of beach erosion or on extremely high tides (Jamarillo et al. 2000 cited in Dugan et al. 2000b). Dugan and Hubbard (1996) reported that higher abundances of older sand crabs may occur on beaches where sand is retained throughout winter months and survival is higher, in contrast to beaches that experience substantial sand scour and erosion.

Species display various morphological adaptations for burrowing. Burrowing mollusks generally are disc-like, blade-like, or cylindrical in shape with a well developed foot (Stanley 1970 cited in Mauer et a. 1986). Burrowing crustaceans have body forms and mobility that facilitate burrowing (Mauer et al. 1986). Coordination between legs, tailfan, and abdomen is adapted for burrowing in *Emerita* sand crabs and *Blepharopoda* and *Lepidopa* mole crabs (Faulkes and Paul 1997 cited in Dugan et al. 2000b). Physiological adaptations in crustaceans may include ventilatory reversals that clear the branchial chambers of sediment and cardiovascular modulation (McGaw 2003). Morphological attributes of burrowing worms may include one or more of the following features: tapered or flattened bodies, strong parapodia, large proboscis, external cilia, mucus production (MacGinitie and MacGinitie 1968, Morris et al. 1980, Mauer et al. 1986, Brusca and Brusca 1990).

Species vary in burrowing capabilities and tolerance to sedimentation. For example, shallow burrowing bivalve mollusks with siphons and juvenile deep burrowing siphonate species were able to escape overburdens of native sediment ranging between 4 and 20 inches (10 and 50 cm) (Kranz 1972 cited in Maurer et al. 1986). Relatively sedentary bivalves (borers, infaunal non-siphonate species, mucous tube feeders, labial palp deposit feeder) or bivalves living on the sediment surface (epifaunal suspension feeders) were unable to escape < 1 inch of overburden. Krantz (1972) reported that deep burrowing siphonate species also were highly sensitive to sedimentation.

Shallow burrowing species such as *Donax* clams are adapted to maintain position near the surface of shifting sediments, which requires more energy than does emergency and reburial during migration (Ansell and Trueman 1973 cited in Mauer et al. 1986). In contrast, deep burrowing sipohonate species (e.g., razor clams) may respond to disturbance by digging deeper into the sediment (Morris et al. 1980). Northern razor clam, found along coast in central and northern California, is sensitive to silt; a sediment silt/clay concentration of 2.2% was estimated as a critical threshold for this species (Nickerson 1975 cited in Lassuy and Simons 1989).

Several studies show that sediment grain size characteristics influence burrowing capabilities of sandy beach invertebrates. Laboratory experiments demonstrated that burrowing performance of *Donax serra* and *D. sordidus* was influenced by grain size and sorting (Nel et al. 2001). Fastest burial times were measured in fine and medium sands (0.12 to 0.5 mm) that were well sorted, and were slower towards very fine (0.09 to 0.12 mm) and coarse extremes (0.5 to 2 mm). Burial times were slowest in moderately sorted sediments, particularly for coarser sands (> 0.5 mm). Burial times also were slower for larger than small individuals. Nel et al. (2001) suggested that based on burial rates, the larger *D. serra* was more adapted to dissipative beaches, while smaller *D, sordidus* was adapted to a broader range of beach morphodynamic conditions (dissipative/intermediate).

Burrowing times of the intertidal isopods *Excirolana armata* and *E. braziliensis* were affected by sediment type and water content; non saturated sand precluded burial and coarse sand retarded burial (Yannicelli 2002). *E. armata*, which occurs in the mid to upper intertidal of dissipative to intermediate beach types, was a stronger swimmer than *E. braziliensis*, which inhabits the upper intertidal over a wider range of beach states.

McLachlan (1996) found that disposal of coarse sand mine tailings changed sediment and morphodynamic conditions at a beach in Namibia with substantial impact to macrofauna. Grain size changed from fine (0.11 to 0.16 mm) to coarse (0.5 to 0.8 mm), beach morphodynamics changed from dissipative to intermediate state. The number of species on the changed beach was 8 to 12 per transect and abundance ranged from 640 to 4,710 per meter. In comparison, unaffected beaches nearby had 15 to 20 species and abundances of 24,120 to 129,276 per meter.

Studies indicate that burrowing rates and ability to escape from sediment overburdens decrease with increasing overburden depth, exotic sediments, and increased time since burial. Several studies are reviewed below that were conducted mainly on estuarine species and/or in estuarine habitats. They are included in this review because they provide insight regarding differential survival associated with overburden depth and response when sediments are sandy versus high in silt-clay. However, it should be recognized that overburden depths and/or silt-clay concentrations applicable to estuarine invertebrate response may differ from that on the more dynamic open coast.

Mauer et al. (1981, 1982, 1986) conducted laboratory experiments examining the response of species to 14 to 16 inches (36 to 40 cm) of sediment overburden for different sediment types (100 percent sand, 17 to 21 percent silt-clay, 35 to 43 percent silt-clay, and 92 to 99 percent silt-clay) over time periods of one, eight, and fifteen days. All animals were able to survive short-term (1 day) burial and responded by vertically migrating towards the sediment surface; however, survivorship varied depending on species and sediment type. The amphipod *Parahautorius longimerus* and polychaete *Scoloplos fragilis* displayed similar response with relatively good survival (5 to 36 percent mortality) during the 8- and 15-day experiments with sandy substrate, but relatively poor survival (68 to 100 percent mortality) in sediments with silt concentrations ranging from 17 to 99 percent. The polychaete *Nereis succinea* showed a higher degree of vertical migration and survival (17 to 26 percent mortality) in silt-clay, and moderate survival (30 to 61 percent mortality) in mixed and sandy sediments during the 8- and 15-day experiments. The mollusk *Mercenaria mercenaria* had higher survival (27 to 55 percent mortality) in either the silt-clay or sandy sediments, but decreased survival in mixed sediments between the 8-day (33 to 70 percent mortality) and 15-day (81 to 92 percent mortality).

Turk and Risk (1981) also found different responses to sedimentation for two different species of bivalves and a tube-dwelling amphipod crustacean inhabiting an estuarine flat. The tube-dwelling amphipod *Corophium volutator* was sensitive to an accumulation rate of 2 to 2 ½ cm/month of silty sediment. The bivalve *Malcoma balthica* was unaffected by sedimentation rates of 1.9 to 10.2 cm/month. In contrast, the bivalve *Mya arenaria*, which is common in northern and central California bays, had a sediment overburden LD_{50} (dose where 50 percent mortality occurs) that was lower (< 2 inches, 3 to 6 cm) when sediments were silts or fine sands compared to 9 inches (24 cm) for coarse sands (Turk and Risk 1981). *Mya* has a slow hydraulic mode **of** burrowing that generally is sufficient to cope with

the slow sedimentation and erosion rates of the tidal flats in which it typically lives (Checa and Cadee 1997).

Substantial storm-related deposition of up to 4 inches (10 cm) of terrestrial sediments (characterized by high proportion of silt-clays, organic matter) was observed to have deleterious impacts on intertidal estuarine sandflats, shellfish beds, and seagrass beds in New Zealand that took years to recover (reviewed in Cummings et al. 2003). Researchers undertook as series of field and laboratory experiments to increase understanding regarding nature of impact and biological response. An experimental field study demonstrated that terrigenous clay deposition induced hypoxia and anoxia and reduced numbers of intertidal individuals by more than 50% after 3 days and by more than 90% after 10 days, irrespective of clay thickness; mud crabs were the only animals able to emerge through the clay layer (Norkko et al. 2002).

Another field experiment demonstrated substantial impact with terrestrial sediment slurries of 30 to 60% silt-clay up to 4 inches (10 cm) thick; numbers of colonists remained low during the 4.5 month experiment, but temporal changes in the community were strongly correlated with coarse sand and potential food (chlorophyll *a*) (Cummings et al. 2003). Field manipulative experiments demonstrated that thin layers of terrigenous sediment (< 1 cm) induced negative effects, reducing numbers of taxa and individuals of small species near the surface (large bivalves and deeper dwelling species were less affected) (Loher et al. 2004). Local differences in hydrodynamic conditions and macrobenthic communities resulted in site specific colonization after experimental treatments with terrigenous sediment; little mixing of deposited and existing sediment by waves or bioturbators was observed (Hewitt et al. 2004). Laboratory experiments demonstrated that the burrowing response of juvenile bivalves (*Paphies australis*, *Macomoma liliana*) common to the New Zealand sandflats were adversely affected by terrestrial sediment layers as thin as 1-cm thick (Cummings and Thrush 2004).

Human disturbance may modify sandy beach communities. Beach grooming involves the practice of debris removal along the backshore of some public recreational beaches. Dugan et al. (2003) estimated that over 45% of the coastline in southern California is subject to grooming with heavy equipment. Few studies of the impacts to sandy beach communities associated with beach grooming have been conducted. Brown and McLachlan (2002) reviewed that beach grooming that removes kelp, wrack, and carrion deprive the ecosystem of nutritional input (particularly talitrid amphipods, oniscid isopods, and ocypodid ghost crabs), and machines that filter sand also may remove and eliminate these types of animals. Substantial reductions in wrack-associated invertebrates (e.g., talitrid amphipods, oniscid isopods, insects) were documented on groomed compared to ungroomed beaches in a study conducted in Santa Barbara, California, which was interpreted as having the potential for secondary effects by reducing prey for some shorebirds (e.g., black-bellied and western snowy plovers) based on correlations of their abundance to macrophyte wrack cover and abundance of wrack-associated invertebrates on studied beaches (Dugan et al. 2003).

Other off-road vehicle use on California beaches is limited, primarily involving lifeguards, emergency response, and/or shoreline protection projects. Stephenson (1999) reviewed available studies and concluded that impacts to intertidal macrofauna appeared to be minor, particularly during the day, but additional research was needed. Results of relevant studies on species functionally similar to those in California are briefly summarized below. Studies in North Carolina and South Africa showed mortality rates of undetected to < 10% for mole crabs (*Emerita talpoida)*, bivalves (*Donax serra, D. sordidus, D. variabilis*), and a mysid

(*Gastrosaccus psammodytes*) from off road vehicles (Wolcott & Wolcott 1984, and van de Merwe and van de Merwe 1991 reviewed in Stephenson 1999). Impacts to supralittoral isopods (*Tylos capensis*) on the backshore of a South Africa beach increased with intensity of vehicle use with approximately 10% of the animals damaged by 17 consecutive vehicle passes; this nocturnal species was considered more susceptible to damage at night (van de Merwe and van de Merwe 1991). Brown and McLachlan (2002) considered reported impacts to semi-terrestrial *Tylos* also applicable to talitrid amphipods. Potential vehicle Impacts to other species such as ghost crabs (*Ocypode quadrata*) and turtle hatchlings were reviewed (e.g., Wolcott & Wolcott 1984, Stephenson 1999, Brown and McLachlan 2002); however, these animals do not occur on California beaches.

Potential Impacts from Sediment Management Activities:

One of the earliest reviews of effects of sediment management on beaches was performed as part of a broader review of ecological effects of offshore dredging and beach nourishment (Thompson 1973). Most of the discussion for the beach habitat was based on literature review of ecological considerations such as zonation, physical adaptations of fauna, biotic dependence on physical and chemical characteristics, and the statement that studies of succession in areas nourished with material taken inland showed rapid invasion of fauna and little apparent lasting harm.

No detrimental effects from deposition of offshore sediments as beach fill were foreseen, although further research was stated as being needed. It was stated that the least effect would be expected if the placed sand resembled the original sand in grain size and other physical characteristics. The effects of profile change was unknown, but considered potentially important. It was recommended that design should be given careful attention to avoid damage, and monitoring of projects should include before, during, and after studies. Generally similar conclusions have been made in more recent reviews based on available monitoring from beach nourishment projects (NRC 1985, Greene 2002). Sediment compatibility still is considered the best measure to reduce impacts. However, compatibility defined based only on sediment grain size has resulted in some beach nourishment projects with more substantial environmental impacts as a result of inclusion of shell hash and/or mud balls (Reilly and Bellis 1983, Peterson et al. 2002).

Types of sediment management activities and potential impacts to sandy beach infauna may include:

- Maintenance dredging of embayments – not applicable.
- Offshore borrow site dredging – not applicable.
- Nearshore placement – sedimentation.
- Profile placement – equipment damage, burial, sedimentation, turbidity.
- Beach placement – equipment damage, burial, sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted Functions	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Sand Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Vibration	Direct Damage,			
Behavior		X		X		
Foraging				X	X	
Growth				X	X	
Habitat			X	X		X
Reproduction /Recruitment			X	X	X	
Respiration				X	X	

Equipment

Use of heavy equipment to redistribute sediment during sediment placement has the potential to crush marine invertebrates on the beach. Activities involving pipeline placement across the beach has the potential to crush invertebrates present within the area of operations. Few studies have examined the effects of vehicles and equipment on sandy beach communities during beach nourishment and/or placement.

A study of bulldozer impacts associated with creation of a berm for shore protection was examined in North Carolina and found to significantly reduce the abundance of ghost crabs in the upper beach, mainly because the moved sediments were too coarse to support their burrows and probable difficulty in re-burrowing to the surface after burial (Peterson et al. 2000). Fewer (35 to 37%) small *Emerita* sand crabs were observed during high and low tides at bulldozed sites compared to non bulldozed sites, no difference in abundance of large sand crabs was observed and no consistent response was seen for *Donax* clams. These effects were observed three to four months after the bulldozing project was completed; the duration of impacts was not examined.

Relevant studies indicate that off-road vehicle use impacts may be minor in the intertidal; however, upper and supratidal invertebrates (e.g., talitrid amphipods, ghost crabs) may be more susceptible to repetitive vehicle use (van der Merwe and van der Merwe 1991 reviewed in Brown and McLachlan 2002). These semi-terrestrial crustaceans (and other wrack-associated invertebrates) also may be impacted by beach grooming practices (Brown and McLachlan 2002, Dugan et al. 2003).

Some sandy beach invertebrates may be sensitive to vibration. For example, sand crabs may retreat from approach. Hayden and Dolan (1974 cited in Reilly and Bellis 1983) suggested that the East Coast species *E. tailpoida* relocated to adjacent but unimpacted areas until beach nourishment was over. Effects of vibration and noise during beach nourishment on sandy beach populations have not been examined.

Burial/Sedimentation

The physical character of the beach is altered with beach placement, which generally results in a wider beach, steeper profile, and distinct scarp or berm until the beach fill adjusts

through the profile from wave action. Greene (2002) reported that the scarp may hinder or eliminate the movement of some organisms between the swash zone and upper beach based on review of East Coast (Reilly and Bellis 1978, Nelson et al. 1987) and a west coast project (Parr et al. 1978). Although Parr et al. (1978) did report that the nourishment project initially resulted in a small berm, no reference to it being an impediment was reported.

Reilly and Bellis (1983) reported in their comprehensive review of impacts from beach nourishment at Bogue Banks, North Carolina that several mechanisms may have contributed to reductions in ghost shrimp, which live in burrows in the upper beach and forage in the intertidal during receding tides, however, the scarp was not mentioned as a possible factor. They did consider the possibility that the pipeline used to carry sediments to the beach, which was located at the back beach, acted as a physical barrier preventing their movement to the beach. However, that mechanism was largely dismissed based on nighttime surveys that showed them moving over the pipeline with no difficulty because of natural bridges of windblown sand. Instead they considered emigration from the area in search of food more plausible due to substantial reduction in their intertidal prey from burial. Direct burial of burrows was considered unlikely due to sediment placement location.

The same type of ghost shrimp does not occur on the upper beach along the California coast, but another species of ghost shrimp may occur in the middle intertidal of protected beaches (Morris et al. 1980). Burrowing species that may occur in the upper beach of exposed sandy beaches in California are beach hopper amphipods, which feed on stranded macrophyte wrack and/or drift algae. Temporary berm creation from beach nourishment may not be the primary concern relative to beach hoppers, which if present during sand placement would be expected to experience high mortality from deep sediment overburdens. Beach hoppers may or may not be present on a beach depending on its physical condition.

Reconnaissance surveys prior to the 2001 Regional Beach Sand Project did not find beach hoppers during spring surveys of potential receiver sites when upper intertidal zones were erosive and characterized by shallow sand depths and exposed rock and/or cobble (MEC 2000a). However, beach hoppers were seen on some beaches during the summer when sand depths were greater across the beach profile (*ibid.*). Surveys conducted at City of Encinitas beaches two to four years after the San Diego Regional Beach Sand Project found beach hoppers in the upper intertidal at all three surveyed receiver sites during the third year after nourishment during both spring and summer seasons (SAIC 2006).

The primary direct impact to sand beach invertebrates from sediment placement projects is associated with the substantial overburden depth of sediment placed at the site that results in unavoidable burial, crushing, and/or smothering of invertebrates (NRC 1985, Greene 2002). The amount of overburden depth varies along the beach and is deepest in the upper beach and generally decreases intertidally. Placed sand depths may range from > 3 ft to inches (> 1 m to several centimeters) across the fill (NRC 1995). Experimental studies indicate that some intertidal species are able to burrow through overburdens of > 1 to < 2 ft (40 to 50 cm), while other species have much lower tolerances (e.g., inches) (Kranz 1975, Nelson 1985, Maurer et al. 1986). Nelson (1993) reported that common dominants on the East Coast such as *Emerita*, *Donax*, and *Terebra* had some ability to handle instantaneous burial up to 4 in (10 cm). Lynch (1994) conducted vertical migration experiments in association with his master thesis work of evaluating effects of beach nourishment at Folly Beach, South Carolina, and found several species capable of burrowing through sediment depths of 23 to 35 inches (60 to 90 cm) (cited in NRC 1985, Greene 2002).

Based on burrowing capabilities, some species may be able to escape mortality along the outer and/or leading edges of the fill where overburden depths are less. Maurer et al. (1986) showed that burrowing ability substantially decreased over short time frames (e.g., 3 days). Therefore, escape from burial is only expected during the early part of the construction period. Reduced vertical migration rates and increased mortality have been associated with overburdens having silt/clay contents ranging from 17 to 99 percent depending on species (Turk and Risk 1981, Maurer et al. 1986). Maurer et al. (1986) concluded that vertical migration is one mechanism that may contribute to invertebrate recolonization when deposits are similar to native sediments, but did not expect this to be a viable mechanism when placed sediments were dissimilar or in areas where deposits exceeded 2.9 ft (0.9 m) of overburden.

Because of this differential survival capability associated with overburden depth, the degree of impact to the sandy beach community may be expected to vary with project size not only from the linear dimension of coverage but also with respect to vertical depth of placement. Because mortality associated with substantial overburden depths is unavoidable, the recovery rate of the community, which represents prey base to higher trophic levels, has been the greater issue in reviews of ecological effects of beach nourishment (NRC 1995, Greene 2002).

Sediment dissimilarity can lead to an altered community. In a study conducted in Africa, placement of coarse sand (0.5 to 0.8 mm) on an otherwise fine sand (0.11 to 0.16 mm) beach apparently had limited and localized smothering effects on the invertebrates, but resulted in 40 to 50% lower species richness and > 90% lower abundance than on a nearby similar beach (McLachlan 1996). Petersen et al. (2002) presented results of laboratory studies that showed reduced abundance and burrowing time for *Donax* in nourished beach material with a mix of sand and shell hash compared to that of native sand beaches in North Carolina. Elevated shell content (5-20%) was of some concern for nourishment at Imperial Beach, California; however, waves reworked the shell deposits into smaller fragments or buried them in the nearshore and did not have an obvious negative influence on benthic invertebrates (Parr et al. 1978).

Indirect sedimentation along the intertidal and subtidal profile of the beach will occur from beach, nearshore, and/or profile placement as fill material redistributes to a more stable profile (Section 4.2.7). Indirect sedimentation also may result from dune placement and redistribution of sands during higher tides. Indirect sedimentation may be expected to influence downcurrent beaches as reworked sands are carried alongshore with littoral drift. This sedimentation would be expected to occur over time scales associated with natural beach erosion and accretion cycles and littoral transport.

Few studies have examined indirect sedimentation of downcurrent beaches from beach nourishment. SAIC (2006) found that invertebrate populations were enhanced at and at distances 1,000 to 2,500 ft (300 to 760m) downcurrent from receiver sites two to four years after beach nourishment compared to what was found during erosive conditions prior to nourishment. Effects of indirect sedimentation on subtidal benthic communities are reviewed in Section 4.2.7.

<u>Turbidity</u>

Reviews indicate that marine and estuarine invertebrates generally are tolerant of high suspended solids concentrations over reasonably short durations (Stern and Stickle 1978,

NRC 1985, LaSalle et al. 1991, O'Connor 1991, Clarke and Wilbur 2000). However, prolonged exposure to high concentrations may be lethal and/or substantially reduce habitat quality.

Several dominant sandy beach fauna are suspension and/or filter feeders (e.g., sand crabs, clams) on microscopic plankton and other organic material. Organisms living in the intertidal to nearshore zone often have morphological adaptations that provide protection from naturally turbid conditions, which occur during storm and/or high wave conditions. For example, Pismo clams have papillae in their inhalant siphon that excludes larger sand particles (CDFG 2001).

However, filter-feeding organisms may be vulnerable to turbidity interfering with feeding behavior. For example, mole crabs suffer impaired feeding with increased turbidity (Turner 1990). Lassuy and Simons (1989) reported that razor clams are susceptible to suffocation from silt, and recommended that silt-generating activities in the vicinity of razor clam beds should be avoided.

Reilly and Bellis (1983) found few invertebrates along transects immediately adjacent but outside the area receiving beach nourishment, which they attributed to turbidity effects. They also surmised that turbidity interfered with recruitment of invertebrates during beach nourishment based on observations that a substantial number of juvenile *Emerita* mole crabs were collected three days after nourishment operations ceased.

Microcosm experiments lasting two weeks showed that growth of *Donax variabilis* was the same as controls when turbidity was 9 NTU, but growth was statistically lower (approximately 0.15 mm) lower when turbidity was 96 NTU; no significant difference in the condition of the clams were observed over this range of turbidity (Petersen et al. 2001).

Laboratory experiments of 3 and 21 days whereby surf clams (*Spisula solidissima*) were dosed with clay suspensions of 100, 500, and 1,000 mg/L showed decreased chlorophyll consumption and increased pseudofecal production over all tested concentrations during the 3-day experiments (Robinson et al. 1984). Clams were unable to acclimate to clay suspensions of 100 to 500 mg/L over 21-day experiments showing higher chlorophyll consumption relative to 3-day experiments, but were unable to acclimate to the 1,000 mg/L concentration.

Laboratory experiments conducted on species of clams may occur in the intertidal and/or subtidal habitats in more protected embayments found responses to be sublethal at concentrations < 500 mg/L; lethal concentrations ranged from 500 to >100,000 mg/L. The studies also showed that early life stages may be more sensitive than adults to suspended sediment concentrations. For example, American oyster (*Crassostrea virginica*) larvae were more sensitive (e.g., 20-31% larval mortality at 750-2,000 mg/L) than adults (> 4,000 mg/L detrimental) (Davis and Hidu 1969, Wilson 1950, both cited in LaSalle et a. 1991). Quahog (*Mercenaria mercenaria*) eggs had reduced development at 188-375 mg/L; larval response ranged from 50% mortality from 500 mg/L of artificial substrate to no effect from 1,000 mg/L of silt (Davis 1960 cited in LaSalle et al. 1991). Sublethal siphon response (retraction, prolongation) was observed for soft-shelled clams (*Mya arenaria*) after exposure to 100-200 mg/L for periods ranging from 7 to 30 days (Grant and Thorpe 1991 cited in Clarke and Wilbur 2002). The introduced Japanese littleneck clam (*Tapes japonica*) tolerated exposure to 100,000 mg/L of kaolin clay for 10 days without mortality (Peddicord et al. 1975 cited in LaSalle et al. 1991).

Recovery from Disturbance:

Generally, impacts to sandy beach intertidal fauna have been considered temporary, with recovery reported within weeks to months (Hurme and Pullen 1988, NRC 1995, Greene 2002). However, the NRC (1995) cautioned that sampling efforts for many of the studies were limited with respect to number of samples collected and duration and frequency of sampling. Peterson and Bishop (2005) also question validity of reports of rapid recovery based on sampling design deficiencies.

	Recovery Rates				
Impact	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	X				
Burial	X	X			
Sedimentation	X				
Turbidity	X				
Habitat Loss					X

Sandy beach invertebrate life history and natural seasonal occurrence patterns provide the basis for understanding the rapid recovery rates often reported. Invertebrate abundance on a beach varies across season, with increasing development from spring to summer associated with planktonic recruitment and immigration, which also coincides with the seasonal period of sand accretion; invertebrate abundance decreases from late summer through winter, which begins to occur prior to winter erosion. This strong benthic-pelagic coupling between sandy beach habitat and invertebrate recruitment means that beaches are natural receiver sites of sand and colonizing invertebrates each year. This relationship is most extreme at erosional beaches that strip to cobble and/or bedrock and/or intermediate beaches with substantial seasonal sand migration. Beaches with seasonally persistent sand may support a more diverse fauna and long-lived species (McLachlan 1990, Dexter 1992, Dugan et al. 2000a, Brown and McLachlan 2002, Dugan et al. 2003, SAIC 2006).

Invertebrate recovery after beach nourishment begins almost immediately after cessation of construction activities. Recovery rates of community structure vary from weeks to > 1 year (Table 4.2-1). Reported recovery rates generally have been based on community structure measures of number of species, abundance, and sometimes biomass, and derived measures such as diversity, eveness, and dominance (e.g., Parr et al. 1978, Gorzelany and Nelson 1987, Burlas et al. 2001). Sometimes species composition and age structure also have been considered (e.g., Reilly and Bellis 1983).

Re-establishment of the community results largely from larval recruitment, but also may be influenced by immigration from shallow nearshore and adjacent beaches, and possible survival of some residents (Parr et al. 1978, Grant 1981, Reilly and Bellis 1983). The relative contribution of recovery by adults versus larval recruitement may vary depending on life history characteristics of species, habitat characteristics, and scale of impact (Dauer and Simon 1976, Santos and Simon 1980, Levin 1984). Because recovery is strongly tied to the seasonal recruitment period, rates of recovery may be substantially altered if disturbance from beach nourishment extends into the recruitment period.

Table 4.2-1. Summary of timeframes for recovery of sandy beach benthic invertebrates after beach nourishment and/or sand placement.

Reference	Project Location and Volume (cy)	Recovery Rate	Notes On Recovery Time as Reported by Author(s)
Beach Placement			
SAIC 2006	Encinitas, California 3 sites, 101,000 to 132,000 cy	< 2 years	Study commenced two years after sand placement
Burlas et al. 2001	Asbury to Manasquan, New Jersey 8,083,440 cy Phase 1 completed October, Phase 2 completed mid December	Intertidal 2->5 months (study duration) Subtidal > 5 months (study duration)	Faster recovery in intertidal when sands placed during fall (seasonal high), than when placed during winter (seasonal low)
Gorzelany and Nelson 1987	Melbourne and Idialantic Beaches, Florida 540,204 cy Nov-Feb	3 months	
Jutte et al. 1999*	Mrytle Beach, South Carolina 2.6 million cy	3-6 months	
Parr et al. 1978	Imperial Beach, California 1,000,620 cy Mar-Jun	< 2-4 months	Recovery evaluation based on community summary measures (abundance, number of species) and key species abundance.
Peterson et al. 2000a	Bogue Bank, North Carolina 278,000 cy Mar-May	> 2 months (study duration)	Extensive shell hash, mud balls, sediment compacted (harder)
Reilly and Bellis 1983	Bogue Bank, North Carolina 1.18 million cy Dec-June	> 2 months (duration of post project period)	Shell hash, clay balls. Authors suggested high turbidity (> 1,000 mg/L) associated with fill in spring may have impacted larval recruitment
Rakocinski et al. 1996	Perdido Key, Florida 5.36 million cy Autumn 1989-1990	Substantial 1 year	
Saloman and Naughton 1984*	Panama City, Florida 400,248	5-6 weeks	
Van Dolah et al. 1994*	Folly Beach, South Carolina	2-3 months	
Versar 2004	North Carolina 5.6 million cy 4 sites Spring2001 – Winter 2002	Donax 1 year 2 sites > 1 year 2 sites *Emerita* 1 year 3 sites > 1 year 1 site Ghost crabs 1 year all 4 sites	Abundance of *Donax, Emerita,* and ghost crabs pre- and post-project (1 year later) Authors suggested no delay at sites completed in fall and winter, but delay at sites completed in spring, summer

* cited in Burlas et al. 2001

Timing of disturbance also may influence colonization of species (Levin 1984). For example, Peterson et al. (2001) showed that a one month difference in timing of project completion during spring made a difference in recruitment and/or size distribution of the numerically abundant *Emerita* mole crabs and *Donax* clams. For instance, abundance and size distribution of *Emerita* at a nourished beach was more similar to that of a control beach when construction was completed earlier (May) rather than later (June) in spring; a similar result was seen for *Donax* size, but was not as obvious for abundance.

Rapid recovery rates would not be expected to apply to slow growing and long-lived species such as Pismo clams and northern razor clams, particularly when considering recovery of age structure of populations. These species attain old age and large size on relatively broad and flat beaches. Based on different community development patterns associated with beach morphodynamics, it would be expected that recovery of a more diverse fauna such as occurs on dissipative beaches would take longer than simpler communities on erosive beaches.

Minor disturbance to the upper 1 ft (0.3 m) of the beach, as may be expected from temporary equipment impacts, would be expected to be rapid based on studies of vehicle impacts and experimental studies. Experimental removal of 1 ft (0.3 m) of sediment from a 200 square meter area of mid-intertidal sandy beach habitat resulted in a relatively rapid redistribution of sediment and only temporary reductions in abundance and abundance and biomass of the dominant species *Donax*, which were not significantly different from controls after approximately two weeks (Schoeman et al. 2000).

Parr et al. (1978) monitored invertebrate recovery before and after hydraulic pumping of approximately 1 million cy onto 0.85 mi (1.37 km) of shoreline at Imperial Beach, California (Section 4.2.6). The project was completed over a 4 month period, March to June. Material was 70 to 85% sand, 5 to 15% silt/clay, and 5 to 15% shell material. During beach nourishment there was a temporary increase in fine sand content in the intertidal (median diameter ~0.13 mm) that was short-lived. The percentage of coarse sand was higher by 4 to 10% after beach nourishment. Beach slope also was steeper after nourishment but became less so after 5 months. Parr et al. (1978) reported rapid recovery on the order of < 2 months based on consideration of community summary measures (abundance, number of species, diversity) and abundnace patterns of major species. The project was moderately large (1,000,620 cy) and sand placement was completed over four months (March through June). The spring conclusion of the project was within a month of the onset of the recruitment period.

During a recent 8.1 million cy nourishment project in New Jersey, project timing was considered important to recovery rate with quicker recovery observed when one phase of the project was completed during fall (period of high recruitment) and slower recovery when the project phase was complete during winter (period of low recruitment) (Burlas et al. 2001). Abundance, biomass, and taxa richness of the intertidal assemblages were reported as recovered within 2 months or estimated as 6.5 months based on trend analysis, depending on project phase. Recovery difference was not due to project timing, but rather response to natural recruitment events; i.e., rapid after fall phase when recruitment was ongoing, and lag after winter project phase coinciding with seasonal low and being tied to next possible recruitment period (spring). It is likely that the reported 2 month recovery after fall placement was initial recovery response associated with planktonic recruitment and not recovery of population structure since there would have been an insufficient time to develop

a size range distribution that develops over an entire season. Nevertheless, study results showed recovery following a natural seasonal pattern after both fall and winter phases.

Versar (2004) examined the effects of placement of 5.6 million cy of dredged material at four beach sites in North Carolina by comparing pre- and post-construction (one-year later) abundance of dominant species in the swash and wrack zones. Significantly lower abundance in the swash zone was noted for *Donax* clams and *Emerita* mole crabs at two of the four beach sites. One site was constructed in the spring. The other site was constructed during summer and was disturbed twice by sand placement due to contractor error. No significant impacts to clam or mole crab abundance attributed to sand placement were reported at the two beach sites constructed in fall and winter. No significant differences in ghost crab abundance in the wrack zone from sand placement were reported.

Rakocinski et al. (1996, 2001) monitored recovery at Perdido Key, Florida associated with a 9.2 million cy beach nourishment project that placed approximately 60% of the material on the beach, and the remainder subtidally at a water depth of 22 ft 6.7 m). Both intertidal and subtidal phases took 1-year to complete, spanning autumn to autumn seasons. Monitoring was conducted once before, immediately after beach nourishment and quarterly for two years after nourishment. The sandy material retained on the beach was < 4% silt/clay. Intertidal recovery (species number, density, diversity, evenness) was reported as nearly complete within 1 year. Subtidal recovery took longer (see Section 4.3.7).

Slower recovery rates have been attributed to unfavorable project timing and dissimilarity in grain size characteristics of placed sediments with the native beach. Reilly and Bellis (1983) considered beach nourishment interference with spring recruitment one of the contributing factors to incomplete recovery of the beach invertebrate community within two months of completion of the project, which spanned winter through late spring seasons (December through June). Turbidity was considered by them the probable cause of interference since they observed substantial recruitment of sand crabs within three days of project cessation. Turbidity was very high (1,760 to 4,700 mg/L) in the surf zone due to unconfined discharge in the swash zone and sediment characteristics, which had coarser grain size, shell hash, and clay balls associated with the dredge sometimes encountering clay lenses.

Peterson et al. (2000a) examined short term recovery after placement of approximately 278,000 cy on two beach sites at Boque Banks, North Carolina between March and May. Densities of *Donax coquina* clams and *Emerita* mole crabs were 86-99% lower on nourished beaches compared to unnourished beaches 5-10 weeks after nourishment. A change in sediment characteristics from 0.2 mm to very fine sand (0.08 mm) sand with shell was suggested as being influential based on consideration of reported grain size preference (0.25 to 0.5 mm) of *Emerita*.

Nelson (1993) summarized based on his review of several beach nourishment projects that community level effects tend to occur only where inappropriate sediments are used, particularly with a poor match in grain size or those in high organic matter or fine particles.

Based on the literature review, rapid recovery is expected at seasonally dynamic beaches that primarily support species recruited from the plankton. However, rapid recovery does not apply to persistent sand beaches that support species that are long-lived and/or do not rely on planktonic recruitement.

Failings of studies that are too short in duration appear to relate more to lack of documentation of recovery of size structure of populations rather than species recruitment, although that too may be the case if beach nourishment occurs at productive dissipative to high intermediate beach types. Important findings from available studies are that factors such as changed substrate type, project timing relative to recruitment, and multiple disturbances in a season are influential to recovery rates.

Critical Impact Thresholds:

Little to no survival of benthic invertebrates occurs when buried by > 2 to 3 ft (60 to 90 cm) of sediment. Substrate change that resulted in habitat degradation for invertebrates and secondary consumers would be significant.

Data Gaps:

Few studies have examined the benefits of beach nourishment to sandy beach habitat functions at erosive beaches. Available studies indicate substantial changes in coarse and/or silt/clay fractions of sediments may alter benthic communities. However, critical thresholds with respect to changes in substrate characteristics are not well understood. Few data are available on recovery rates where there is periodic beach nourishment.

Restoration:

Beach nourishment does not result in habitat loss that would require restoration of invertebrates. There are reported cases of sediments being placed on beaches with substantially different sediment characteristics than native sands, resulting in changed biological resources. Restoration may be warranted in cases where sediment dissimilarity results in reduced biological function of sandy beach habitat. Bulldozers have been used to remove muddy sandy placed during beach nourishment at some beaches on the East Coast of the United States. Restoration could range from removal and replacing sediment with compatible sands and/or covering over incompatible material with compatible sands (e.g., similar to beach nourishment in sand eroded areas).

Summary:

Impacts to sandy beach invertebrates from beach nourishment generally are unavoidable. Impacts may vary depending on volume of placed material, compatibility between source sands and native sands, existing habitat quality, and seasonal timing of project. Direct impacts during beach or profile placement include destruction of immobile and sedentary invertebrates from burial and spreading of fill material with earth moving equipment. Although some invertebrates may escape impacts, mortality is substantial and nearly complete.

Most reports of recovery of the intertidal invertebrate community after beach nourishment are a year or less. Sandy beach habitats display seasonal development in invertebrate populations associated with natural erosion and accretion cycles. This is most pronounced at seasonally erosive beaches, where development of invertebrate populations occurs after sufficient sand has accreted to the beach and seasonal recruitment is from planktonic larval recruitment. Peak recruitment times of invertebrates to California beaches range from spring through early summer. Studies indicate that invertebrate recovery may be quicker when beach nourishment is completed before the onset of spring recruitment.

Relatively slower recovery would be expected for dissipative to high intermediate beach types with persistent sand and more diverse assemblages, including long-lived species such as Pismo and northern razor clams. Dissipative and high intermediate beach types are not sand limited; therefore, beach nourishment impacts can be minimized by not using those types of beaches but instead selecting receiver sites based on shoreline erosion concerns.

Turbidity impacts generally cease with construction; however, it has been inferred that elevated turbidity during beach nourishment may delay larval recruitment to the beach (Reilly and Bellis 1983). This suggestion is consistent with studies reporting delayed recovery when beach nourishment is conducted in spring and/or summer.

Sandy beach invertebrates appear to be tolerant of vehicle impacts along the intertidal. However, semi-terrestrial crustaceans that live in burrows at the forshore-backshore boundary such as talitrid amphipods are vulnerable. These species also may be impacted by beach grooming.

Because of the burrowing capability of sandy beach invertebrates, no substantial adverse impacts from post-project sand transport are expected unless there is a substantial change in substrate characteristics. Studies indicate sandy beach habitat may be enhanced by sand transport sedimentation in erosive beach areas. However, sediment chararcteristics of source sediments are important to habitat quality. Studies indicate sandy beach fauna may be adversely affected by silty, coarse sand, high shell content, and muddy substrate. The most frequently referenced factor thought to contribute to rapid recovery is compatibility between native and nourishment source sediments. Critical thresholds with respect to substrate conditions are poorly understood.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on sandy beach invertebrates.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	Documented	Relevant documentation	Documented	Protective conservatism	Documented to anecdotal
Critical Impact Thresholds	NA	Destruction of habitat for semi-terrestrial crustaceans	> 3 ft (1 m), Incompatible substrate that degrades habitat	Incompatible substrate that degrades habitat	Impair recruitment
Impact Responses	Enhance invertebrate diversity and biomass	Disturbance, crushing, burial, removal, mortality	Crushing, smothering, vertical migration escape	Beneficial or adverse habitat alteration	Decreased respiration, feeding, larval recruitment, mortality
Duration of Impacts	Months-years	Days-months	Weeks-months	Months-years	Days-months
Potential for Restoration	NA	Unnecessary	Unnecessary unless unless habitat degradation	Unnecessary unless habitat degradation	Unnecessary

NA = not applicable

4.2.7 Sandy Subtidal Invertebrates

Photo credit: SAIC

Regulatory Status:

Endangered	
Threatened	
CDFG Managed	Fishery species
None	X

Invertebrates associated with sandy subtidal areas may include managed fisheries species such as Dungeness crab, Pismo clam, and warty sea cucumber (*Parastichopus parvimensis*). Most species do not have special regulatory status, but all are residents of Essential Fish Habitat.

Description and Distribution:

Subtidal sand habitat and associated invertebrates occur along exposed and protected coastlines of California. Benthic invertebrates include meiofauna (very small), macroinvertebrate infauna that live within subtidal sands, and mobile macroinvertebrates that live in association with the sediment-water interface (epifauna).

Life Stage or Function	California			On Land	Inter-tidal	Near-shore < 30 ft	Off-shore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X			X	X	E, P
Juvenile	X	X	X			X	X	E, P
Egg/Larvae	X	X	X			X	X	E, P
Primary Habitat	X	X	X			X	X	E, P
Foraging Habitat	X	X	X			X	X	E, P
Spawning Habitat	X	X	X			X	X	E, P

Subtidal invertebrate distribution is related to physical controlling factors such as wave energy, substrate stability, sediment grain size and character, and sediment organic content. Generally, there is a decrease in epifauna density and suspension feeders and an increase in infauna and a greater variety of feeding and motility types with increasing depth (Barnard 1963, Oliver et al. 1980, Thompson et al. 1993).

Inshore sands are dominated by infauna species adapted to living in and/or unstable shifting sands. This area has been referred to as the crustacean zone due to numerical dominance by small, burrowing deposit feeding crustaceans (amphipods, cumaceans, ostracods) (Oliver et al. 1980). Other common species may include mole crabs, Dungeness crabs, swimming crabs (e.g., *Callinectes* spp., *Portunus xantusii*), bean clams, Pismo clams, northern razor clams (*Siliqua patula*), other clams (e.g., *Ensis* spp.), moon snails (*Polinices* spp.), sand dollars (*Dendraster excentricus*), burrowing anemones (*Harenactis attenuata*, *Zaolutus actius*), sea pansies (*Renilla kollikeri*), sea stars (e.g., *Astropectin armatus*), and burrowing worms (e.g., *Chaetezone setosa*, *Dispio uncinata*, *Nephtys caecoides, Scoloplos armiger*) (Parr et al. 1978, Morris et al. 1980, Thompson et al. 1993, USDN 1995). Most species inhabiting the shallow nearshore are suspension and/or surface deposit/detritus

feeders. Sand dollars and Pismo clams may form discrete beds in nearshore waters (Parr et al. 1978, Morris et al. 1980).

Offshore sediments generally are characterized by a greater variety and density of invertebrate species represented by more feeding types, including subsurface deposit feeders on sediment incorporated organic material, and sedentary tube- and burrow-dwelling species (Oliver et al. 1980, Thompson et al. 1993). Polychaete worms generally dominate; some of more conspicuous species include tubiculous onuphids (*Diopatra ornata, D. spendidissima, Nothria elegans*), tubiculous oweniids (*Owenia fusiformis*), tubiculous maldanids (*Euclymene* spp.), tubiculous spionids (*Prionospio* spp., *Spiophanes* spp.), burrow-dwelling magelonids (*Magelona sacculata*), and burrowing terebellids (*Amaena occidentalis*) (Oliver et al. 1980, SCCWRP 1994, SCCWRP 1998, MEC 2000). Assemblages also may include a variety of crustaceans (amphipods, cumaceans, ostracods, crabs, shrimp), clams (e.g., *Solamen columbiana*, *Tellina* spp.), moon snails, brittle stars (*Amphiodia* spp.), heart urchins (*Brissopsis pacifica, Lovenia cordiformis*), sea cucumbers (*Leptosynapta* sp., *Parastichopus parvimensis*), sand dollars, sea stars (*Astropectin armatus, A. verilli*), sea pens (*Stylatula elongata*), and burrowing anemones (e.g., *Zaolutus actius*) (Oliver et al. 1977, Parr et al. 1978, Morris et al. 1980, Thompson et al. 1993, SCCWRP 1994, SCCWRP 1998, MEC 2000). Generally, a greater variety of sedentary species (burrow and/or tube-dwelling) and feeding types occur in more stable sediments (Oliver et al. 1977, Thompson et al. 1993).

Some invertebrate species occur in densities that stabilize sands. For example, densities of the burrowing anemone *Zaolutus* actius and worm *Owenia fusiformis* may stabilize the substrate by reducing sand shift due to wave surge, enabling colonization by other benthic animals (Morris et al. 1980).

Potential Functions:

Nearshore sand habitat provides invertebrates primary living, foraging, and reproductive habitat. Epifaunal invertebrates such as Dungeness crabs and sea cucumbers may be taken by commercial and recreational fishermen, although most fishing occurs in deeper subtidal areas. Nearshore sand bottom invertebrates provide forage base for a variety of demersal-feeding fish, other invertebrates, and marine mammals. Threatened sea otters have been documented to have substantial impact on Pismo clam beds (CDFG 2001).

Associated Species	Forage/ Prey	Eaten By
Detritus, Diatoms, Sediment	X	
Plankton	X	
Invertebrates	X	X
Fish		X
Birds		
Vegetation	X	
Marine Mammals		X
Terrestrial Animals		
Humans		X

Life History Facts:

A variety of reproductive methods apply to subtidal invertebrates associated with nearshore and offshore sand areas. For example, most crustaceans brood eggs and release larvae that have one or more planktonic stages before settling; clams and echinoderms spawn directly to the sea and have planktonic larvae; worms may brood eggs, lay an egg mass, and/or release eggs to the sea that develop into planktonic larvae; oon snails lay eggs in a “sand collar” where larvae reside until the collar disintegrates; and cnidarians (burrowing

anemones, sea pansies, sea pens) release planula larvae that settle quickly (1 to 3 days) to the bottom (MacGinitie and MacGinitie 1968, Shroeder and Hermans 1975, Morris et al. 1980).

Seasonal changes in invertebrate abundance may reflect a combination of larval availability and season differences in wave climate. Oliver et al. (1980) found that polychaete worm abundance in inshore waters was lowest in fall-winter when wave-induced substrate movement was greatest; whereas, abundance patterns in deeper nearshore waters was considered a reflection of seasonal changes in larval availability. Crustaceans were found to have less regularity in seasonal pattern than polychaetes.

Most nearshore invertebrates have relatively short life spans, one to three years, while a few are long lived such as the Pismo clam (up to 50 years), northern razor clam (> 10 years), and sand dollars (6-10 years) (Morris et al. 1980).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Spawn Planktonic	Spring-early Fall peak	Year round	None	None	< 1 to >10 years	Sedentary to mobile

Adaptations and/or Behaviors to Disturbance:

Most species living in nearshore sands are active burrowers, which is an adaptation to unstable sands. Some species (e.g., mobile crustaceans) swim in search of food, and may swim from disturbance. Since many of the same species occur in low intertidal to shallow subtidal depths the discussion of adaptations for sandy beach fauna also is generally applicable here (Section 4.2.6). Many crustaceans are mobile and can presumably emigrate from an area if it becomes inhospitable (Wilber et al. 2005).

Coastal estuaries and embayments may be used as nursery areas for some coastal species such as shrimp and Dungeness crabs (Section 4.2.3). Bays and estuaries also support a diverse resident fauna, including a variety of worms, crustaceans, and mollusks

Invertebrates range in life history characteristics from opportunistic species with high turnover rates, which are early colonizers after disturbance, to longer-lived species that replace early colonizers in a typical pattern of succession associated with community development (see Recovery from Disturbance subsection below).

Subtidal invertebrates have various reproductive strategies. Some species have high reproductive output and planktonic larvae favoring wide dispersal and recruitment potential. Other species have different strategies (e.g., brood eggs, release late stage larvae, larvae quickly settle and metamorphose) that limit dispersal and favor recruitment within existing populations.

Life Stage	Behavior			Protective Shell	Habitat	High Reproductive Output and/or Growth
	Burrow	Crawl/ Walk	Swim			
Adult	X	X	X	X	X	
Juvenile	X	X	X	X	X	
Egg/larvae						X

Potential Impacts from Sediment Management Activities:

Sediment management activities will directly affect subtidal benthic invertebrates during nearshore placement, profile placement, and/or borrow site dredging projects. Habitat and associated organisms will be subject to burial and equipment impacts during nearshore or profile placement projects and removal and equipment impacts during dredging projects. Indirect sand transport sedimentation will occur from beach placement projects as sediments move offshore and redistribute within the beach profile and move downdrift.

Subtidal invertebrates also will be indirectly impacted by turbidity associated with implementation of any of these types of placement and/or coastal dredging projects.

Types of sediment management activities and potential impacts to abalone may include:

- Maintenance dredging of embayments – equipment damage, sedimentation, turbidity.
- Offshore borrow site dredging – equipment damage, sedimentation, turbidity.
- Nearshore placement – equipment damage, burial, sedimentation, turbidity.
- Profile placement – equipment damage, burial, sedimentation, turbidity.
- Beach placement – sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging			X	X	X	
Growth			X	X		
Habitat			X	X		X
Reproduction				X	X	X
Respiration						

<u>Equipment</u>

Dredges will remove sediment and associated benthic invertebrates. Examination of core samples from dredged sediments pumped to a beach has indicated no survival of benthic organisms (Parr et al. 1978). It has been hypotesized that the localized defaunation of the sediment may indirectly affect demersal feeding species (e.g., fish, motile epifaunal invertebrates) that use the benthos as a food source (NRC 1995, Newell et al. 1998, Boyd et al. 2004)

Dredging also may involve removal of organisms (e.g. demersal fish eggs, larval and juvenile fish, crabs, shrimp) along with water during dredging (termed entrainment). Entrainment losses vary depending on species, although mortality rates generally are high

(LaSalle et al. 1991). Some survival of undamaged organisms has been reported from dredge overflow (Newell et al. 1998).

Biological impact and differences in recovery associated with dredging may vary depending on environmental conditions at the dredge site. Dredged source sands used for beach nourishment may result from maintenance dredging projects in embayments and/or from coastal dredging at borrow site areas. Due to the substantial difference in these environments, dredge impacts are separately reviewed for embayment and open coastal habitats below. Following the dredge excavation discussions, a brief overview of entrainment issues is presented.

Embayment Dredging/Excavation

Dredging and/or excavation in coastal ports, harbors, lagoons, and sloughs remove benthic invertebrates along with the dredged materials and disturb adjacent populations from sediment resuspension and turbidity. A substantial body of literature has been compiled regarding effects of dredging on marine and estuarine invertebrate communities. Generally, recovery rates of benthic communities vary as a function of post-project hydrographic and sedimentological conditions and frequency of dredging (NRC 1985, Newell et al. 1998). Recovery rates may range from < 1 to 2 years in navigational channels subject to periodic maintenance (McCauley et al. 1977, Van Dolah et al. 1984, NRC 1985). In areas of less frequent disturbance and/or where there is a substantial change in sediment characteristics and/or salinity, recovery may take several years if at all (Oliver and Slattery 1977, NRC 1985).

No long term obvious adverse impacts to benthic habitat and invertebrates were documented 3 to 4 years after borrow site dredging in Long Beach Harbor, southern California (SAIC and MEC 1996). Materials from the borrow site were used to provide sediment for use as landfill associated with port development. With the exception of median grain size being slightly larger in the borrow site, there were no significant differences in sediment grain size characteristics and total organic carbon between the borrow site and harbor reference area. Water quality (clarity, transmissivity, pH, dissolved oxygen, salinity, and temperature) also was similar between the borrow site and reference area. Infauna community measures (number of species, abundance, biomass) were similar to higher within compared to outside the borrow site. The abundance of crustaceans and echinoderms were higher within the borrow site. There were similar numbers of species and biomass, but higher abundance, of trawl-caught macroinvertebrates inside compared to outside the borrow site.

Dredging has been shown to result in temporary enhancement of species diversity and abundance of benthic infauna and epifauna adjacent to dredged channels, likely associated with sediment disturbance release of organics (Newell et al. 1998).

Open Coast Dredging (Borrow Sites, Mine Sites, Aggregate Extraction)

Locations of dredging along the open coast to provide sands for beach nourishment have been variously referred to as offshore borrow sites or sand mine sites; more often the term borrow site has been used in the United States and was adopted for simplicity in this document (Navqi and Pullen 1982, NRC 1995, Greene 2002). Some borrow sites have been located inshore, but most have been located outside the depth of closure in deeper water.

Hydraulic suction dredges typically have been used for offshore dredging, although cutterhead dredges sometimes have been employed off the southeastern coast of the United States (Navqi and Pullen 1982, Newell et al. 1998). Cutterhead dredges are not recommended in areas near coral reefs and/or hard bottom habitat due to increased sedimentation (Navqi and Pullen 1982).

Dredging has been performed while anchored resulting in localized deep pits (up to 66 ft, 20 m in depth) or has been conducted while underway by a trailer suction dredge, which produces relatively shallow, furrows (from < 1 to nearly 3 ft deep by 6.5 to 10 ft wide, 20 to 70 cm deep by 2 to 3 m wide) (Newell et al. 1998). The physical characteristics of borrow sites have spanned a broad range from deep excavations in localized areas, shallow excavations over broader areas, and excavation of bathymetric peaks rather than level sand bottom (Navqi and Pullen 1982, NRC 1995, SANDAG and USDN 2000, Burlas et al. 2001, Posey and Alphin 2001, Jutte et al. 2002).

Deep pits as well as dredge furrows may be persistent features on the seafloor for several years. Side-scan sonar records indicate that dredge furrows and tracks may be persistent features for several years (Kenny and Reis 1996, Boyd et al. 2004), although days were reported for the highly energetic Norfolk Banks, United Kingdom (Newell et al. 1998). The persistence of dredged pits and/or furrows is related to excavation depth, nature of the substrate, and environmental variability, with more rapid infill rates generally associated with shallower coastal areas than deeper waters (Newell et al. 1998, Hitchcock and Bell 2004).

In deep bathymetric depressions, a reduction in water quality (e.g., anoxia) may result from deposition of fine particulates and organics (NRC 1995, Newell et al. 1998). Little substrate change may occur in areas where slumping of adjacent undredged areas contributes to infill rates and/or dredging occurs in areas where sediments are frequently reworked (VanDolah et al. 1984, NRC 1995, Newell et al. 1998, Greene 2002, Byrnes et al. 2004).

Several sediment management projects in southern California have involved dredging of borrow sites. Recent projects included the 2001 San Diego Regional Beach Sand Project, which dredged approximately 2 million cy of sediment from six offshore borrow sites to nourish 13 beaches (SANDAG and USDN 2000), and several beach nourishment projects that involved use of borrow sites offshore Surfside-Sunset Beach in the 1980s and 1990s (USACE 1989, 1995). Borrow sites for the 2001 San Diego Regional Beach Sand Project ranged from 19 to 127 acres (< 8 to 51 hectares) with depths < 15 ft (< 4.6 m) (SANDAG and USDN 2000). A borrow site of 271 acres (110 hectares) with depths of 10 ft (3 m) was used in support of beach nourishment off Surfside-Sunset, Orange County (USACE 1995).

Reish (1982) concluded that dredging had no long-term effect on the benthic population in an offshore borrow site at Surfside-Sunset Beach. Species composition was similar between dredged and undredged areas; however, abundance was lower in the dredged area three years later (cited in Thompson et al. 1993). The study was conducted over three-year period. Subsequent observations indicated substrate was of muddy consistency in the borrow site compared to surrounding sandy substrate (N. Davis, personal communication cited in Chamber Group 1992). No surveys were conducted after the SANDAG borrow site dredging.

Most information on the effects of offshore dredging on benthic invertebrate resources comes from studies of borrow sites on the East Coast of the United States (reviewed by

Naqvi and Pullen 1982, Hurme and Pullen 1988, NRC 1995, Greene 2002). In addition, substantial relevant information is available from studies conducted at commercial marine aggregate mining areas in Europe (reviewed by Newell et al. 1998, Boyd et al. 2004).

Changes to subtidal sand habitat from coastal sand mining may include alteration of sediment composition, water quality, and modification of sand transport and wave dynamics. Exposure of coarser sediment, deposition of silt/clays, and/or accumulation of organic matter may occur in depressions and/or pits left by dredging depending on sediment characteristics at and in the vicinity of the borrow site (Naqvi and Pullen 1982, NRC 1995, Newell et al. 1998, Greene 2002). Post construction changes in water quality (elevated turbidity, reduced oxygen, increased hydrosulfide levels) have been associated with some projects that resulted in deep excavations in areas of poor circulation (NRC 1995, Greene 2002). Alteration of wave energy, stability of ebb-tide shoals, or reduced downdrift sediment transport are concerns when the borrow site lies within the depth of closure (NRC 1995). The duration of physical alteration of subtidal sand habitat relates to the depth of excavation and rate of sediment infilling.

Recovery rates of benthic infauna after offshore dredging may be relatively rapid (e.g., 2 to 3 years) in relatively shallow nearshore areas with sandy substrates; however, recovery may take several years in more stable, gravelly sands and deeper water communities (see Recovery section below). Recovery also may take years in areas subject to high intensity dreging over multiple years (Boyd et al. 2004).

Biological enhancement (increased densities, biomass) of infauna and epifauna has been observed on the periphery and up to (0.6 mi) (1 km) downcurrent of dredging operations (Poiner and Kennedy 1984, Boyd and Rees 2003 cited in Boyd et al. 2004). Newell et al. (1999) suggested that enhancement may be related to deposition of organic particulates (and fragmented invertebrates) from the dispersing plume generated during dredging and/or discharged with the outwash from dredges. Boyd et al. (2004) considered enhancement a relatively temporary effect and considered it improbable that enhancement would persist over a number of years following cessation of dredging.

Dredge Entrainment

LaSalle et al. (1991) reviewed that dredge entrainment generally is low, but has the potential to be significant in embayments during certain periods of the year under site specific conditions. This was based on consideration of several studies of different dredges (clamshell, cutterhead pipeline, hopper) on shellfish in Grays Harbor, Washington. The studies were conducted on Dungeness crab, sand shrimp (*Crangon* spp.), and ghost shrimp (*Callianassa californiensis*). Demersal and pelagic eggs, larvae, and juveniles were found to be susceptible to entrainment due to their limited mobility. Entrainment rates for Dungeness crab ranged from 0.00017 to 0.518 organism per cubic yard of dredged material, sand shrimp rates were 0.001 to 3.404 organisms per cubic yard, and ghost shrimp were entrained at a rate of 0.727 organism per cubic yard from one area of the harbor. Entrainment rate was correlated with shellfish abundance. Larval oyster entrainment by cuttterhead dredges was estimated between 0.005 and 0.3 percent per cubic yard based on mathematical modeling, which was not tested (*ibid.*). LaSalle el al. (1991) considered the potential for adverse entrainment impacts could be minimized by avoiding dredging in spawning areas and in narrow channels during high occurrence periods of sensitive species.

Anchoring, Pipeline Placement

Relevant studies from offshore oil exploration studies indicate benthic invertebrates may be removed and buried by anchoring, dragging of anchor chains, and pipeline placement/removal (Lissner et al. 1991). Invertebrate recovery rates in nearshore sands would be expected to be relatively rapid due to the localized extent of impact.

Burial/Sedimentation

Indirect Sedimentation from Beach Placement

Beach placement results in indirect sedimentation to the adjacent nearshore during and after nourishment as sediments winnow and move off- and onshore with seasonal erosion and accretion cycles. Shellfish may use deposited sediments as habitat, substrate, and/or a source of nutrition (Wilber et al. 2005).

Parr et al. (1978) monitored invertebrate recovery before and after hydraulic pumping of 1,00,620 cy onto 0.85 mi (1.37 km) of shoreline at Imperial Beach, California (Section 4.2.6). The project was completed over a 4 month period, March to June. Material was 70 to 85% sand, 5 to 15% silt/clay, and 5 to 15% shell material. Median grain size ranged from from 0.125 to 0.165 at -12 ft (-3.7 m) and 0.08 to 0.11 mm at -20 ft (-6.1 m). During beach nourishment there was temporary increase in fine sediment associated with the fine fraction being transported offshore, which reduced the overall median diameter to 0.062 to ~0.08 mm at -20 ft (-6.1 m) and -12 ft (-3.7 m) depths, respectively. Silt/clay deposits 0.8 to 2.4 in (2 to 6 cm) thick were measured at water depths of -12 and -20 ft (-3.7 and -6.1 m). The increase in fines did not persist more than 2 months at the inshore sites and 5 months at the deeper nearshore sites. Fine sediments were 1 to 4 in (3 to 9 cm) thick at nearshore stations; sand dollars buried in the silty sediments were reported as healthy. The authors reported variable results at the -12 ft (-3.7 m) station with enhanced abundance and similar or lower species number offshore the fill sites relative to the control and pre-project. Similar number of species and short-term enhanced abundance were seen at -10 ft (-6.1 m). Significant positive relationships were reported between increased silt (and organic carbon) and abundance and species number at inshore and deeper nearshore stations. The enhancement, which was primarily due to crustaceans and opportunistic polychaetes, was of short duration before the onset of winter storms.

Gorzelany and Nelson (1987) found little evidence of offshore sand movement effects on benthic invertebrates over a one-year period following placement of 540,204 cy of terrestrial source sands on a Florida beach. Similar trends in number of species and abundance were observed at shallow subtidal sites ≤ 10 ft (≤ 3 m) off the nourished beach compared before and after and to control sites; distance from high tide line and seasonal differences appeared more influential than beach nourishment. The authors suggested that negative impacts may have been minimized due to seasonal offshore movement of coquina clams, apparent lack of substantial offshore sand movement, and close match in sediment characteristics between source and native sediments.

Burlas et al. (2001) reported dynamic sediment conditions that did not appear to be related to an 8.1 million cy beach nourishment project off New Jersey. Nearshore benthic assemblages offshore the nourishment area had similar species composition before and after nourishment; however, temporary declines in abundance of *Donax* clams and the polychaete *Asabellides oculata* were reported. The author's reported few results attributed

to beach nourishment, declines in number of taxa abundance, and biomass at the end of the study off one of the nourished areas was noted to be within the range of variation of pre-nourishment values.

Versar (2004) examined the indirect sedimentation effects from placement of 5.6 million cy of dredged material at four beach sites in North Carolina by comparing pre- and post-construction (one-year later) benthic invertebrate communities (abundance, biomass, number of taxa, Shannon Wiener diversity) inhabiting inshore surf zone and adjacent offshore areas. In the surf zone, one beach displayed significantly lower abundance one-year later mainly due to reduced numbers of *Donax* clams, which was attributed to reduced recruitment associated with sand placement. It was suggested that the reduced recruitment may have been related to sand placement occurring at two different times over the summer at that beach (coinciding with the species recruitment period); whereas other beaches had a single construction period in spring, fall, or winter.

In contrast, excessive and persistent siltation in the nearshore resulted from the 9.2 million cy (7.1 million m^3) beach nourishment project at Perdido Key, Florida in 1989-1990 (Rakocinski et al. 1996, 2001). Although beach compatible sands were used, the silt/clay content in the surface layer of nearshore sediments 984 ft (300 m) directly offshore the main part of the fill were 100% immediately after placement, and two years later silt-loads were still 40% compared to native sediments with $\leq$ 2% silt/clay. A combination of factors may have contributed to silt-loading and persistence with that project. For example, the volume of silt/clay generated by a project depends on its percentage in source sediments and project volume. Although the silt/clay percentage was not reported, the large project volume would have generated silt/clay volumes of several hundred thousand cubic yards even with a silt/clay content less than 10%. Dredging, which was from Pensacola Pass, also may have encountered lenses of elevated silt/clay content (Rakocinski, personal communication 2006). Although not mentioned by the authors, it is considered possible that the relatively low, wave energy of the receiving environment in the Gulf of Mexico perhaps contributed to the persistence of the silt-loading in the nearshore.

Nearshore Placement

Limited effects were observed immediately following nearshore placement of sands at depths of approximately 40 feet off McGrath State Beach in Ventura, southern California (Chambers 1992). One discharge site showed a 32% reduction in number of invertebrate taxa and 52% reduction in abundance following discharge with a shift in species composition to increased dominance by mobile crustaceans compared to pre-disposal conditions. The other discharge site and all controls showed an increase in number of taxa and abundance after disposal, which was presumed to be related to spring recruitment. No obvious differences related to discharge were observed for large, trawl-caught macroinvertebrates, which showed a greater decrease after disposal in variety and abundance at control sites than the disposal site. No subsequent surveys were conducted; therefore, recovery rate is unknown.

Rakocinski et al. (1996, 2001) monitored recovery at Perdido Key, Florida associated with a 9.2 million cy (7.1 million m^3) beach nourishment project that placed approximately 60% of the material on the beach, and the remainder subtidally at a water depth of 22 ft 6.7 m). Both intertidal and subtidal phases took 1-year to complete; spanning autumn to autumn seasons (also see Section 4.2.6). Monitoring was conducted once before, immediately after beach nourishment and quarterly for two years after nourishment. Sampling was conducted

from intertidal to offshore depths along four transects: A, "control" site approximately 1.8 mi (3 km) away; B, near the west end of the beach fill; C, in the main area of beach and subtidal placement; and D, near the east end of the beach and subtidal placements. The sandy material retained on the beach was < 4% silt/clay. Intertidal recovery was described as relatively rapid (see Section 4.2.6). Nearshore sites that received indirect silt-loading displayed altered community structure (taxa, abundance) over two years of post-nourishment monitoring. Offshore sites in the area where subtidal nourishment occurred had lower species number and densities during and after placement; less disturbance was seen off the west end of beach fill where subitdal placement did not occur. Offshore stations had not recovered within 1 year of subtidal placement, which the authors' stated, supported the hypothesis that diverse offshore assemblages may be less resilient than contiguous sandy beach assemblages.

In Bay Disposal

LaSalle et al. (1991) reviewed that hydraulic discharge of low-density fluid muds can present severe problems for benthic organims due to burial, sediment instability, and low oxygen content.

Limited effects were observed on the macrofauna community after release of a relatively small volume 37,245 cy of muddy sediment in a South Carolina estuary (Van Dolah et al. 1984). Although this project was conducted in an estuary with substantially finer sediments than used for beach nourishment, results provide some relevance because the disposal site sediments were sands over bedrock. Effects of sediment disposal were limited and most differences among surveys, conducted over a 10-month period, were attributed to sampling and seasonal variability. The minimal effects at the disposal site were attributed to surface release of sediments, strong tidal currents that rapidly dispersed the released muds, and disposal during late autumn when faunal recruitment was low.

Diaz and Boesch (1977) documented detrimental effects of discharge of low-density fluid mud on benthic communities, but reported recovery within a few months (cited in LaSalle et al. 1991).

<u>Turbidity</u>

Reviews indicate that marine and estuarine invertebrates generally are tolerant of high suspended solids concentrations over reasonably short durations (Stern and Stickle 1978, NRC 1985, LaSalle et al. 1991, O'Connor 1991, Clarke and Wilbur 2002, Wilber et al. 2005). However, prolonged exposure to high concentrations may be lethal and/or substantially reduce habitat quality.

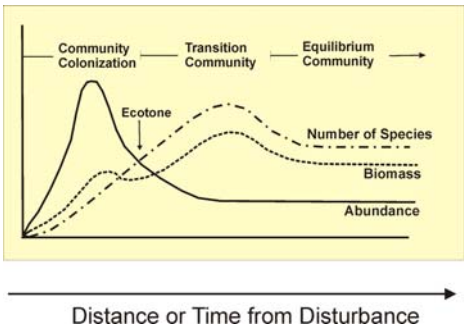
Crabs and shrimp that spend a portion of their life cycle in estuaries or nearshore coastal habitats where they are exposed to turbid conditions may be relatively tolerant (Wilber et al. 2005). However, LaSalle et al. (1991) suggested that frequent repositioning and/or increased burrow maintenance activities associated with response to dredge induced sedimentation could result in energy deficits for growth and reproduction in shellfish based on consideration of studies of energy costs for burrowing (cited Trueman and Foster-Smith 1976).

A 48-hour field experiment during a storm resuspension event where total suspended solids ranged from 1 to 30 mg/l showed an increase in ingestion rate of sea scallops (*Placopecten*

magellanicus) with increased availability of suspended particulates (Cranford et al. 1998). Differences in nutritional absorption rates related to the organic content of seston; however, the lower food quality of the resuspended matter was offset by its increased availability and higher ingestion rates. Lower clearance rates were observed at relatively low (< 4 cm/sec) and high (> 9 cm/sec) flow speeds.

Recovery from Disturbance:

Recovery from disturbance of subtidal invertebrates after beach nourishment and/or dredging mainly relates to cessation of human disturbance effects associated with construction, and recovery of the invertebrate fauna. Disturbance impacts associated with equipment use and turbidity are associated with the construction period and generally cease after construction is completed. However, turbidity may occur more frequently in the event of silt-loading.



Modified from Pearson and Rosenberg 1978 and Newell et al. 1998
Drawn by: Karen Green

Recovery of benthic infauna invertebrates after major disturbance generally follows a similar pattern, including colonization and enhanced abundance of opportunistic species (peak of opportunists), followed by a transitional community composed of opportunists and some longer-lived species, and then recovery of an equilibrium community (Pearson and Rosenberg 1978, Newell et al. 1998). Mobile epifauna also may be temporarily attracted to dredged deposits during the early recolonization phase (Boyd et al. 2004).

Opportunists (also termed *r*-strategists) are species that quickly colonize empty habitats created by disturbance with large populations based on their life-cycle traits of small size, high fecundity, rapid growth, and high mortality (Newell et al. 1998). After a major disturbance, very high abundances of opportunists may occur. As more species colonize the peak of opportunists decline and total number of species increases (termed ecotone) and the community is considered transitional. Under stable environmental conditions, the community is controlled more by biological interactions than environmental extremes, and organisms have an equilibrium strategy (also termed *k*-strategists) to optimize their competitive ability with more energy spent in growth, predator avoidance, and increased size. Other species may be intermediate between these two extremes. Distinction between the life history strategies of opportunists and equilibrium species helps explain differences in recovery rates of benthic invertebrate communities.

Colonization occurs by migration of adults from adjacent undredged areas, larval settlement, organisms carried into the dredged area from slumping of sediments from the sides of pits and furrows, and some return of undamaged organisms from dredge overflow (Newell et al. 1998). Reviews indicate that post-settlement processes (predation, competition, starvation) may be more important to community development than larval availability (Olaffson et al. 1994, Gorsselin and Qian 1997). However, the larger the disturbed site, the more important larval recruitment is to the recovery process (Santos and Simon 1980, Boyd et al. 2004). In addition, larval availability may be more important to recovery of species with limited dispersal. For example, dispersal range is broad for lobster because larvae remain in the

plankton for months; whereas dispersal range is limited for Pismo clam because their larvae settle from the plankton in a few days (see Sections 4.2.2 and 4.2.4).
The time it takes for benthic infauna recovery will depend on the characteristics of the community at the time of disturbance. Reviews indicate a positive relationship between community resilience and environmental variability (e.g., higher environmental variability, faster recovery) (LaSalle et al. 1991, Newell et al. 1998). For example, frequently disturbed and/or shallow water communities may quickly recover to their opportunist-dominated original species composition. In stable environmental conditions and/or deeper waters, the replacement of initial colonizers in the transitional community follows complex interactions with and among equilibrium species and may take several years. Slow recovery also has been reported at commercial sand extraction areas subject to a high intensity of dredging over multiple years (Boyd et al. 2004).

	Recovery Rates				
Impact	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment		X	X		
Burial		X	X		
Sedimentation	X	X			
Turbidity	X				
Habitat Loss			X		

This pattern of benthic infauna recovery, characterized by increased abundance by opportunists followed by more steady state assemblages, has been reported for invertebrates affected by beach nourishment, dredging from borrow sites, and dredging in embayments (Naqvi and Pullen 1982, Soloman et al. 1982, Newell et al. 1998, Van Dalfsen and Essink 2001, Boyd et al. 2004).

Short-term enhancement by opportunists also may occur in response to nutrient enrichment. Parr et al. (1978) noted increased invertebrate abundance in the nearshore in response to silt (and organic) deposition after beach placement nourishment; the enhancement was short-term (generally less than 2 months) and due to a few species of mobile crustaceans and polychaetes. Enhanced abundance from opportunists lasted longer (8 months) after coastal borrow site sand extraction at a nearshore sandy site off the Netherlands (Van Dalfsen and Essink 2001).

Few studies have examined recovery rates of meiofauna at borrow sites. Available information indicates that small meiofauna may take years to recover from dredging disturbance at borrow sites and marine aggregate extracton areas (reviewed in Navqi and Pullen, Vanaverbeke et al. 2003 cited in Boyd et al. 2004). Meiofauna distribution and abundance are highly influenced by sediment characteristics (particularly silts that fill interstitial spaces), organic content, and depth of the anoxic layer (Oakden 1996). Therefore, recovery rates would be expected to be influenced by changes in hydrodynamics and substrate characteristics. Meiobenthos also are considered indicators of environmental disturbance. Pequenat (1975 cited in Navqi and Pullen 1982) considered meiobenthos sensitive to low levels of environmental disturbance and suggested they may reflect ecosystem degradation and recovery. Vanaverbeke et al. (2003) recently proposed use of nematode biomass spectra as descriptors of impact.

Limited information is available on response of mobile epifauna to sediment management activities. Boyd et al. (2004) reported reduced diversity, density, and biomass of epifauna, but enhanced numbers of some mobile decapod crustacean, fish, and gastropod mollusk species at sites that formely had experienced high intensity aggregate extraction activities; the result was observed several years after cessation of extraction activities, suggesting a persistent effect. The enhancement included an increase in abundance of invertebrate scavengers and predators. which they noted is a common feature of disturbed areas (Hall 1994) They noted that there was no evidence of a shift to smaller sized specimens, but rather an absence or lower abundance of smaller size classes indicating a decline in productivity.

Most studies of benthic community recovery have focused on macroinvertebrate infauna (generally defined as ≥ 1 mm in size) living in the upper 2 ft (60 cm) of sediment. Reported recovery rates have been based on community structure metrics such as abundance, number of species (and/or diversity), and biomass.

Recovery of nearshore infauna from direct placement may take several months to > 1 year (Table 4.2-2). Oliver et al. (1977) conducted an experimental study of recolonization after deposition of 1,000 cy of sand loads dredged from Moss Landing Harbor at water depths of 29 ft (9 m), 59 (18 m), and 79 ft (24 m). Stations were established in areas of three different overburden depths of approximately 6.6 ft, 1 ft, 4 in (2 m, 30 cm, 10 cm) and at unaffected sites at the same survey depths. A large storm occurred during the study period, obliteriating main piles. Recovery (species number, abundance, similarity, biomass, major species abundance) was no more than 7 months at the shallowest station, 1 year at mid-depth, and > 1.5 years at the deepest station.

Recovery from indirect sedimentation from beach nourishment may be rapid (< 1 year) (e.g., Parr et al. 1978) or prolonged (e.g., Rakocinski et al. 1996, 2001). Project size and/or hydrodynamic conditions may influence recovery rates and infauna response. For example, silt/clay loading resulted in enhancement of infauna, but did not persist past the first storm after a 1,000,620 cy project off southern California (Parr et al. 1978). However, silt/clay loading resulted in depression of the infauna assemblage that was still evident two years after a several million cy project in the relatively lower wave energy environment off Perdido Key, Florida (Rakocinski et al. 1996, 2001).

Recovery of benthic infauna communities (dominated by opportunistic species) in frequently disturbed shipping channels in harbors may occur rapidly (weeks) (McCauley et al. 1977). Although the above reference is often cited as being representative of expected benthic recovery rates, it should be noted that the study was based on a very small dredging project (8,000 cy) of silty substrate. Newell et al. (1998) considered recovery estimates of 6 to 8 months more characteristic of estuarine channel muds based on review of several projects. In areas of less frequent disturbance, recovery may exceed 1 year (e.g., Kaplan 1975, Oliver et al. 1977). Experimental studies of infauna recovery after clamshell dredging in different areas of Moss Landing Harbor, California indicated more rapid recovery (months) of opportunist dominated fauna in silty inner harbor areas than sandy outer harbor areas (2 to 3 years) (Oliver and Slattery 1973, 1977).

Table 4.2-2 . Summary of timeframes for recovery of subtidal benthic invertebrates from direct burial, sedimentation, and dredging.

Reference	Project Location and Volume (cy)	Recovery Rate	Notes On Recovery Time Frame
Nearshore Placement (Direct Burial)			
Burlas et al. 2001	Asbury to Manasquan, New Jersey ~8.1 million cy	Subtidal > 5 months (study duration)	
Oliver et al. 1977	Monterey Bay, California 1,000 cy Experiments	≤7 months to > 1.5 years	Recovery ≤7 mo (9 m depth), 1 yr (18 m depth), > 1.5 yrs (24 m depth).
Rakocinski et al. 1996		> 1 year	Substantial recovery in 1 year
Beach Placement (Indirect Sedimentation)			
Parr et al. 1978	Imperial Beach, California 1,000,620 cy	2-4 months	Short term enhancement correlated with increased fines and organics from transport from beach receiver site.
Culter and Mahadevan 1982	Panama City, Florida 400,248	Unknown, but within 3 years	Study initiated 3 years after sand placement
Rakocinski et al. 1996	Perdido Key, Florida 3.8 million cy	> 2 years	Silt/clay loading of sediments depressed infauna assemblage
Versar 2004	North Carolina 5.6 million cy	> 1 year at 1 of 4 sites, < 1 year at 3 of 4 surf zone sites < 1 year at shallow offshore outside breaker zone	Examined density, number of species, biomass, diversity at surf zone and adjacent offshore outside breaker zone proximate to 4 beach nourishment sites.
Harbor/Lagoon Dredging			
Clarke et al. 1990[3]	Mobile Bay, Alabama	6 months	Channel mud.
Kaplan et al. 1975	Goose Creek, Long Island, New York	> 11 months (study duration)	Lagoon mud.
McCauley et al. 1977	Coos Bay, Oregon 8,000 cy	4 weeks to readjust to pre-dredge conditions	Dominant fauna in shipping channel opportunistic and disturbance tolerant. Authors point out that they measured re-adjustment, not recovery.
Oliver and Slattery 1973, 1977	Moss Landing Harbor, California Clamshell dredge Experiments	Months to 3 years	Inner harbor recovery in months, outer harbor recovery in 2 to 3 years. Density, number of species, diversity, evenness.
Pfitzenmeyer 1970[3]	Chesapeake Bay	18 months	Mud-sand.
Van Dolah et al. 1984	Dawho River, South Carolina 37,253	Substantial within 3 months	Number of species, density, diversity, evenness, species richness, and cluster analysis.
Harbor Borrow Site Dredging			
SAIC and MEC 1996	Long Beach, California	Within 3 years	Study initiated 3 years after dredging.

Table 4.2-2 (Continued).

Reference	Project Location and Volume (cy)	Recovery Rate	Notes On Recovery Time Frame
Nearshore Dredging (Offshore Borrow Site and Marine Aggregate Extraction)			
Barry Vittor & Associates 1999[1]	Coney Island, NY	> 10 years	Bathymetric depression filled with silt resulting in changed community composition.
Burlas et al. 2001	Asbury to Manasquan, New Jersey (6,180,000 cm)	1.5-2.5 years	Recovery evaluation based on abundance, biomass, number of species, age structure of sand dollars. Authors suggested deeper burrowing animals will take > 3 years to recover.
Posey and Alphin 2001	Kure Beach, North Carolina	< 1 year	Natural habitat disturbance (from hurricanes) and dominance by opportunistic species considered influential to fast recovery.
Jutte et al. 2002	Myrtle Beach, South Carolina 2,600,000 cy	2.5 years	Hopper dredge with shallow dredge furrows (1 m below grade) considered contributing factor to rapid recovery by authors.
Applied Biology, Inc. 1979[2]	Duval County, Florida	14 months	Density and abundance variable.
Johnson and Nelson 1985	Fort Pierce, Florida 372,780	> 1 year	Number of species, abundance, and species composition evaluated.
Saloman et al. 1982	Panama City, Florida 400,248	> 1 year	Recovery reported as nearly complete in 1 year, but not supported by data.
Culter and Mahadevan 1982	Panama City, Florida 400,248	Within 3 years	Study initiated 3 years after sand placement
Taylor Biological Company 1978**	Treasure Island, Florida	> 4 years	In-filled with soft sediment
Kenny and Rees 1996	Lowestorft, North Norfolk, United Kingdom 52,000 tons	> 2 years	Gravels, Subsurface gravel exposed by dredging and sediment became coarser after project.
Hitchcock et al. 2002	South coast, United Kingdom	2-3 years to > 20 years	Shallow water coastal sands reported to recover in 2-3 years; deepwater communities with individuals living to at least 20 years old may require > 20 years to recover size/age distribution.
Newell et al. 2004	South coast, United Kingdom	> 18 months	Gravels
Boyd et al. 2004	North Sea and eastern English Channel, United Kingdom	>6 to > 10 years	Gravelly sands, commercial aggregate mining sites after low to high intensity use over multiple years.
Deprez 1992[3]	Dieppe, France	> 2 years	Sands-gravels.
Deprez 2000[4]	French coast, English Channel	Alterred community	Coarse sands changed to fine sands.
Wright 1977[3]	Beaufort Sea	12 years	Sands-gravels.
Dalfsen and Essink 2001	North Sea, Netherlands	2-4 years	Sands; abundance within 2 years, biomass and diversity within 2-4 years.
de Groot 1986[2]	North Sea, Netherlands	3 years	Sands.
Sardá et al. 2000[4]	Catalan, western Mediterranean Sea	Within 2-3 years	Sands became finer following sand extraction.

Cited in Brynes et al. 2004[1], Naqvi and Pullen 1982[2], and Newell et al. 1998[3], Boyd et al. 2004[4]

Reported recovery rates offshore benthic infauna communities after borrow site dredging vary across a greater time span (> 1 to several years) (Table 4.2-2). Recovery processes in open coastal areas are more complex and apparently relate to a combination of factors related to dynamic interaction between sediments and hydrodynamics (Newell et al. 1998, Boyd et al. 2004). Results suggest recovery rates are faster for shallow dredge furrows than deep pits (Newell et al. 1998, Jutte et al. 2002). Generally, nearshore benthic infaunal communities in sandy areas recover from dredging impacts within 2 to 3 years and as substrate becomes coarser may reach 5 to 10 years (Newell et al. 1998, Boyd et al. 2004). Slower recovery rates have been associated with slow infill rates, changed substrate, and/or environmental stability and the mature nature of the pre-dredge community.

Several examples of the variability associated with recovery of infaunal communities after coastal dredging are briefly reviewed below. Results of this review indicates that rapid recovery rates of nearshore borrow sites should not be assumed in the absence of site specific information on existing environmental conditions, substrate characteristics, and benthic community composition.

Relatively rapid recovery (within 1 year) may occur in areas subject to relatively frequent natural disturbance.

- Posey and Alphin (2001) conducted a five-year study of the effects of borrow site dredging on benthic infauna and siltation of adjacent hardbottom habitat at Kure Beach, North Carolina. A BACI (before-after-control-impact) study design was used. Benthic communities exhibited little difference in density, species richness, and diversity after nine months; the communities also displayed relatively quick recovery after three hurricanes that occurred during the study period. Little net change in hardbottom cover was observed. The authors considered the following factors influential to the observed minimal effects: project schedule (during fall before major recruitment period), habitat subject to other disturbances (hurricanes), dominance by opportunistic species, and similarity in pre- and post-project sediment characteristics.

More commonly, recovery rates of 2 to 3 years have been reported for borrow sites located in nearshore areas with sandy sediments when dredging was conducted to relatively shallow to moderate depths (3 to < 15 ft, 1 to < 5m). Similar recovery rates have been reported both for moderate (<300,000 cy) and large size projects (several million cy).

- No long term adverse impacts to the benthic infauna community were documented from dredging more than 2.6 million cy of sands approximately 3 ft (1 m) below grade in the nearshore off Mrytle Beach, South Carolina (Jutte et al. 2002). Before and after surveys were conducted at the borrow site and nearby reference area. Sediment characteristics underwent significant changes during the study period at the borrow site in sand, silt/clay, shell (calcium carbonate), and organic content. The most notable change was in organic content, which was 2 to 3 percent after dredging relative to 1 percent before dredging. Sand content exceeded 90 percent throughout the study period. Mean grain size ranged between 2 and 2.1 phi (medium sand) before and after dredging, but coarsened (< 1.9 phi) between the winter of 1998 and winter 1999. Sediment grain size showed greater variability at the reference area (2.2 to 2.4 phi) over the study period. The benthic infauna community was similar to enhanced at the borrow site 27-30 months after dredging relative to before dredging based on number of species, abundance, Shannon-Weaver diversity (H'), Pielou eveness (J'), and Margalef species richness. Cluster analysis showed that species-

abundance patterns at the borrow site across all seasons after dredging (1997-1998) were relatively similar to before dredging patterns in spring and summer 1996 but dissimilar to those in fall 1995 and winter 1996. The dissimilarity in fall-winter species-abundance patterns between 1995-1996 (before dredging) and 1997-1998 (after dredging) may or may not have been dredge-related since a similar dissimilarity was observed among surveys at the reference site.

- Burlas et al. (2001) reported benthic infauna recovery as complete within 2.5 years of dredging nealy 8.1 million cy of sands off New Jersey during two separate dredging operations. The dredging was unique from other commonly employed methods because it involved dredging of bathymetric peaks rather than depressions. Because the borrow sites were in areas of strong currents and sand movement, it was assumed that any depression resulting from sand borrowing would be ephemeral and water quality would remain unaltered. The authors' reported that abundance, biomass, and taxa richness recovered after the first dredging operation with no detectable difference between dredged and undisturbed areas by the following spring. After the second dredging episode in 1999, abundance recovered, but biomass and taxa richness had not recovered by the following spring (May 2000). Changes in biomass took 1.5 to 2.5 years to recover, primarily associated with the time for population of sand dollars to recover (major contributor to biomass). No changes in grain size or water qaulity attributed to dredging were reported.
- Johnson and Nelson (1985) monitored recovery of benthic infauna after a relatively small (372,780 cy) nearshore dredging project off Fort Pierce, Florida. The borrow site was located at 23 ft (7 m) and dredged to a depth of 11.5 ft (3.5 m). Grain size changed initially changed from medium to very fine sand, but was similar to pre-dredge conditions 1 year later. Transects across borrow areas had similar numbers of taxa in the dredge trench as in non trench and control areas after 9 months. However, abundance was lower in the trench compared to other surveyed areas after 1 year. In addition, species composition in the trench shifted to being more dominated by polychaetes.
- A recovery rate of 3 years was reported after dredging sandy sediments in Dutch coastal waters (deGroot 1986 cited in Newell et al. 1998).
- Posey (2002) compared a borrow area with control areas in the relatively shallow Cape Fear River after 10 years and found no long-term differences in benthic communities, although topographic differences were still present.

Longer time frames may be required for recovery of biomass and age structure of longer-lived species in more stable habitats.

- Benthic infauna community recovery at a nearshore (63 ft, 20 m depth) sand extraction site in a coastal area of the Netherlands took at least 4 years (Van Dalfsen and Essink 2001). Recovery included an initial enhancement by opportunistic species, which started to stabilize eight months after extraction. Abundance recovered after 2 years, biomass and diversity re-gained pre-disturbance values between 2 and 4 years, and age structure of long-lived species were similar 4 years after extraction.
- Hitchcock et al. (2002) reported recovery rates of 2 to 3 years for benthic infauna communities in shallow water coastal sands. However, in stable, deeper water communities with some individual species living at least 20 years, recovery of size-age distributions and biomass may take at least 20 years.

Fining of sediment within extraction sites is commonly reported, but may not substantially affect recovery rates unless substantial.

- Boyd et al. (2004) reviewed that fining of sediment was reported by Sardá et al. (2000) associated with sand extraction from shallow, sandy habitat in the western Mediterranean Sea, and by van Dalfsen et al. 2000 associated with marine sand extraction from the North Sea and western Mediterranean Sea. Recovery was reported for both studies within 2 to 3 years (cited in Boyd et al. 2004).

Longer recovery rates have been reported at sites where deeper depths and/or hydrodynamics resulted in slower infill rates.

- Saloman et al. (1982) studied benthic infauna recovery after dredging of 6 nearshore borrow sites off Panama City, Florida. Borrow sites were located at depths between 19 and 30 ft (6 and 9 m) and were dredged to 16 ft (5 m) or less. Diver's collected core samples within and outside the borrow sites 1 year after dredging. General grain size characteristics were found to be similar 1 year after dredging between stations inside (98.6 to 99.86% sand) and outside (99.52-99.88% sand) the 6 borrow sites. Mean grain size was coarser at one borrow site (1.75 phi), but otherwise similar inside (2.01-2.50 phi) and outside (2.11-2.45 phi) borrow sites. The borrow site area where time sequence monitoring was conducted showed that the borrow site initially filled with dark, silty material, but at end of study (16 months later) had filled to within 3 ft (1 m) of surrounding bottom with grain size similar to conditions outside borrow pit. Saloman et al. (1982) considered recovery of borrow site invertebrates essentially complete, or nearly so, within 1 year. Review of this study indicates that substantial recovery occurred within 1 year; however, lack of information on biomass and differences in species-abundance patterns at 3 of the 6 borrow site areas suggest recovery times likely exceeded 1 year.
- Culter and Mahadevan (1982) re-examined benthic infauna communities in the borrow areas off Panama City, Florida three years after dredging. Sediments generally were similar in the borrow site (2.29 phi with 0.02% silt/clay) as outside (2.26 phi with 0.22% silt/clay). The authors' reported that the number of species and densities at the borrow site 20 ft (6.1 m depth) were lower than deeper stations 29 to 33 ft (9-10 m) outside, but more similar to those at shallower 10 to 13 ft (3-4 m) depths. Given the expectation for higher diversity offshore, the greater similarity of species number at the borrow site with shallower depths suggests that the benthic community had not recovered in the 3 years since dredging. Species composition in the borrow site also was reported as changed relative to pre-dredging.
- Naqvi and Pullen (1982) reviewed two studies of the same borrow sites off Treasure Island, Florida that exhibited slow recovery. Soloman (1974) found abundance and diversity of benthic infauna lower in borrow pits compared to controls 3 years after dredging at Treasure Island due to siltation and low dissolved oxygen. Taylor Biological Company (1978) examined the same sites 4 years after dredging and also concluded the sites were slow in recovering.
- Bryrnes et al. (2004b) reviewed that a borrow site located 2.2 mi (3.6 km) off Long Island, New York had a persistent bathymetric depression, which accumulated silts. Recovery was incomplete after 10 years (Barry Vittor & Associates 1999).

Recovery of stable communities associated with gravelly sands appears to take longer than sandy sediments.

- Kenny and Rees (1996) monitored benthic infauna recovery at North Norfolk offshore aggregate mining areas before and after dredging 52,000 tons of sandy gravels. After dredging, the sea bed lowered by 1 to 6.5 ft (0.3 to 2 m) in dredge areas; the tracks were weathered/eroded and only just visible with side scan sonar 2 years later. Grain size was more variable and somewhat coarser after dredging due to exposure of a gravel layer. Within 1 year, 67% of the taxa had recolonized, and the number and type of species was not significantly different from the reference location 1 year after dredging. However, abundance and biomass were significantly lower than the reference site 1 to 2 years after dredging, suggesting recovery was incomplete. The authors suggested that the bottom may have been more susceptible to tide and wave action disturbance after dredging.

Shifts in species composition have been associated with changes in substrate characteristics.

- Turbeville and Marsh (1982) examined longer term recovery (5 to 6 years later) by examining benthic infauna communities at 3 stations within and 3 stations outside a borrow site off Hillsboro Beach, Florida. Grain size was medium sand at all stations, but coarser fractions were observed at the borrow site; total organic carbon levels were similar within and outside the borrow site. The authors' reported no reduction in number of species, Shannon-Wiener diversity index, or abundance among stations and concluded there were no long-term impacts from the dredging. However, there was a shift in species composition in the borrow area that differed from reference areas (Johnson and Nelson 1985).
- Changes in sediment composition from coarse to fine sands from industrial extraction off Dieppe, France resulted in a changed benthic infauna community structure (Desprez 2000 cited in Boyd et al. 2004).

Limited information is available with respect to consequences of intensive dredging operations on benthic infauna communities. Available results suggest recovery rates may be less in high energy coastal habitats lightly exploited by commercial dredgers than areas with a high intensity of operations.

- Newell et al. (2004) compared recovery rates of infauna at sites dredged by anchor dredge and trailer suction dredge off the south coast of the United Kingdom. Impacts on species composition were limited to the anchor dredge site boundaries. No suppression of community structure was observed 100 m beyond the dredge site, although enhancement (number of species, abundance, biomass, size) was observed for as much as 2 km in each direction. Restoration of species variety and biomass at the anchor dredge site had not occurred by 18 months. At the trailer-dredge site, number of species recovered within 2 months, but biomass had not recovered within the 2 month period.
- Boyd et al. (2004) conducted a comprehensive study of rehabilitation of the seabed following marine aggregate dredging consisting of comparison of physical and biological characteristics at several sites in the North Sea, offshore the Humber estuary, and within the eastern English Channel that had experienced different intensities of dredging (high, low) over many years (e.g., up to 25 years) and time after cessation of dredging (3, 4, 7, and 10 years). Surrounding habitat included gravels to gravelly sands, which generally have higher species diversity than sands. Sediments in the dredged areas displayed greater variability in sediment composition

than surrounding areas, presumably due to the uneven impact of the dredger draghead on the seafloor. Results indicated that the benthic infauna community remains in a perturbed state for several years in areas previously subjected to high levels of dredging intensity. Areas exposed to relatively lower levels of dredging were almost indistinguishable from surrounding sediments in terms of species variety and densities within 6 to 7 years after cessation of mining. The authors discussed that the long recovery periods indicated by their study in contrast to other studies reporting relatively rapid recovery rates (e.g., 2 to 3 years) likely reflect differences in magnitude of dredging disturbance. They also noted that more rapid recovery reported by Newell et al. (2002) for one of the same sites in their study may have related to sampling location, suggesting spatial variability in benthic communities may occur in dredge areas due to different intensities of disturbance.

Critical Impact Thresholds:

Little to no survival of benthic invertebrates occurs when buried by > 3 ft (1 m) of sediment.

Data Gaps:

Limited information is available on shellfish spawning/nursery grounds (locations, time of year) in the nearshore. Such information would improve project planning to avoid and/or minimize potential nearshore burial and/or dredging impacts.

Limited information is available regarding recovery rates associated with borrow sites of different size and/or shape (Posey 2002). This type of information potentially could improve project design for minimizing biological impacts and/or enhancing recovery times.

Restoration:

Because impact to sandy subtidal habitat from beach nourishment does not impact sensitive aquatic sites and are generally short-term, restoration would not be necessary.

Summary:

Direct burial associated with nearshore and/or profile sand placement will result in crushing, smothering, mortality, and disturbance of subtidal benthic invertebrates. Subtidal infauna of nearshore sand habitats are less resilient than intertidal fauna and generally display slower recovery rates.

Dredge equipment-related recovey may be rapid in navigational channels of embayments subject to periodic maintenance dredging. Recovery rates after dredging offshore borrow sites may range from 2 to several years depending on size of area, dredge method, local envioronmental conditions, substrate characteristics, and existing community characteristics.

Indirect sedimentation of downdrift areas will result in variable levels of sediment accumulation adjacent to nearshore placement sites and/or dredge locations. Indirect sedimentation may also affect the nearshore during and after beach nourishment projects. Minor sedimentation may result in temporary enhancement. Few studies have examined the consequence of increased silt-loading sedimentation on subtidal invertebrates. Persistent silt-loading, if it occurs, may lead to altered community composition.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on sandy subtidal invertebrates.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Documented	Documented	Documented	Relevant reports
Critical Impact Thresholds	NA	Changed substrate and/or hydrodynamics and degrade habitat	> 3 ft (1 m), Incompatible substrate that degrades habitat	Incompatible substrate that degrades habitat	Smother invertebrates
Impact Responses	NA	Crushing, burial, removal,	Crushing, smothering, migration escape	vertical migration escape	Decreased respiration, feeding, recruitment,
Duration of Impacts	NA	Months-years	Months-years	Months-years	Days-months
Potential for Restoration	NA	No	No	Unnecessary	Unnecessary

4.2.8 Rocky Intertidal Invertebrates

Photo by: Karen Green

Regulatory Status:

Endangered	X
Threatened	
CDFG Managed	X
None	X

Black abalone, California spiny lobster, and sea urchins, which were described previously (Sections 4.2.1.1 to 4.2.1.3), are examples of sensitive and/or managed fishery species that may occur in lower intertidal habitat. Black abalone is a candidate species for listing under the federal Endangered Species Act. Red and purple sea urchins cannot be harvested from the intertidal. Lobster recruitment occurs in vegetated rocky low intertidal to shallow subtidal areas, particularly surfgrass beds. Another managed invertebrate species that may occur in rocky intertidal habitat is California mussel, which has a recreational bag limit of 10 pounds (CDFG 2005a). Other rocky intertidal invertebrates lack special regulatory status, but all reside within Essential Fish Habitat.

Description and Distribution:

Rocky intertidal habitat and associated invertebrates occur throughout California. Marine invertebrates (and plants) exhibit pronounced vertical zonation in rocky intertidal habitats associated with variable tolerances to tidal exposure (see Section 3.2.4). The splash zone is characterized by acorn barnacles (*Chthamalus* spp.) and periwinkles (*Littorina* spp.). Barnacles, periwinkles, limpets (*Collisella* spp.), and lined shore crab (*Pachygrapsus crassipes*) are common in the upper intertidal.

Life Stage or Function	California			On Land	Inter-tidal	Near-shore < 30 ft	Off-shore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X		X			E, P
Juvenile	X	X	X		X			E, P
Egg	X	X	X		X			E, P
Primary Habitat	X	X	X		X			E, P
Foraging Habitat	X	X	X		X			E, P
Spawning Habitat	X	X	X		X			E, P

Representative species in the middle intertidal include California mussel (*Mytillus californianus*), aggregating sea anemone (*Anthopleura elegantissima*), goose neck barnacle (*Pollicipes polymerus*), and red (*Tetraclita rubescens*) barnacle, lined shore crab, owl limpet (*Lottia gigantea*), turban snails (*Tegula* spp.), and chitons (e.g., *Mopalia muscosa, Nuttalina* spp.).

The greatest variety of species occur in the low intertidal. Representative species include crabs, purple sea urchins, brittle stars (e.g., *Amphipholis* spp., *Ophiothrix* spp.), ochre starfish (*Pisaster ochraceus*), colonial sand tube worm (*Phragmatopoma californica*), Calfiornia sea hare (*Aplysia californica*), and a variety of snails (e.g., *Acanthina* spp.,

Ocenebra spp., *Roperia poulsina*). Under very low tides, motile predators such as octopus may be seen in tidepool areas.

Functions:

Rocky intertidal substrate may provide primary living, foraging, and reproductive habitat functions for a variety of marine invertebrates. Rocky intertidal invertebrates are eaten by other invertebrates, fish, and birds. The black abalone, which is a candidate species for listing under the federal Endangered Species Act, has uncommon occurrence in California rocky intertidal areas (see Section 4.2.1).

Invertebrates also display a variety of feeding behaviors. Barnacles, mussels, colonial sand turbe worms, and spirorbid tube worms filter or suspension feed on plankton. Chitons, limpets, sea hares, and some snails feed on marine vegetation. Octopus, sea anemones, sea stars, and some snails are predators. Crabs and hermit crabs are herbivores and scavengers.

Associated Species	Forage/ Prey	Eaten By
Plankton	X	
Invertebrates	X	X
Fish		X
Birds		X
Vegetation	X	
Marine Mammals		
Terrestrial Animals		X
Humans		X

Over 300 species of invertebrates have been reported in association with rocky intertidal habitats in southern California (Littler 1979 cited in Thompson et al. 1993). The number of invertebrates at any particular location, however, relates to habitat characteristics, exposure to waves and swash, intensity of sand scour, and frequency of sand burial (Seapy and Littler 1978, Taylor and Littler 1982, Thompson et al. 1993). Beaches with smooth, unstable rocks have less life than craggy, high-relief, bedrock shores that provide numerous microhabitats (Ambrose et al. 1989). Small boulders that are frequently overturned may support only sparse early succesional stage communities of green algae and barnacles (Sousa 1979a). A greater diversity of plants and animals generally is found at rocky shores partially protected by a headland, island, or offshore reef than unprotected surf swept shores (Ambrose et al. 1989).

The following descriptions provide examples of the range of invertebrate resource development associated with different rocky intertidal substrate.

- MEC (2000a) reported no invertebrates on cobble beaches, few invertebrates (aggregating sea anemones, hermit crabs) on low-relief reefs (aggregating sea anemone, hermit crabs), and substantially more invertebrates (> 18 species) on variable height reefs ranging up to 3 ft (1 m).
- Similarly, CRM (1997) reported 15 to 26 invertebrate species at variable height, 1 to 3.6 ft (0.3 to 1.1 m), rocky intertidal areas in Malibu, California.

Life History Facts:

Rocky intertidal invertebrates encompass a wide variety of animals with variable life history characteristics (Morris et al. 1980). Rocks provide attachment sites for abalone, sea anemones, barnacles, chitons, limpets, mussels, sponges, tunicates, and various tube worms. Hermit crabs and marine snails are highly mobile, and move about the rock surfaces feeding on plant detritus other organic matter. Crabs and octopus also are mobile,

but shelter in rock crevices and/or among rocks and marine vegetation. Many rocky intertidal invertebrates are broadcast spawners with planktonic larvae. Crabs and barnacles brood eggs and release swimming planktonic larvae. Sea anemones may reproduce either sexually or asexually.

Reproductive times vary among species (Morris et al. 1980). California mussel spawns throughout the year, but has peaks in July and between December and May (Morris et al. 1980, Shaw et al. 1988). Barnacles also are reproductive year round. Ochre starfish spawn in spring. Mossy chiton (*Mopalia muscosa*) spawns from July to September in central and northern California and winter-spring in southern California.

Rocky intertidal invertebrates vary in life span (Morris et al. 1980). Some of the hardiest upper intertidal species such as barnacles, periwinkles, and limpets may live < 3 years. The California sea hare often lives one year or less. However, many species live > 5 years. Some species may live more than 20 years (e.g., black abalone, goose neck barnacles, ochre starfish,). Purple sea urchins are believed to live > 100 years. Aggregating sea anemones, which establish clones by longitudinal fission, are likely to persist indefinitely in areas of normal disturbance (Sebens 1983).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Spawn Egg/brood Planktonic Asexual	Year round	Year round	None	None	1->3 Years	Mobile-Sedentary

Adaptations and/or Behaviors to Disturbance:

Invertebrates exhibit various adaptations to disturbance based on morphology, behavior, reproduction, and/or habitat characteristics. Some such as barnacles, chitons, hermit crabs, limpets, and snails have hard protective shells. Colonial sand tube worms build extensive tube formations from mucus-cemented sand grains. Many species are mobile (e.g., crabs, octopus, sea hares, snails, and sea stars). Aggregating sea anemones attach small rocks and shell debris to their body and when disturbed, contract and pull-in their tentacles; thus, forming low encrusted mounds.

Seasonal sand movement is an important disturbance factor in rocky intertidal habitats. Sand inundation buries and sand movement scours all or portions of rocks and reefs, depending on height, on a seasonal basis. This burial and scour often determines the lower tide zone limit of rocky intertidal species assemblages (Littler et al. 1983, Engle 2005).

Life Stage	Behavior			Protective Shell, Exo-skeleton	Habitat	High Reproductive Output and/or Growth
	Crawl/ walk	Clamp onto rock	Extend or retract body			
Adult	X	X	X	X	X	
Juvenile	X	X	X	X	X	
Egg/larvae						X

Some rocky intertidal invertebrates obtain protection from sedimentation based on microhabitat distribution, i.e., living on rocks above the depth of seasonal sand inundation. Examples include California mussel, black abalone, and owl limpet (Littler et al. 1983). Other species have life history and/or behavioral adaptations for persisting in areas with natural sand inundation. Rocky intertidal areas subject to routine seasonal sedimentation generally develop subclimax associations consisting of opportunists, migration strategists, and sand stress-tolerant species (Taylor and Littler 1982, Littler et al. 1983).

Opportunistic invertebrates include barnacles (e.g., *Chthamalus fissus/dalli*, *Tetraclita rubescens*) and the colonial sand tube worm (*Phragmatopoma californica*). Opportunists are not necessarily tolerant of prolonged sedimentation. For example, *Phragmatapoma californica* tolerated short-term sedimentation, but experienced 95 percent mortality after 5 days (Taylor and Littler 1982 cited in Main and Nelson 1988). However, opportunists are able to quickly reoccupy open space due to high recruitment capability. Mobile species such as the black turban snail (e.g., *Tegula funebralis*) was found to migrate to and from sand inundated areas (Littler et al. 1983).

Sand stress-tolerant species included the aggregating sea anemone (*Anthopleura elegantissima*) and mossy chiton (*Mopalia muscosa*) (Littler et al. 1983). Clonal aggregating sea anemones are adapted morphologically, reproductively, behaviorally, and physiologically to both sand deposition and desiccation (Taylor and Littler 1982). Aggregating sea anemones withstand shallow burial by extending its columns so the oral disc and tentacles remained above the surface, and metabolism of body tissue (Sebens 1980) was considered likely during prolonged burial (> 3 months). The mossy chiton tolerated sand burial for several weeks with no apparent effect (Taylor and Littler 1983).

Surveys conducted in the vicinity of the Portuguese Bend landslide in southern California provide relevant information on species adapted to chronic sedimentation and turbidity disturbance. Comparison of the landslide affected site (Portugese Bend) with partially affected (Abalone Cove) and mainly unaffected (Palos Verdes Point) areas showed little difference in total numbers of invertebrate species (i.e., each had a total of 35 or 36 species) (Pondella et al. 1996). However, there was a substantial difference in the number of species between transects at the headlands bordering the main slide and those within the main slide area. Substantially more invertebrates were found at the headlands (22 to 27) than within the slide area (8 to 10). There was 25 to 39% fewer species at the headlands and 71 to 78% fewer species in the slide area, suggesting that rocky intertidal invertebrates may be affected by but are more tolerant of turbidity than sedimentation effects.

The Portuguese landslide study also provides relevant information on species adapted to chronic sedimentation and turbidity disturbance. The most frequently occurring species in areas closest to the active slide included barnacles (*Balanus glanula*), California mussel, sea anemones, chitons (*Mopalia mucosa, Nutallina californica*), and lined shore crab (*Pachygrapsus crassipes*) (Pondella et al. 1996).

Additional species at partially affected Abalone Cove included barnacles (*Tetraclita rubescens*), rough limpet (*Collisella scabra*), file limpet (*Collisella limatula*), owl limpet, black turban snail (*Tegula funebralis*), purple sea urchins, and hermit crabs (*Pagurus* sp.). Additional species at unaffected Palos Verdes Point included spirorbid tube worms, ribbed limpet (*Collisella digitalis*), shield limpet (*Collisella pelta*), rough limpet, owl limpet, periwinkles (*Littorina* sp.), black turban snail, banded turban snail, purple sea urchins, and hermit crabs. Most of the additional species away from the landslide activity were

vegetation-associated herbivores (limpets, littorine and turban snails, sea urchins), herbivore-scavengers (hermit crabs), or suspension feeders (spirorbid worms). The number of plant species and average percent plant cover was higher at unaffected Palos Verdes Point (17, 32%) than the landslide site (11, 27%); the partially affected Abalone Cove site also had fewer plant species but did not show reduction in percent plant cover (10, 32%). These results suggest chronic turbidity reduced the number of vegetation-associated species (and vegetation) and may have reduced filter feeders (although few occurred intertidally at the unaffected site).

Surveys off Malibu, California also suggest rocky intertidal invertebrates may be influenced, but are relatively tolerant of turbidity. CRM (1997) reported 21 to 26 species of invertebrates at beaches where substrate consisted of low to high relief bedrock and boulders and inshore visibility ranged from 3 to 17 ft (1 to 5.1 m). There were 19 to 35% fewer species (15 to 17) at beaches where substrate was granite rip rap or low to moderate reef and inshore underwater visibility was < 1 to 5 ft (< 0.3 to 1.7 m). Some differences between sites probably related to substrate differences; however, comparison of just the sites with variable low to high relief substrate had the following number of species and inshore turbidities: 15 species where inshore visibility was < 1 to 5 ft (< 0.3 to 1.7 m), 21 species where inshore visibility was 3 to 5 ft (1 to 1.7 m), and 21 to 26 species where inshore visibility was 5 to 17 ft (1.7 to 5.1 m). Sand levels varied among tidepools, but were generally < 4 inches (< 10 cm), suggesting limited sedimentation influence. Effects were more pronounced for marine plants with 7 to 15 species in areas with lower underwater visibility and 20 to 26 species in areas with higher visibility.

Potential Impacts from Sediment Management Activities:

Concerns regarding potential impacts from sediment management activities on rocky intertidal habitat relate to the limited distribution and high biological productivity that may be associated with this habitat. Invertebrates have the potential to be impacted in rocky intertidal habitat, if located in the vicinity of sediment management activities.

Rocky intertidal habitats also may include low relief, ephemeral reefs subject to seasonal sand burial and scour that lack substantial invertebrate assemblages. Such areas may be associated with eroded sandy beaches and/or occur in regions where reef development is patchy.
Indirect impacts could include sedimentation and/or turbidity depending on proximity of rocky intertidal to beach nourishment location.

Types of sediment management activities and potential impacts to rocky intertidal invertebrates may include:

- Maintenance dredging of embayments – not applicable.
- Offshore borrow site dredging – not applicable
- Nearshore placement – sedimentation, turbidity.
- Profile placement – equipment damage, burial, sedimentation, turbidity.
- Beach placement –equipment damage, burial, sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging				X	X	X
Growth				X	X	X
Habitat			X	X		X
Reproduction				X	X	X
Respiration				X	X	X

Equipment

Placement of pipelines in order to convey sands to the beach from offshore hopper vessels has the potential to overturn rocks resulting in displacement and/or damage to marine invertebrates, if present. Temporary construction impacts could be adverse in rocky intertidal areas supporting diverse and/or sensitive rocky intertidal invertebrate resources. Equipment use in areas with cobble substrate and/or low relief ephemeral reefs with few to no invertebrate species would have little potential for adverse impact.

Avoidance of direct disturbance of sensitive rocky intertidal areas has been incorporated into project design of some California beach nourishment projects (e.g., SANDAG and USDN 2000, Moffatt & Nichol 2001). Pre-construction environmental surveys also were used to minimize the potential for impacts to sensitive rocky reef resources during the 2001 San Diego Regional Beach Sand Project (AMEC 2002) and 2003 Goleta Beach Demonstration Project (Chambers Group 2003, Moffatt & Nichol 2003). Pre-construction surveys to finalize pipeline routes in areas with intertidal reefs have been recommended as a beach nourishment mitigation measure (Chambers 1992, 2000b).

Burial/Sedimentation

Direct burial of sensitive rocky intertidal areas are unlikely to be permitted in California. Several California beach nourishment projects have been designed during project planning to avoid direct placement of sand in areas with persistent rocky intertidal (Tekmarine and Analytic Planning Service 1990; Chambers 1992; USDN 1997a, b; SANDAG and USDN 2000; Moffatt & Nichol 2001).

Potential impacts to invertebrates could result from indirect sedimentation of reefs from post-construction sand transport from beach nourishment sites. Potential impacts would probably depend on the nature and duration of sedimentation, substrate characteristics (e.g., cobble versus rocks, and reef heights), and associated species. Rocky intertidal invertebrate assemblages appear to be fairly tolerant of seasonal sedimentation. However, field studies indicate that reduced assemblages of only the most tolerant species occur in areas with frequent and/or persistent sedimentation. Loss of rocky intertidal invertebrates would not be expected unless there was complete and persistent burial.

Monitoring conducted before and after the 2001 San Diego Regional Beach Sand Project reported no obvious impacts of sedimentation from that project on rocky intertidal habitat

within 3,400 to 4,200 ft (1,000 to 1,280 m) downcoast of a receiver site that received 101,000 cy of sand (Engle 2005). Although some sand burial effects were noted, including mortality of some barnacles and mussels, those effects were considered within natural seasonal ranges of sand inundation effects.

Monitoring before and 1-year after the Goleta Beach Demonstration Project showed little sedimentation effects on the closest rocky intertidal habitat approximately 1 mile downcoast of a 58,937 cy project (Chambers Group 2002). Percent sand cover varied within a similar range before and after the project at the downcoast site, and at an upcoast site outside potential project influence. Sand depths may have showed project influence with a maximum depth of approximately 1 ft (0.3 m) at the downcoast site compared to 0.5 ft (0.1 m) at the upcoast site, however, the deeper sand depths were not persistent between surveys conducted at 4 month intervals. Percent cover of invertebrates was low before (0 to 1%) and after (0 to 2%) the project at the downcoast site and at the upcoast site (0 to 4%).

Turbidity

Rocky intertidal invertebrates are adapted to seasonally turbid waters. In the laboratory, California mussels were able to tolerate short-term exposure (8 days) to very high concentrations of kaolin clay, with a LC_{50} at 96,000 mg/L (Peddicord et al. 1975 cited in O'Connor 1991). The East Coast species of the colonial sand worm *Phragmatopoma lapidosa* tolerated 1 to 4 day exposures of 2,000 to 6,000 mg/L Fuller's earth with no apparent effect (Main and Nelson1988).

Surveys in areas of chronic turbidity provide indirect evidence that many invertebrate species are relatively tolerant of turbidity, but prolonged turbidity may result in some reduction in number of species. Herbivores appear to be most affected, which probably relates to turbidity induced reductions in marine vegetation.

Rocky intertidal invertebrates would be expected to be tolerant of short-term exposures to elevated suspended sediment concentrations. No significant impacts would be expected unless prolonged turbidity resulted in reduction in marine vegetation.

Recovery from Disturbance:

Recovery rates of rocky intertidal invertebrates vary depending on species. Recovery of intertidal communities does not follow an orderly succession, but rather may be characterized as colonization by opportunists followed by different dominants (Dayton 1971) or colonization by opportunists and/or dominants (Connell 1972). White acorn barnacles are capable of rapid recovery, but mussel beds can take years to recover, depending on recruitment and other factors (Vesco and Gillard 1980). Barnacles are early colonists of bare substrate (Sousa 1979b). The opportunistic *Phragmatopoma californica* may recover in < 1 year (Taylor and Littler 1982).

Recovery of large mussel patches may take 2.5 to > 3 years (Morris et al. 1980, Littler et al. 1983, Dethier 1984), although recovery may take 2 years to begin and take 5 to 7 years for full recovery (Paine and Levin 1981). Mussels require secondary space (certain algae, barnacles, or byssal threads) for larval settlement (Dayton 1971). Recovery of aggregating sea anemones may range from 1 year for partial losses to > 3 years for total losses (Taylor and Littler 1982, Dethier 1984).

Recovery rates may be rapid in the case of minor disturbance such as short-term turbidity and/or sedimentation resulting in only temporary burial effects. Potential indirect impacts associated with sand transport sedimentation are not well understood. Recovery rates would probably relate to the nature and magnitude of the effects as well as diversity of the invertebrate assemblage. Recovery of low relief substrate with low species diversity would not take as long as variable height and/or high relief substrate with higher species diversity. Recovery could take years if indirect sand transport sedimentation resulted in substantial reduction in invertebrate assemblages. Turbidity effects generally would be limited to the construction period, but actual exposure duration would vary depending on project- and site specific conditions. Recovery rates from turbidity would begin when construction ended. No significant impacts would be expected unless prolonged turbidity resulted in a decline in vegetation. Recovery rates of marine vegetation may be fairly rapid once water quality improves.

	Recovery Rates				
Impact	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	X			X	
Burial	X	X	X		
Sedimentation	X	X	X		
Turbidity	X			X	
Habitat Loss			X		

Critical Impact Thresholds:

No critical impact thresholds have been established for rocky intertidal invertebrates.

Data Gaps:

Limited information is available on recovery rates from sedimentation and prolonged turbidity.

Restoration:

It is technically feasible to create rocky intertidal habitat, although successful restoration of tidepools has not been demonstrated.

Summary:

Rocky intertidal invertebrate assemblages display considerable variability relative to habitat characteristics, particularly substrate relief and height and sand inundation. Cobble habitats support few if any biological resources. Low relief substrate subject to seasonal sand burial and scour also may support few to no invertebrate species. Substrate above the normal seasonal sand inundation level may support diverse invertebrate assemblages. Variable height reefs may support a combination of subclimax and diverse species assemblages. Thus, considerable variability exists among rocky intertidal habitat quality and environmental sensitivity.

No beneficial or adverse impacts to rocky intertidal invertebrates attributed to sediment management activities have been documented in California. Direct impacts from equipment and/or sand placement burial are unlikely to be permitted in sensitive rocky intertidal areas

where substantial invertebrate assemblages live. If equipment impacts were to occur, they could result in localized disturbance and/or mortality of individual animals. Direct burial could result in complete to partial habitat loss over a period of years.

Protective conservatism is the primary basis of concern for indirect sedimentation and turbidity impacts. Natural sedimentation is considered a primary factor affecting distribution and diversity of rocky invertebrate invertebrates. Species differ in sensitivity and tolerance to burial, contributing to differences in intertidal species assemblages at any particular location and between years. Impacts to rocky intertidal invertebrates from indirect sand transport sedimentation could range from minor to significant. Impacts from temporary sand inundation and/or partial burial may be within the range of natural seasonal variability. Substantial and persistent sedimentation could result in partial and/or complete loss of habitat and associated biological resources for several years. Complete recovery of diverse intertidal invertebrate assemblages would take several years.

Laboratory and indirect field studies indicate rocky intertidal invertebrates are relatively tolerant of turbidity. Turbidity associated with sediment management activities generally is limited to the period of construction, ranging from days to months. No adverse impacts to invertebrates would be expected from short-term exposures to turbidity. No significant impacts would be expected unless prolonged turbidity resulted in reduction in marine vegetation and associated invertebrates.

Critical impact thresholds for rocky intertidal invertebrates are unknown, but generally considered high due to natural life history, morphological, and behavioral adaptations for living in the harsh intertidal environment. Loss of sensitive intertidal rocky habitat due to persistent sedimentation would require restoration to avoid significant impact to Essential Fish Habitat. It may be possible to re-create tidepool habitat if it was permanently lost as a result of sedimentation, but restoration of tidepools has not been demonstrated and remains uncertain. Project design avoidance and/or pre-construction surveys to finalize pipeline routes have been used to avoid impacts to sensitive rocky intertidal habitats.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on rocky intertidal invertebrates.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Protective conservatism	Documented	Documented	Relevant Reports
Critical Impact Thresholds	NA	Rocks overturned Mortality	Burial of attachment substrate, habitat loss	Burial of attachment substrate, loss of algal food base	Loss of algal food base
Impact Responses	NA	Disturbance mortality	No effect, displacement, reduced forage, mortality	No effect, displacement, reduced forage, mortality	No effect, reduced forage, mortality
Duration of Impacts	NA	Days-months	Months-years	Months-years	Days-months
Potential for Restoration	NA	Unnecessary	Feasible, but not demonstrated	Feasible, but not demonstrated	Unnecessary.

NA = not applicable

4.2.9 Rocky Subtidal Invertebrates

Sea fan
Photo by: Daniel Heilprin, SAIC

Regulatory Status:

Endangered	X
Threatened	
CDFG Managed	Fishery species
None	X

White abalone was listed as endangered under the federal Endangered Species Act in 2001 (NMFS, NOAA 2001). Black abalone is a candidate species for listing under the federal Endangered Species Act (http://www.CDFG. ca.gov/mrd/fforum2004.html#abalone).

Commercial fisheries for red and purple sea urchins, California spiny lobster, California sea cucumber (*Parastichopus californicus*), and wavy turban snail (*Lithopoma undosum*) occur in subtidal reef and kelp bed areas. Recreational fishing limits apply to California spiny lobster (7), red abalone (3), and rock scallops (10) (CDFG 2005a). Other recreationally fished species may include octopus (no limit, but must be taken by hand). Other rocky intertidal species lack special status, but all rocky subtidal invertebrates are residents of Essential Fish Habitat.

Description and Distribution:

Subtidal reef invertebrates occur throughout California, although reefs generally are more numerous in central and northern California and around the Channel Islands than along the mainland of southern California (Ambrose et al. 1989).

Life Stage or Function	California			On Land	Inter-tidal	Near-shore < 30 ft	Off-shore > 30 ft	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Juvenile	X	X	X			X	X	E, P
Egg	X	X	X			X	X	E, P
Primary Habitat	X	X	X			X	X	E, P
Foraging Habitat	X	X	X			X	X	E, P
Nesting/Spawning Habitat	X	X	X			X	X	E, P
Resting/Roosting Habitat								

Potential Functions:

Rocky substrate provides primary living, foraging, and reproductive habitat functions for a variety of marine invertebrates. Rock surfaces provide attachment sites for barnacles, bryozoans, limpets, sea fans, sea anemones, sponges, and tunicates. A wide variety of crustaceans (crabs, hermit crabs, lobster), echinoderms (brittle stars, sea cucumbers, sea urchins, starfish), and mollusks (snails, nudibranchs, sea hares) move about the rock surfaces feeding on vegetation, animals, and/or detritus. Crevices provide shelter and/or protection from predation for abalone, crabs, lobsters, and octopus.

Associated Species	Forage/ Prey	Eaten By
Plankton	X	
Invertebrates	X	X
Fish		X
Birds		
Vegetation	X	
Marine Mammals		X
Terrestrial Animals		
Humans		X

Several species, including abalone, California spiny lobster, sea cucumber (*Parastichopus californicus*), and sea urchins may be taken by commercial and recreational fishermen (CDFG 2001). Threatened sea otters and pinnipeds feed on large invertebrates associated with rocky subtidal habitats.

Several factors affect the diversity and abundance of invertebrates associated with subtidal hard bottom habitats. Generally, higher relief reefs support more diverse communities than low relief reefs that experience excessive siltation or sand scour (Ambrose et al. 1989; also see Section 3.2.5). Consequently, hard bottom areas within littoral depths (to beach depth of closure) are often less diverse due to greater disturbance from waves, sedimentation, turbidity than sublittoral reefs. Resource development is higher for vegetated than non-vegetated reefs; macroalgae provides food, structural complexity, refuge from predation, and spawning/nursery sites for invertebrates (Foster and Schiel 1985).

The following reef descriptions provide examples of the range of invertebrate resource development associated with nearshore reefs in California. Generally, relatively few species of macroinvertebrates have been reported from shallow nearshore waters (< 30 ft, < 9 m), as follows:

- no invertebrates - low-relief (< 3 ft, < 1 m) patch reefs surrounded by sand, 3 species - low relief reefs with surfgrass, 6 species - reef heights varied from low to high (> 3 ft, > 1m) with surfgrass at depths < 20 ft (6 m) offshore Cardiff and Solana Beach in San Diego County (MEC 1995 cited in MEC 2000a).
- 10 species - reconnaissance surveys of low to high-relief subtidal reefs at water depths ranging from 10 to 30 ft (3 to 9 m) offshore several beaches in San Diego County (USDN 1997a,b)

A greater variety of invertebrates has been reported at sublittoral depths (e.g., > 30 ft). Over 300 species of invertebrates have been reported to inhabit rocky reefs and kelp beds off California, however, that number includes visible macroinvertebrates and small, cryptic invertebrates encrusting on rock and/or associated with vegetation holdfasts and/or blades.

The number of invertebrates may vary depending on reef characteristics, presence of kelp, and location. The following examples provide relevant examples:

- 33 invertebrate species – sand bottom with giant kelp at depths > 35 ft (11 m) offshore Corral Canyon, Santa Barbara, southern California (Chambers Consultants 1982).
- 300 invertebrates (observed plus collected from rock scrapings) - mixed bottom, high-relief (maximum height 23 ft) siltstone reef, which lacked giant kelp, in 31 to 59 ft (9.5 to 18 m) depths offshore Corona Del Mar, southern California (Pequegnat 1974);
- 204 invertebrates (observed during 30 SCUBA dives) from kelp forest reef south of Monterey, central California (McLean 1962 cited in Foster and Schiel 1985).

- 38 observed species - Bureaucrat artificial reef made from large quarry rocks, located at depth of 40 ft (12 m) off Torrey Pines, southern California (Wilson et al. cited in Ambrose 1986).

Life History Facts:

Similar to intertidal invertebrates, rocky subtidal invertebrates encompass a wide variety of animals with variable life history and behavior characteristics (Morris et al. 1980). Rocks provide attachment sites for barnacles, bryozoans, chitons, limpets, mussels, rock scallops (*Hinnites giganteus*), scaled worm snail (*Serpulorbis squamigerus*), sea anemones, sea fans, sponges, and tunicates. Rock-boring pholad bivalve molllusks (e.g., *Chaceia ovoidea, Parapholas californica*) may bore to depths of 11 to 24 inches (28 to 60 cm) in hard clay, soft sandstone and/or soft-shale reefs (Morris et al. 1980).

Brittle stars, hermit crabs, marine snails, sea urchins, and starfish are highly mobile. Crabs and octopus also are mobile, but shelter in rock crevices and/or among rocks and marine vegetation. Rock scallops and octopus may swim when disturbed.

Many rocky subtidal invertebrates are broadcast spawners with planktonic larvae (Morris et al. 1980). Crabs and barnacles brood eggs and release swimming planktonic larvae. Rock scallops spawn in April. Ochre starfish and giant starfish (*Pisaster giganteus*) spawn in spring. The California sea cucumber *Parastichopus californicus* breed in the summer and larvae have a pelagic phase that lasts 7 to 13 weeks. Sea fans (*Muricea appressa*) reproduce when the water temperature is > 14°C (54 ^{o}F) and larvae settle after approximately 1 month; sea fans are very slow growing and reach sexual maturity when 5 to 10 years old.

Several invertebrates lay eggs on the bottom, which upon hatching may have a brief planktonic stage (Morris et al. 1980). Octopus larvae have a pelagic phase for approximately 1 month. Limited information is available regarding the duration of the pelagic stage of nudibranch sea slug larvae; settlement occurs after 2 hours for *Archidoris montereyensis*. Sea hares are simultaneous hermaphrodites that must mate; hatched larvae settle after approximately 1 month. Many of the snails lay eggs on rocks. Scaled worm snails lay eggs on inside of their shell.

Sea anemones may reproduce either sexually or asexually. The giant green sea anemone (*Anthopleura xanthogrammica*) reproduces sexually, releasing eggs in late spring and summer. Reproductive times vary among species (Morris et al. 1980). Strawberry anemones (*Corynactis californica*) reproduce asexually.

Rocky subtidal invertebrates vary in life span (Morris et al. 1980). The California sea hare often lives one year or less. Many species live > 5 years. Some species may live more than 20 years (e.g., abalone, starfish, purple sea urchins, rock scallop, sea fans).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Spawn Egg/brood Planktonic Asexual	Year round	Year round	None	None	1->3 Years	Mobile-Sedentary

Rocky subtidal invertebrates display a variety of feeding behaviors (Morris et al. 1980). Barnacles, bryozoans, mussels, feather duster worms, sponges, sea fans, scaled worm snails, and tunicates filter or suspension feed on plankton and small particles. Grazing mollusks (chitons, limpets, sea hares, some snails) and sea urchins feed on marine vegetation. Nudibranchs, octopuses, sea anemones, starfish, and some snails are predators. Crabs and hermit crabs are herbivores and scavengers. Lobsters are omnivores. Some brittle stars are detrivores, predators, and/or scavengers; others are suspension feeders on small particles. Sponges feed on bacteria and fine detritus. Sea cucumbers feed on organic detritus and small animals either by ingesting sediment (*Parastichopus*) or by trapping with their tentacles from the water (*Cucumaria* spp.).

Adaptations and/or Behaviors to Disturbance:

Invertebrates exhibit various adaptations to disturbance based on morphology, behavior, reproduction, and/or habitat characteristics. Some such as barnacles, chitons, hermit crabs, limpets, and snails have hard protective shells. Many species are mobile (e.g., brittle stars, crabs, lobsters, octopus, sea cucumbers, sea hares, snails, and sea stars).

Seasonal sand movement is an important disturbance factor of shallow rocky subtidal habitats. Sand inundation buries and sand movement scours all or portions of rocks and reefs, depending on height, on a seasonal basis.

Filter-feeding invertebrates such as sponges and tunicates are sensitive to thin layers (millimeters) of sedimentation, which may clog canals and chambers (Bakus 1968). These species as well as other sensitive rocky subtidal invertebrates may obtain protection from sedimentation based on microhabitat distribution; i.e., living on rocks above the depth of seasonal sand inundation. Abalones and sea fans have been reported to occupy upper parts of rocks generally above seasonal sand inundation levels (Littler et al. 1983, AMEC 2005).

Some sedentary invertebrates are tolerant of shallow burial (Morris et al. 1980). Rock-boring pholads have extensible siphons, and *Parapholas californica* has been observed to tolerate sand cover up to 6 inches (15 cm). Similar to the intertidal aggregating sea anemone, sea anemones that occur from low intertidal to shallow subtidal depths off rocky shore may extend their column so tentacles remain above shallow sand inundation levels. For example, the solitary green sea anemone *Anthopleura xanthogrammica* has a column that may reach 12 inches (30 cm), *Anthopleura* may elongate its 2-inch (5 cm) column to 10 inches (25 cm), and *Tealia lofotenis* has a 6-inch (15 cm) column.

Life Stage	Behavior			Protective Shell, Exo-skeleton	Habitat	High Reproductive Output and/or Growth
	Crawl/ walk	Clamp onto rock	Extend or retract body			
Adult	X	X	X	X	X	
Juvenile	X	X	X	X	X	
Egg/larvae						X

Point source discharges (power plants, ocean outfalls) that result in chronic turbidity and redistribute sediments have been associated with adverse effects to kelp beds and

associated communities (Murray and Bray 1993, CDFG 2001). Studies conducted in the vicinity of the San Onofre Nuclear Generating Station (SONGS) provided evidence of adverse impacts associated with increased particulate loads. Schroeter et al. (1993) found there were statistically significant reductions in density of snails, sea urchins, and starfish in a kelp bed within approximately 0.4 km from the SONGS discharge compared to another kelp bed 1.4 km away; the turbidity plume with increased suspended inorganic and organic materials (+46% at the impact site nearest to the discharge) was considered the most plausible explanation. Although the overall effect was adverse, populations of two filter-feeding species, a gorgonian coral and a sponge, showed relative increases in density.

Experiments by Duggins et al. (1990) showed various recruitment responses of invertebrates to sedimentation and reduced light levels associated with understory kelp canopies. For example, increased sedimentation and reduced light adversely affected recruitment of serpulid and spirobid polychaetes, increased sedimentation affected recruitment of *Membranipora* bryozoans, and increased sedimentation and higher light intensity affected recruitment of *Tubulipora* bryozoans (*ibid.*).

Chronic sedimentation can substantially modify resource development on subtidal reefs and in kelp beds. Surveys conducted in the vicinity of the Portuguese Bend landslide in southern California provides relevant information on impacts to resource development as well as species adapted to chronic sedimentation and turbidity disturbance. Comparisons were made of subtidal invertebrates along transects at depths of 20, 30, and 40 ft (6, 9, 12 m) at unaffected Palos Verdes Point, partially affected Abalone Cove, and landslide affected Portuguese Bend. The number of invertebrate species across depths was 25 at Palos Verdes Point, 18 at Abalone Cove, and 30 at Portuguese Bend (Pondella et al. 1996). The higher number at Portuguese Bend was related to variability among species collected along the different transects. Substantially more invertebrates were found at the headlands bordering the slide area (19 to 24 species across depths) than within the center of the slide area (2 to 5 species across depths). The similar number of species at the turbidity affected headlands and Abalone Cove to that at Palos Verdes Point suggests that rocky subtidal invertebrates are relatively tolerant of turbidity. The substantially fewer numbers of species off the central landslide area indicates sensitivity to sedimentation.

The Portuguese landslide study also provides relevant information on species adapted to chronic sedimentation and turbidity disturbance. The only species in areas closest to the active slide included barnacles (*Balanus* sp.), ornate tube worm (*Diopatra ornata*), sandflat elbow crab (*Heterocrypta occidentalis*), purple globe crab (*Randallia ornata*), and spiny sand star (*Astropecten armatus*) (Pondella et al. 1996). With the exception of barnacles, these species are common in sandy areas; little to no exposed rocks occurred in the area. Species along the headland transects, which had some silt covering, included a mix of sandy and hard bottom fauna; rocky subtidal invertebrates included bryozoans, hermit crabs, aggregating sea anemone, strawberry sea anemone, sea fans, giant starfish, purple and red sea urchins, sea hares, red sponge nudibranch (*Rostanga pulchra*), banded turban snail, chestnut cowry (*Cypraea spadicea*), Kellet's whelk (*Kelletia kelletii*), California cone snail (*Conus californicus*), colonial sand tube worm, and sponges.

Rocky subtidal invertebrates at partially affected Abalone Cove included many of the above named species and additionally the lobster, sea cucumber (*Cucumaria salma*), tunicates, and scaled worm snail. Additional rocky subtidal invertebrates at the unaffected Palos Verdes Point included brittle stars (*Ophiopterus papillosa*), fragile star (*Linckia columbiae*), bat star (*Patiria miniata*), fragile tube worms (*Salmacina tribranchiata*), wavy turban snail,

giant keyhole limpet (*Megathura crenulata*), Norris's top snail (*Norrisia norrisi*), scaled worm snail, sponges, and tunicates. Additional species at the unaffected site were herbivores (snails), herbivores and/or carnivores on tunicates (giant keyhole limpet), suspension or filter feeders (brittle star, fragile star, tube worms, scaled worm snail, sponges, tunicates), or omnivores (bat star). Therefore, the results indicate an increasing number of vegetation-associated and filter/suspension feeders farther away from the landslide influence. Kelp and understory algae also were more prevalent at Palos Verdes Point. These results suggest chronic turbidity reduced the number of vegetation-associated species (and vegetation) and reduced the variety of filter/suspension feeders.

Differences in substrate type and perhaps to a lesser extent sedimentation/turbidity influenced rocky subtidal invertebrate assemblages offshore Malibu, southern California. Transects were surveyed at depths between 10 and 24 ft (3 to 7.3 m) and marine resources occurring on sand and hard substrate were recorded (CRM 1997). At sites with hard bottom habitat, the fewest number of rocky subtidal invertebrates (10 species) was reported where hard substrate was low relief (< 3 ft) cobble/boulder, silt was evident on rocks, and underwater visibility was < 1 to 5 ft (< 0.3 to 1.7 m). Moderate numbers (16 species) occurred where hard substrate was low relief (< 3 ft), some silt was observed, and visibility was 3 to 16 ft (1 to 5 m). Moderate to high numbers (17 to 30 species) occurred where hard substrate was low to high relief (> 3 ft) boulder/bedrock, silt was not observed, and visibility was 5 to 16 ft (1.7 to 5.1 m). The number of species of vegetation was substantially higher at the low to high reefs without visible silt (14 to 15 species) than at low relief reefs with some silt (6 species) and cobble/boulder reefs with obvious silt (2 species). These results suggest that rocky subtidal invertebrates are less sensitive to turbidity than vegetation.

Potential Impacts from Sediment Management Activities:

Concerns regarding potential impacts to rocky subtidal reefs relate to the limited distribution and high biological productivity that may be associated with this habitat. Fauna and flora occurring on subtidal reefs have the potential to be impacted if located in the vicinity of sediment management activities. No direct impacts to sensitive (i.e., well developed) subtidal reefs would be expected based on current environmental laws. Indirect impacts could include sedimentation and/or turbidity, if reefs occurred in the vicinity of sediment management activities.

Low relief, ephemeral reefs subject to seasonal sand scour that lack substantial resource development do not have the same ecological sensitivity as persistent rocky areas. Direct (equipment, burial) and indirect (sedimentation, turbidity) impacts to ephemeral reefs could potentially occur, if present in the vicinity of sediment management activities.

Types of sediment management activities and potential impacts to rocky subtidal invertebrates may include:

- Maintenance dredging of embayments – not applicable.
- Offshore borrow site dredging – equipment damage, sedimentation, turbidity.
- Nearshore placement – equipment damage, burial, sedimentation, turbidity.
- Profile placement – equipment damage, burial, sedimentation, turbidity.
- Beach placement – sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging			X	X	X	X
Growth			X	X	X	X
Habitat			X	X	X	X
Reproduction				X	X	X
Respiration					X	

Equipment

Anchoring associated with offshore dredging of sand borrow areas, nearshore discharge, and/or pipeline placement to convey sands to the beach have the potential to overturn rocks and/or damage invertebrates living on subtidal reefs. Temporary displacement of mobile invertebrates could occur from disturbance.

Direct disturbance of well developed rocky subtidal reefs are unlikely to be permitted in California because of the sensitive status of the habitat. Inadvertent equipment impacts, if they were to occur, would be expected to be localized and could disturb and/or damage individual invertebrates.

Damage to reefs during sediment management activities has been reported off the southeastern coast of the United States. Coral reefs were damaged when dredge equipment associated with borrow site dredging was dragged across a reef or when cutting heads of the dredge dug into reef surfaces off Hallandale, Florida (Courtney et al. 1972). The authors considered these as unnecessary accidents resulting from inadequate surveying prior to construction. Temporary movement of motile invertebrates (lobsters, crabs, shrimp) occurred during borrow site dredging; some species of invertebrates were absent from the area for 9 months. Reef damage off Hallandale was not evident 5 years later (Marsh et al. 1981). Reef damage off Delray Beach occurred from dredge anchor and cable dragging, which uprooted soft corals, fragmented sponges, overturned and/or scarred coral heads (Spadoni 1978 cited in Naqvi and Pullen 1982).

Pre-construction environmental surveys were used to finalize pipeline and vessel routes to avoid direct impacts to kelp canopies and sensitive rocky reef resources during the 2001 San Diego Regional Beach Sand Project (AMEC 2002) and 2003 Goleta Beach Nourishment Demonstration Project (Chambers Group 2003, Moffatt & Nichol 2003). Pre-construction surveys to finalize pipeline and vessel routes in areas with nearshore reefs were recommended as a mitigation measure for the BEACON Beach Nourishment Demonstration Project (Chambers 1992, 2000b).

Burial/Sedimentation

Nearshore and/or profile (nearshore component) placement have the potential to directly bury rocky subtidal habitat, if present within the receiver site. All beach nourishment methods (nearshore, profile, beach, dune) add sand to the littoral system and have the potential to result in indirect sedimentation of hard substrate habitat, if present within the area of potential effect of sand transport from the project. The area of potential effect is project specific and would relate to project volume and sediment characteristics, local bathymetry and currents, and oceanographic conditions.

Rocky subtidal invertebrates have various life histories, morphology, and behavior characteristics that result in species assemblages adapted to the particular physical and environmental conditions that define each hard substrate area. For example, rocky subtidal invertebrates may be absent or only a few tolerant species may occur on reefs subject to seasonal sand burial or substantial sedimentation/turbidity. In contrast, diverse assemblages of invertebrates may occur on reefs that experience little sedimentation. Therefore, impact to rocky subtidal invertebrates could range from little to no effect to significant depending on the ecological sensitivity of the hard substrate habitat (e.g., type and development of invertebrate resources), vulnerability to sedimentation based on habitat characteristics (e.g., persistent versus ephemeral reefs, reef heights), and magnitude and duration of burial/sedimentation.

Direct burial of sensitive rocky subtidal areas is unlikely to be permitted in California. For example, several California beach nourishment projects have been designed during project planning to avoid direct placement of sand in areas with persistent rocky subtidal habitats with sensitive resources (Chambers 1992; USDN 1997a, b; SANDAG and USDN 2000; Moffatt & Nichol 2001). Sensitive reefs were variously identified. In some cases, the reefs were well known areas identified from prior studies and/or reports; e.g., Carpinteria reef (Moffatt & Nichol 2001). In other cases, sensitive reefs were identified during pre-project environmental surveys based on occurrence of “indicator” species (surfgrass, giant kelp, feather boa kelp, sea palms, sea fans) (USDN 1997a, b; SANDAG and USDN 2000). A key aspect of these projects was adequate pre-project information on biological habitats and resources during project planning so that direct burial of sensitive resources was avoided.

Few studies have examined post-construction sedimentation impacts to rocky subtidal invertebrates associated with beach nourishment in California. Monitoring associated with the 2001 San Diego Regional Beach Sand Project focused on target species. Invertebrate target species on rocky subtidal nearshore reefs included sea fans, which occurred in low densities both before and for four years after the project; statistical comparisons or correlations relative to the project were not made for sea fans because they were infrequently encountered (AMEC 2005). Although not mentioned by the authors, comparison of sites where sea fans were reported with the summary table of changes in sand cover indicated no potential for project impact either because there was no projected related change in sand cover or very low sand cover (< 10%) occurred at the site.

Invertebrate target species monitored in kelp beds before and after the 2001 included sea fans, red and purple sea urchins, wavy turban snails, starfish (*Pisaster giganteus, P. ochraceous, P. brevispinus*), rock-boring pholad bivalves (*Chaceia ovoidea, Parapholas coalifornica*), ornate tube worms (*Diopatra ornata*), Kellet’s whelk, and encrusting invertebrates (bryozoan ectoprocts, sponges, tunicates) (AMEC 2005). The monitoring sites were positioned on the shoreward fringe of the kelp bed (i.e., the closest location to any

replenishment effort) and were generally composed of rocky reef habitat with some sand. Sand levels remained relatively constant at most sites or were within levels observed prior to the project, suggesting natural variation. AMEC (2005) concluded that changes in sand cover did not appear to affect the distribution and abundance patterns of monitored indicator species.

Sedimentation impacts to hard substrate reefs as a result of beach nourishment projects have been reported for several projects on the southeastern coast of the United States. Courtenay et al. (1972) reported that attached mollusks, algae, and hard corals were killed by suffocation from sediment accumulation; whereas, erect soft corals showed no damage during offshore borrow site dredging off Florida. Stony corals apparently are more sensitive to silt accumulation and turbidity generated during dreging than soft corals and sponges (Marszalek 1980 cited in Naqvi and Pullen 1982). Burial of coral reefs from previous dredge-fill projects off Broward County, Florida was reported by Goreau (2001).

Burial of nearshore hard bottom was reported for beach nourishment projects at Anna Maria Island and Boca Raton, Florida; artificial reefs were required as mitigation for those projects (Coastal Planning & Engineering, Inc. 2004a, b). A subsequent beach nourishment project at Anna Maria Island in 2002 did not indicate any obvious impacts to nearshore hard bottom community from the 1.9 million project during the first two years after construction (Coastal Planning & Engineering, Inc. 2004a). Hard bottom consisted of low relief (<1 to < 2 ft) limestone rock platforms in water depths ≤ 8 ft (≤ m). Seasonal sand inundation of the low relief habitat in the nearshore zone was similar or less than pre-project levels. The ephemeral hard bottom communities were dominated by species that rapidly colonize newly available habitat (e.g., green algae, turf algae, hydroids), and included few invertebrates and fish. Improved visibility and some increases in macroalgae may have contributed to more cryptic invertebrates and fish being observed two years after nourishment compared to pre-project conditions.

Monitoring two years after a recent beach nourishment project at Boca Raton, Florida documented sand burial effects; however, they were attributed to movement of the substantial ebb tide shoal that forms from littoral transport around Boca Raton Inlet rather from the 343,000 cy South Boca Raton Beach Nourishment Project (Coastal Planning & Engineering, Inc. 2004b). Sand inundation occurred to both natural hard bottom low relief and the newly constructed artificial reef, the placement of which was determined to have been too close to the inlet. The hard bottom areas included low relief reef (1 ft) dominated by colonizing turf and coralline algae and higher relief reef (2-3 ft) with a greater diversity of benthic organisms (macroalgae, sponges, tunicates, octocorals) and fish.

No sedimentation impacts to patch reefs (depths of 35 to 70 ft) attributed to borrow site excavation or placement of 500,000 cy from the Central Boca Raton Beach Nourishment Project were noted during and immediately post project compared to pre-project conditions (Coastal Planning and Engineering 2004c). Patch reefs ranged from low (~ 1 ft) to moderate (~ 3 ft) relief, with greater occurrence of scleractinian corals associated with higher relief. Patch reefs were subject to consistent presence of sediment both before and after construction, with no apparent trend relative to project activities. .

<u>Turbidity</u>

No specific information on the response of rocky subtidal invertebrates to suspended solids concentrations from beach nourishment activities is available. Suspended solids have the

potential to interfere with feeding and respiration of invertebrates. Field studies show that reduced invertebrate species assemblages may result in areas where vegetation is reduced by chronic turbidity and sedimentation (e.g., Pondella et al. 1996).

American lobster (*Homarus americanus*) and spiny lobster (*Panulirus argus)* are sensitive to sedimentation of thier habitat (Section 4.2.2). However, exposure to concentrations of 50,000 mg/L was tolerated by adult American lobsters for 25 days without mortality; juveniles tolerated concentrations up to 20,000 mg/L (Peddicord and McFarland 1978). No apparent response to concentrations of 360 mg/L (natural sediment) was observed for rock lobster (*Jasus edwardsii*) (Perry 1999).

Courtenay et al. (1972) reported temporary movement of motile invertebrates (lobsters, crabs, shrimps) from a hard bottom area in the vicinity of offshore dredging off Hallandale, Florida with some species of invertebrates absent from the area for 9 months.

Recovery from Disturbance:

Recovery rates of a disturbed patch within hard bottom habitat will depend on life history attributes of surrounding species. For example, recovery from small-scale disturbance may occur rapidly (e.g., weeks or months) if dominant organisms include short-lived opportunists and/or colonial species (Lissner et al. 1991). Generally, recovery rates are slower if dominant species include long-lived, solitary forms. Recovery of coral reefs may take 8 to 10 years to re-establish long-lived species (reviewed in Newell et al. 1998). Turbidity effects generally would be limited to the construction period, but actual exposure duration would vary depending on project- and site specific conditions. No significant impacts would be expected unless prolonged turbidity resulted in a decline in vegetation. Recovery rates of marine vegetation may be fairly rapid once water quality improves.

	Recovery Rates				
Impact	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	X			X	
Burial	X	X	X		
Sedimentation	X	X	X		
Turbidity	X			X	
Habitat Loss			X		

Critical Impact Thresholds:

No critical impact thresholds ahve been established for rocky subtidal invertebrates.

Data Gaps:

Limited information is available on recovery rates from sedimentation and prolonged turbidity. Burial of reefs with sensitive resources and/or substantial inundation that resulted in lost habitat functions (e.g., shelter, occupied space) would be of ecological concern.

Restoration:

It is technically feasible to restore rocky subtidal habitat (Section 3.3.5).

Summary:

Impacts from sediment management activities on sensitive rocky subtidal habitat have been documented. However, similar to the discussion for rocky intertidal invertebrates (see Section 4.2.8), the nature of concern varies depending on the site-specific nature of rocky subtidal habitat, which may range from ecologically rich to depauperate depending on substrate characteristics. Concerns primarily relate to rocky subtidal areas with diverse species assemblages and ecological functions (Section 3.3.5).

Laboratory and indirect field studies indicate rocky subtidal invertebrates are relatively tolerant of turbidity. Turbidity associated with sediment management activities generally is limited to the period of construction, ranging from days to months. No adverse impacts to invertebrates would be expected from short-term exposures to turbidity. No significant impacts would be expected unless prolonged turbidity resulted in reduction in marine vegetation.

Sand inundation and scour can substantially modify species assemblages, causing displacement of some mobile species and dominance by opportunistic, sand-tolerant, and/or sand-loving species. This disturbance naturally affects rocky subtidal habitats to varying degrees throughout California on a seasonal basis. Lower relief reefs are more vulnerable to sand disturbance, while higher relief reefs tend to remain above the sand. Impact concerns relate to the potential for indirect sedimentation occurring above natural levels and adversely impacting sensitive rocky subtidal habitat and resources.

Sand burial and sedimentation have been documented for some beach nourishment projects on the East Coast of the United States. Nelson (1989) made a case for caution when conducting beach nourishment in proximity to hard bottom habitats in Florida because of their ecological productivity and the unknown specific effects of borrow area dredging and fill placement on the vast majority of hard bottom flora and fauna. That caution also is relevant to productive nearshore reefs in California.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on rocky subtidal invertebrates.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Documented	Documented	Documented	Documented
Critical Impact Thresholds	NA	Rocks overturned Mortality	Burial of attachment substrate, habitat loss	Burial of attachment substrate, loss of algal food base	Loss of algal food base
Impact Responses	NA	Damage, Mortality	Habitat conversion or burial (partial or complete)	Habitat conversion or burial (partial or complete)	Impaired photosynthesis, feeding, and respiration
Duration of Impacts	NA	Days-months	Months-years	Months-years	Days-months
Potential for Restoration	NA	Unnecessary	Demonstrated feasibility	Demonstrated feasibility	Unnecessary

NA = not applicable

4.3 Review of Fish Species Responses to Natural Disturbance and Sediment Management Activities

4.3.1 California Grunion

Photo credit: Doug Martin
www.grunion.org

Habitat and/or Species:

Species Scientific Name	***Leuresthes tenuis***

Regulatory Status:

Endangered	
Threatened	
CDFG Managed	Species of Concern

Distribution:

California grunion is found from San Francisco Bay to southern Baja California but is most abundant south of Point Conception (Love 1996). Grunion is a pelagic, schooling fish that generally occurs from just beyond the surf line to a depth of approximately 60 ft (20 m) off sandy beaches. Marking experiments indicate that they are non-migratory (Gregory 2001).

Grunion appear to be attracted to areas of freshwater outlets, including storm drains, creeks, and river mouths (Martin 2006).

Life Stage and/or Function	California			On Land	Intertidal	Nearshore < 30 feet	Offshore > 30 feet	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X		X	X	X	E, P
Juvenile	X	X	X			X	X	E, P
Egg	X	X			X			E, P
Primary Habitat	X				X	X	X	E, P
Foraging Habitat	X	X	X			X	X	E, P
Spawning Habitat	X	X			X			E, P

Potential Functions:

Grunion feed on small planktonic organisms (Gregory 2001). Grunion, in turn, are prey for larger fishes, birds such as terns (including California least tern) and cormorants, dolphins, seals and sea lions, and squid (Love 1996, Gregory 2001, Martin 2006). Spawning grunion also may be eaten by birds herons, egrets, and other shorebirds when they are on shore (Griem 2000, Martin 2006). Grunion eggs are preyed upon by shorebirds, various invertebrates (worms, insects), and ground squirrels (Martin 2006).

A recreational fishery for grunion occurs during spawning runs during March and June through August. The fishing season is closed in April and May ((http://www.CDFG.ca.gov/ mrd/gruschd.html). Grunion may be taken only by hand, no equipment may be used.

Associated Species	Forage/ Prey	Eaten By
Plankton	X	
Invertebrates		X
Fish		X
Birds		X
Vegetation		
Marine Mammals		X
Terrestrial Animals		X
Humans		X

Life History Facts:

California grunion emerge from the ocean to spawn on beaches of southern California (Griem and Martin 2000). The spawning season begins between late February and early March and may extend through early September (Fritzsche et al. 1985, Martin 2006). Grunion typically spawn between March and August, with peak spawning in April through June (Martin 2006, http://arachnid.pepperdine. edu/grunion/). Grunion may spawn on any or all of the 4 to 5 nights following full and new moons, beginning a little after high tide and may be brief or last an hour or more (Gregory 2001, Martin 2006). CDFG makes available each year the predicted grunion runs from March through August (http://www.CDFG.ca.gov/ mrd/gruschd.html).

During spawning, grunion swim as far up the beach as possible on the breaking wave. The female excavates the semi-fluid sand with her tail and buries herself into the sand up to her pectoral fins. Up to 8 males attempt to mate with her by curving around her and releasing their milt as she deposits her eggs a few inches below the surface. Sand from receding waves covers the eggs to a depth of 6 to 8 in (15 to 20 cm) over the next several days (Smyder and Martin 2002); although Fritzsche et al. (1985) reported burial depths up to 18 in (46 cm). Sand-burial protects the eggs from dessication, temperature extremes and aquatic predation (Middaugh et al. 1983 cited in Speer-Bank and Martin 2004).

Grunion eggs
Photo credit: Andrew Stains

The eggs incubate in the sand about 10 days until the next tide series high enough to reach them, but can extend incubation and delay hatching an additional four weeks if waves do not reach them (Martin 1999, Griem and Martin 2000, Smyder and Martin 2002). Mechanical agitation by wave action is the environmental trigger for hatching in California grunion (Griem and Martin 2000).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Spawn	Late February to early September	Spawn at 1 year old	N/A	Non-migratory	2 to 4 years	Mobile

Beach slope and substrate characteristics apparently are important factors to habitat suitability for grunion spawning. Martin and Swiderski (2001) reviewed that eggs are depoited high in the intertidal of sandy beaches for better drainage and oxygen availability, diffusion of oxygen is insufficient underwater to support survival of grunion eggs, and sandy

sediments permit more gas exchange than fine sediment. They also reviewed that additional data are needed to understand physiological tolerances of eggs with respect to spawning substrates.

A grunion grows relatively fast and is about 5 in (13 cm) long and ready to spawn when approximately one year old (Gregory 2001). Individual adult grunion may spawn 6 to 8 times during the spawning season (Friitzsche et al. 1985, Gregory 2001). The normal life span is 2 to 3 years, but individuals up to 4 years old have been found. Marking studies indicate that grunion is a non-migratory species (Gregory 2001).

Adaptations and/or Behaviors to Disturbance:

A grunion responds to predators or other disturbance by swimming away. Their schooling behavior also helps to protect individual fish from predation. By laying their eggs on sand beaches, the eggs avoid planktonic predators. Presumably, the eggs receive some protection by being buried, but they still are vulnerable to predation by shorebirds and intertidal and terrestrial invertebrates (Gregory 2001).

Juvenile California grunion are attracted to artificial light as bright as 10,000 lux (Reynolds et al. 1977 cited in Fritzsche et al. 1985).

Life Stage	Behavior			Habitat	High Reproductive Output
	Swim	School	Spawning runs		
Adult	X	X	X	Lay eggs in sand	
Juvenile	X	X			
Egg/ Larvae					X

Potential Impacts from Sediment Management Activities:

Primary concerns regarding impacts to grunion are that beach nourishment will disturb, bury, and/or otherwise adversely affect spawning success. Adverese impacts also may occur from turbidity during dredging activities.

Types of sediment management activities and potential impacts to California grunion may include:

- Maintenance dredging of embayments – turbidity.
- Offshore borrow site dredging – turbidity.
- Nearshore placement – turbidity.
- Profile placement – equipment damage, burial, sedimentation, turbidity.
- Beach placement – equipment damage, burial, sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging	X	X			X	
Growth						
Habitat				X		X
Reproduction			X	X		
Respiration					X	

Equipment

Sand-moving equipment has the potential to dislodge or crush buried grunion eggs. In addition, if beach nourishment activities take place at night, the lights may discourage grunion from coming ashore on the beach. However, grunions have been documented to spawn near beach disposal operations (Chambers Group 2001a, USACE 1998a). If beach nourishment activities include grooming of the nourished beach, grunion eggs could be damaged. Martin (2002) has found that beach grooming damages grunion eggs. Beach grooming is a beach management rather than a sediment management activity.

Projects have been restricted to outside the grunion spawning season (e.g., September to March) to avoid impacts (USACE 1993, 1994, 1998a, 1998b, 2000, 2002; Chambers Group 1992, 2000, 2001). To minimize impacts to grunion a diked, single-point disposal site may be used (USACE 2001). This method of sand placement limits impacts to a single section of beach, with no impacts to the rest of the beach. Monitors also have been used to determine potential suitability of receiver sites for grunion spawning, and redirecting sediment management activities from spawning areas as necessary to avoid significant impacts (EDAW 2002).

The U.S. Army Corps of Engineers monitored grunion between 1993 and 1997 during March through April dredging and surf zone disposal in Santa Barbara Harbor (USACE 1998a). Statistical analysis of the grunion data indicated that March-April dredging and single point surf zone disposal did not significantly affect grunion. However, all of the dredging and disposal operations occurred early in the spawning season when grunion spawning densities were low. No dredging occurred in May and June when a much greater number of grunion spawned. There was no significant difference in egg pod diameter, depth, or location between dredging and non-dredging periods. The USACE notes that it was possible differences would have been found if spawning densities were higher, but also noted that grunion were observed spawning in "good numbers" within 98 ft (30 m) of the discharge pipe during a 1978 study in Ventura.

Beach placement was conducted on beaches throughout San Diego County by the SANDAG Regional Beach Sand Project. Prior to beach construction beaches were surveyed to determine which beaches had a potential to support grunion spawning (EDAW in AMEC 2002). Those beaches with spawning potential were monitored during predicted grunion runs up to two weeks prior and during beach nourishment. At beaches where significant spawning (thousands of fish) were observed the project footprint was moved to

avoid the spawning areas; no alteration of project footprint occurred when a few to a few hundred grunion were observed. EDAW (2002) reported that significant impacts to grunion were prevented with this measure.

Insufficient information is available on potential effects of night-time beach nourishment operations on grunion spawning. Relevant reports indicate juvenile grunions are attracted to artificial lighting (Reynolds et al. 1977 cited in Fritzsche et al. 1985). Anecdotal observations during adult spawning runs are inconclusive. Artificial lighting at Kellogg Park and at Scripps Pier, San Diego County were reported as reducing the number of grunion that use those stretches of beach as spawning sites (SWRCB 1979). A public education webpage by CDFG reports that lights may scare fish from coming out of water (http://www.CDFG.ca.gov/mrd/grnindx3.html). However, grunion runs have been observed on beaches adjacent to piers with overhead lights (D. Heilprin, fisheries biologist, personal communication).

Noises from dredges are within ranges that could disturb fish (Hastings and Popper 2005); however, noise disturbance effects may be localized (5.3.2.6).

Burial/Sedimentation

Placement of sand on the beach has the potential to bury grunion eggs too deeply for them to hatch if there is direct burial. However, other placement techniques in the surf zone do not appear to result in excess sedimentation. Monitoring of grunion spawning during March-April dredging and surf zone disposal in Santa Barbara Harbor showed no significant difference in egg pod diameter, depth, or location between dredging and non-dredging periods (USACE 1998a). Discharge of sediment to the surf zone did not result in excess sand deposition burial of grunion eggs.

Beach nourishment may be beneficial for grunion because it provides sandy beach for their spawning activities. MEC (2000a) demonstrated that prior to the 2001 beach Diego Regional Beach Sand Project, many of the receiver beaches either had unsuitable habitat (cobble) for grunion or only were suitable part of the year; i.e., sand depths seasonal eroded to inches (cm). SAIC (2006) reexamined three of the receiver sites 2 to 4 years later and found upper intertidal sand depths did not seasonally erode to less than 1 ft (0.3 m); thereby, extending potential habitat suitability across the grunion spawning season. SAIC also observed that two downcurrent beaches received secondary benefit from the movement of sand placed on receiver beaches, and that potential grunion habitat (as measured by sand depth and beach width) also improved on these beaches. Grunion eggs found at two of the sites during surveys for invertebrates confirmed suitability for spawning, but were not the focus of survey effort.

There apparently is little delay in habitat suitability for spawning after beach nourishment. Parr et al. (1978) documented grunion spawning within one month of beach placement of 1,000,620 cy at Imperial Beach, California.

Substrate compatibility is an important consideration for grunion egg incubation. Fine sediments that blocked interstitial spaces in sand could prevent adequate oxygenation of eggs; however, insufficient information is available on physiological response of eggs with respect to spawning substrates (Martin and Swiderski 2001).

Beach slope also may be an important factor to habitat suitability for grunion spawning. Grunion do not spawn on very steep beaches; however, information is limited with respect to beach slope (K. Martin, 2007 personal communication). Beach slope must be sufficient so that grunion eggs do not remain saturated, which reduces oxygen availability and survival (Martin and Swiderski 2001).

Turbidity

Grunion in the water column may be impacted by turbid plumes associated with beach nourishment activities. No information is available on the direct impacts of turbidity on grunion. However, there are studies of turbidity impacts to related planktivorous, water column fishes. Wilber and Clarke (2001) cite data that showed the feeding rate of silversides (same family as grunion) were reduced at high turbidity concentrations (120 NTU) and that reaction distance to prey was reduced at turbidity as low as 28 NTU. Laboratory studies of response of Atlantic silversides to suspensions of Fuller's earth over a 24-hour period found mortality rates increased with increasing concentration, as follows: 10% at 58 mg/L, 50% at 250 mg/L, and 90% at 1,000 mg/L (Sherk et al. 1975 cited in Berry et al. 2003). Sherk et al. (1975) tested several types of fish and ranked them based on their response as tolerant, sensitive, or highly sensitive: Atlantic silversides were considered hightly sensitive.

There is some evidence suggesting that small, schooling water column fishes may avoid turbid discharges. Northern anchovy were observed to move away from the discharge area in response to sediment disposal at the Alcatraz Dredged Material Disposal Site in San Francisco Bay, but returned to the site within an hour or two after the disposal event (O'Conner 1991). Sherk et al. (1975) classified bay anchovy as sensitive to turbidity.

Grunion monitoring during dredging and surf zone disposal in Santa Barbara Harbor did not find any correlation between turbidity and egg deposition either during or after dredging, even though turbidity was significantly higher during dredging (USACE 1998a). That report also referenced a 1978 study at Ventura, where grunion were observed spawning in "good numbers" within 98 ft (30 m) of the discharge pipe (cited SCMI 1997). The USACE (1998a) noted however that the studies were conducted early in the season (March and April) when grunion densities were low and cautioned that results may not be the same if spawning densities were higher.

Grunion monitoring in Santa Barbara documented a run that occurred during elevated turbidity levels caused by higher discharge rates from Mission Creek following a rain storm (USACE 1993).

Available information suggests that grunion behavior is not altered by turbidity levels of similar magnitude as those under storm conditions. Relevant reports of other silverside species suggest that grunion are sensitive to elevated turbidity, experiencing reduced feeding efficiency, and would be expected to move from turbid plumes. However, there also is limited data suggesting that grunion spawn on beaches during beach nourishment operations.

Recovery from Disturbance:

Monitoring studies indicate that there is no delay in suitability of sandy beach substrate for grunion spawning after beach nourishment. Turbidity effects generally would be limited to

the construction period, but actual exposure duration would vary depending on project- and site specific conditions.

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	After cessation of activities				
Burial	After cessation of activities				
Sedimentation					X
Turbidity	After cessation of activities				
Habitat Loss					X

Critical Impact Thresholds:

No critical impact thresholds for grunion have been documented.

Data Gaps:

It would be useful to have specific information regarding grunion response to turbidity.

Restoration:

Because adverse impacts of beach nourishment to grunion are expected to be short-term and long-term impacts are beneficial, no restoration is expected to be necessary.

Summary:

Although no documentation was found of actual damage to grunion eggs from beach nourishment activities, there is the potential that the movement of sand on the beach by heavy equipment could dislodge grunion eggs or harm them by crushing them. Direct burial also could be detrimental.

Turbidity plumes have the potential to reduce the feeding efficiency of water- column fishes such as grunion, which may be sensitive based on relevant reports for a related species. However, grunion may not be as sensitivity to turbidity during spawning. Turbidity effects are expected to be short-term for individual fish; however, turbidity effects will influence an area until in-water construction activities cease. Two studies reported spawning during beach nourishment and another reported spawning after a storm when elevated turbidity was observed. This suggests that grunion will not avoid a beach undergoing nourishment and therefore are vulnerable to potential impacts.

Habitat suitability for spawning may vary seasonally associated with natural erosion and accretion cycles. On erosive beaches, habitat suitability may span fewer months than the grunion spawning season. Beach nourishment was found to extend habitat suitability across the spawning season at several sites after the 2001 San Diego Regional Beach Sand Project. Thus, beach nourishment may benefit California grunion by creating or expanding sandy beach spawning habitat.

Substrate compatibility is an important consideration for habitat suitability. Fine sediments can block interstitial spaces in sand and prevent adequate oxygenation of eggs. However, critical impact thresholds with respect to substrate characteristics are unknown.

Beach slope also may be an important factor to habitat suitability for grunion spawning. Steep slopes or scarps may inhibit spawning and/or limit egg survival. Narrow beach width and/or slopes that are too flat could result in egg wash out or saturation, which can limit survival. Limited information is available on the relationship between beach slope and grunion habitat suitability.

Impacts to grunion have been avoided by limiting beach nourishment activities to the non-spawning season of October through February. Projects conducted during the spawning season have confined operations to a single diked area with surf zone discharge to limit impacts to a small area and avoid the upper intertidal spawning habitat. Monitoring also has been used to identify spawning activity and adjust the project footprint to minimize impact by avoiding areas where grunion are concentrated.

Grunion may be affected by noise, artificial lights, and turbidity during dredging activities. No information is available on the counteracting effects of light and noise on water column fish during nighttime dredging operations. Although no specific data are available for grunion, other species within the same family are considered sensitive to turbidity, displaying reduced feeding rates and/or mortality at moderate concentrations.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on California grunion.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	Documented	Relevant reports	Protective conservatism	Protective conservatism	Relevant reports
Critical Impact Thresholds	NA	Removal or damage to eggs	Burial of eggs, incompatible substrate	Incompatible substrate	Impair spawning
Impact Responses	Enhance habitat	Eggs may be dislodged or harmed	Eggs may be buried too deep to hatch	NA, unless substrate change	Avoidance, impair feeding, sublethal to lethal effects at high levels
Duration of Impacts	Months-years	One or more spawning cycles of 15 days	One or more spawning cycles of 15 days	Months-years	Minutes-months
Potential for Restoration	Unnecessary	Unnecessary	Unnecessary	Unnecessary	Unnecessary

NA = not applicable

4.3.2 Pacific Herring

Species Scientific Name	***Clupea pallasi***

Regulatory Status:

Endangered	
Threatened	
CDFG Managed	X

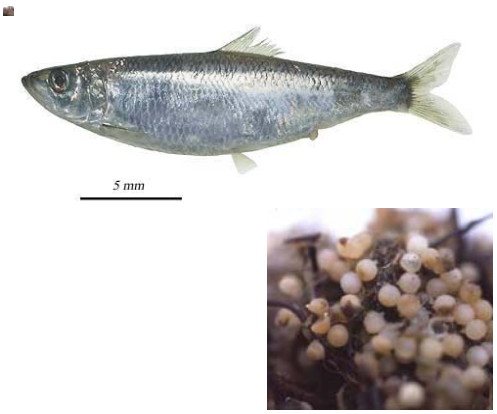


Photo credit: Warren E. Savary and Luis A. Solorzano, californiabiota.com

Distribution:

Pacific herring occur within the coastal zone from Baja California to Alaska and across the Pacific rim to Japan and China (Watters et al. 2001). Most of a herring's life is spent along the open coast, but they spawn in bays and estuaries, returning to the same area to spawn every year (Love 1996). During the November to March spawning season, schools of herrings enter bays and estuaries where they may remain up to three weeks before spawning. Known herring spawning areas in California include San Diego Bay, the San Luis River, Morro Bay, Elkhorn Slough, San Francisco Bay, Tomales Bay, Bodega Bay, the Russian River, the Noyo River, Shelter Cove, Humboldt Bay, and Crescent City Harbor (Barnhart 1988, Watters et al. 2001). San Francisco Bay supports the largest Pacific herring spawning population (Love 1996, Watters 2001).

Most spawning occurs at night in very shallow (usually less than 30 feet), sometimes intertidal, waters (Watters et al. 1996, Love 1996). The sticky eggs attach to suitable substrate, including marine vegetation such as eelgrass, rocks, pilings, and riprap. In California, adult herring return to sea immediately after spawning (Barnhart 1988). Juveniles may remain in the bay until summer or early fall, when they migrate to the open ocean (Watters et al. 2001).

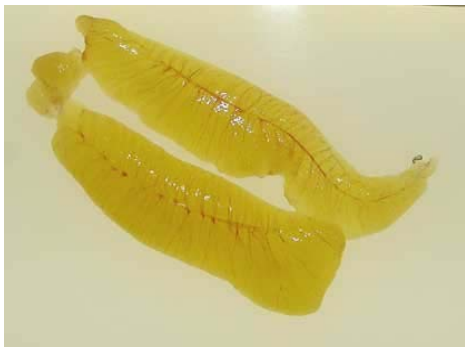
Life Stage and/or Function	California			On Land	Inter-tidal	Nearshore < 30 feet	Offshore > 30 feet	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X		X	X	X	E, P
Juvenile	X	X	X		X	X	X	E, P
Egg	X	X	X		X	X		P
Primary Habitat			X			X	X	E, P
Foraging Habitat	X	X	X		X	X	X	E, P
Nesting/ Spawning Habitat	X	X	X		X	X		P

Potential Functions:

Associated Species	Forage/ Prey	Eaten By
Plankton	X	
Invertebrates		X
Fish	X	X
Birds		X
Vegetation		
Marine Mammals		X
Terrestrial Animals		
Humans		X

Pacific herring are visual predators that eat zooplankton including copepods, amphipods, krill and small fishes (Johnston and Wildish 1982, Love 1996). Herrings, in turn, are eaten by a variety of predators including larger fishes such as salmon, pinnipeds, and dolphins. Herring eggs are eaten by fishes, by invertebrates such as mollusks and amphipods, and by birds including gulls and diving ducks such as scoters (Lassuy 1989, Love 1996, Watters et al. 2001).

There is a commercial fishery for herring roe, which is valuable in Japan (Love 1996). The sac-roe commercial fishery is limited to California's four largest herring spawning areas: San Francisco Bay, Tomales Bay, Humboldt Bay, and Crescent City Harbor (Watters et al. 2001). The four spawning areas are managed separately by the California Department of Fish and Game (http://www.CDFG.ca.gov/mrd/herring/index.html). Most of the roe fishery includes take of herring just before spawning occurs, which may vary from year to year (Spratt 1981). A smaller fishery involves harvest of roe on seaweed after spawning. There also is a small sport fishery for herring by pier and shore anglers (Barnhart 1988, Love 1996).



Herring roe

Photo credit: Luis A. Solorzano, californiabiota.com

In San Francisco Bay, CDFG maintain a Herring Hotline from November through March and provide a recorded message on herring schools and their location, spawning events, and the status of the fishery (http://www.CDFG.ca.gov/mrd/herring/ sf_bay.html).

Life History Facts:

Pacific herring enter bays and estuaries to spawn in early winter (may be as early as October) (Watters et al. 2001). Although spawning may occur from late October through April, most activity takes place December through March and peaks in January–February (Spratt 1981, Love 1996, Watters et al. 2001).

Although winter is the primary spawning season, a smaller June-July spawning peak has been reported in Monterey Bay, Moss Landing Harbor, Elkhorn Slough, and Morro Bay (Wang 1986). Reduced salinity may act as a cue for spawning. When a school is ready to spawn, male herrings release milt, which has a pheromone that triggers spawning by females, which then lay adhesive eggs on suitable substrate (Watters et al. 2001).

Eggs are laid in shallow (nearly intertidal) to deeper waters up to a depth of 60 ft (18 m). Eggs are sticky and may adhere to eelgrass and/or hard substrate. Pacific herring broadcast eggs in eelgrass beds and on rocks, rocky jetties, pilings, other submerged objects, and sandy beaches (Wang 1986). The egg incubation period is about 10 days. Juveniles remain in the bay until summer or early fall when they migrate to the open ocean.

Some herring reach sexual maturity at age 2 when they are about 7 inches in length; all are sexually mature at age 3 (Watters et al. 2001). California herring may live to be 9 or 10 years old and reach a maximum length of 11 inches, although fish older than 7 are rare.

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Spawn	November to March, Peak Jan-Feb	Reach maturity at 2 to 3 years old	N/A	Oct-Mar (adults), summer-fall (juv)	7 to 10 years	Mobile

Pacific herring undertake daily vertical migrations, moving up into the water column at dusk to feed; during the day they gather near the bottom or in mid water schools (Lassuy 1989). They eat zooplankton including copepods, amphipods, krill and small fishes (Love 1996). However, early foods are mostly benthic, including copepods, invertebrate eggs, and diatoms, and juveniles are dependent on on invertebrates that live in eelgrass beds, such as decapod larvae, harpacticoid and calanoid copepods, gammarid amphipods and barnacle larvae (Lassuy 1989 cited Hart 1983 and Levings 1983). Tintinnids (ciliated protozoa) and copepods are primary prey of larval herring in San Francisco Bay (Bollens and Sanders 2004 cited in Ogle 2005). Early feeding is critical to larvae, although newly hatched fish can survive for 6 to 8 days from yolk-sac exhaustion to irreversible starvation (McGurk 1984). If larvae are unable to feed soon after hatching, they may “give up” and die of starvation, which accounts for approximately 18 to 36% mortality of first-feeding larvae in natural populations (McGurk 1984 and Lasker 1985 cited in Lassuy 1989).

Studies indicate hearing and sound production are well developed in herring. Wilson et al. (2003) conducted experiments on Atlantic and Pacific herring demonstrating repetitive production of broadband pulses (1.7 to 22kHz, most above 2 kHz) lasting between 0.6 and 7.6 seconds, which were temed Fast Repetitive Tick (FRT) sounds. They reviewed other studies documenting well developed sound reception capability suggesting hearing may be important to herring (Blaxter and Hunter 1982, Schwarz and Greer 1984, Wislon and Dill 2002). Although the functions of the sound(s) are unknown, it was suggested that social mediation (e.g., contact calls) may be likely. Wilson et al. (2003) reviewed that herring sounds were near or above the known auditory range of most predatory fish (Fay and Simmons 1999), but were well within detection capabilities of marine mammals.

Adaptations and/or Behaviors to Disturbance:

Pacific herring can swim away from disturbances. Laying their eggs on solid substrate protects the eggs from water column predators, but laid eggs, particularly in shallow water, are vulnerable to predation from birds, fishes, and invertebrates.

Life Stage	Behavior			Habitat (Nursery)	High Reproductive Output
	Swim	School	Spawning runs		
Adult	X	X	X		
Juvenile	X	X		X	
Egg/ Larvae				X	X

Potential Impacts from Sediment Management Activities:

Concerns regarding impacts to herring are that turbidity and/or sedimentaion will inhibit spawning, bury spawning substrate and/or eggs, reduce the viability of eggs, and/or interfere with feeding (USACE et al. 2001). Most of these impacts are associated with dredging in bays and estuaries where spawning occurs. Potential beach nourishment impact concerns would be limited to potential turbidity effects.

Types of sediment management activities and potential impacts may include:

- Maintenance dredging of embayments – equipment damage, sedimentation, turbidity.
- Offshore borrow site dredging – turbidity.
- Nearshore placement –turbidity.
- Profile placement – turbidity.
- Beach placement – turbidity.
- Dune placement – not applicable

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging	X	X			X	
Growth						
Habitat			X			X
Reproduction			X	X		X
Respiration					X	

Equipment

Spawning grounds of Pacific herring are vulnerable to impacts from dredging in bays and estuaries. Herring lay eggs on any type of hard substrate, including eelgrass. Eelgrass represents an important nursery area for herrings, and is vulnerable to dredging impacts in embayments.

Herring may be more vulnerable to dredge entrainment during the day than night based on their vertical migration behavior. Dredge entrainment rate with hopper dredging was measured as 0.008 fish per cy (Larson and Moehl 1990 cited in Reine and Clarke 2001).

LFR (2004) reported that Pacific and Atlantic herring exhibit “startle” or “start” response to noise stimuli. Noises from dredges are within ranges that could disturb fish (Hastings and Popper 2005). However, most sounds produced by Pacific herring for social mediation (Wilson et al. 2003) are above the upper frequency range (20 Hz to 2 kHz) associated with

dredging activities (Reine et al. 1998). Noise disturbance would be expected to be limited to close to dredging activities (Section 5.3.2.6).

Pacific herring may experience increased loss from predation during nighttime dredging operations, if attracted by lights. A relevant report by Nightengale and Simenstad (2002) stated that lights attracted juvenile herring and lances, which were reduced in abundance by attraction of their predators. However, no information is available on the possible counteracting effects of light attraction and noise displacement associated with nighttime dredging operations.

Burial/Sedimentation

Spawning habitat and laid eggs would be vulnerable to dredging and/or in-bay disposal in bays and estuaries, if such activities occurred in or in close proximity to spawning areas during the spawning season, which varies somewhat along the coast (generally November to March) (Watters et al. 2001). Presence of sediment and/or silt on potential spawning substrate may inhibit herring spawning on that substrate (Stacy and Hourston 1982 cited in Barnhart 1988, Lassuy 1989, and Ogle 2005). Once the eggs are laid, if excess sediment settles on them it may inhibit respiratory exchange and subsequent development (Barnhart 1988). Laboratory experiments on Atlantic herring showed reduced egg hatching on glass slides coated with sediment and 100% mortality when eggs attached to slides were buried with 1 cm of sediment (Messieh et al. 1981).

Turbidity

Turbidity generated during dredging, in-bay disposal, and/or beach nourishment has the potential to affect Pacific herring if in the vicinity of sediment management activities. Concern has been expressed about unknown effects of dredging-related turbidity on adults approaching spawning sites, juvenile avoidance response, foraging, and all life stages in general (LFR 2004). It is unknown to what extent turbidity may interfere with behavior of Pacific herring and potential approach of spawning areas (LFR 2004).

Ogle (2005) reviewed that no studies of Pacific herring avoidance behavior have been conducted; however, Atlantic herring have displayed avoidance response at concentrations as low as 9 to 12 mg/L (Johnston and Wildish 1981). He also reviewed an experimental study by Hays (1986), who prevented adults from spawning over different time intervals, and then allowed them to spawn; it was reported that delays in spawning of up to two weeks had no affect on fertilization, embryo survival, or hatching succes. Ogle (2005) interpreted the results of these studies as suggesting that temporary delays in spawning caused by avoidance should not be expected to adversely affect reproductive success.

Because Pacific herring feed on plankton they require less distance to react to prey. Studies of reactions of other water column fish species to turbidity suggest that planktivores are less likely to suffer reduced feeding efficiency from turbidity than piscivores (De Robertis et al. 2003). It also has been suggested that turbidity may offer some protection for planktivores from predation by predators requiring greater reaction distance to prey (e.g., predatory fish, marine mammals, and birds) (De Robertis et al. 2003).

Laboratory studies of 10 and 22-day old Pacific herring larvae showed enhanced feeding rates and prey consumption at 2-hour exposures of 500 mg/L, and gradual declines in

organisms consumed at concentrations ranging from 1,000 to 8,000 mg/L (Boehlert and Morgan 1985 cited in Ogle 2005) (Table 4.3-1). Laboratoy studies on larval Atlantic herring showed lower thresholds with enhanced feeding up to 35 JTU, and reduced feeding at 80 JTU (Utne-Palm 2004). Johnston and Wildish (1982) showed reduced prey consumption in Atlantic herring at 20 mg/L.

Ogle (2005) indicated that temporary dredging-related suspended sediments would not be expeced to adversely affect larval survival of Pacific herring since larvae can go up to 6 to 8 days before yolk-sac exhaustion (cited McGurk 1984), and larval feeding may be enhanced (Boehlert and Morgan 1985). However, he also noted the conflicting results of Johnston and Wildish (1982), and suggested that additional study was warranted.

Laboratory studies have demonstrated reduced egg hatching and larval survival of Pacific herring at 1,000 to 2,000 mg/L and complete hatching failure at ≥ 4,000 mg/L using estuarine sediments or volcanic ash with pulsed-static tests (suspensions renewed every 72 hours) lasting 9 days (Boehlert et al. 1983) (Table 4.3-1). In a second test where sediments were kept in suspension, no adverse effects were seen at any of the tested concentrations between 500 and 8,000 mg/L (*ibid.).*

Reduced hatching was seen at 10,000 mg/L, but reduced survival was observed at 500 mg/L over a 4 day test for sediments that were later found to have elevated levels of cadmium (Morgan and Levings cited in Ogle 2005). Shorter duration tests (24 hours) showed epidermal damage at concentrations ≥ 4,000 mg/L, which was considered sufficient to have resulted in mortality with longer exposure (Boehlert 1984). Experiments with Atlantic herring showed similar results, with no apparent effect on egg hatching and larval survival at concentrations ranging from 5 to 700 mg/L over 11 to 14 days, and reduced survival at ≥ 6,000 mg/L over 15 days (Kiorboe et al. 1981, Messieh et al. 1981).

The above reviewed data suggest that early life stages of Pacific herring may be sensitive to turbidity. Reduced larval survival has been reported between 500 and 1,000 mg/L. At concentrations at or below 500 mg/L, larval feeding may be enhanced or reduced. It has been suggested that moderate turbidity may provide some protection of larvae from visual predators. Adult and possibly juvenile Pacific herring may display avoidance behaviors to turbidity based on limited available information for Atlantic herring. Although Ogle (2005) was accurate in his reference to yolk-sac reserves, early feeding is considered critical to survival of first-feeding larvae (McGurk 1984 and Lasker 1985 cited in Lassuy 1989).

Little is known regarding effects of turbidity on juveniles and adults, although mortality of more mobile life stages would not be expected. The potential for turbidity to affect adult movements relative to approach of spawning sites is unknown. Different experimental designs and sometimes conflicting results regarding effects concentrations for early life stages of Pacific and Atlantic herring suggest additional study of turbidity effects is warranted.

Table 4.3-1. Reported responses of herring to suspended sediments.

Species	Life Stage	Concentration (mg/L), Type of Sediment	Exposure	Sublethal	Lethal	Reference
Pacific Herring West Coast	Larvae	500-8,000 Estuarine	24 hours (2 hr pulses)	Epidermal damage ≥4,000	Likely at longer duration	Boehlert 1984
	Larvae Feeding (a) 10-d- and (b) 22-d larvae	a)500 to 8,000 Estuarine, Volcanic	2 hours static/15 min stir	Enhanced at 500, Reduced 1,000-8,000	None	Boehlert and Morgan 1985[1]
		b)500 to 8,000 Estuarine, Volcanic	2 hours	Enhanced at 500, Reduced 1,000-8,000	None	
	Egg Hatching, Larvae Survival	500-10,000 Contaminated sediment	to 96 hours post-hatch	3-day delay at 10,000	Reduced hatching 10,000, Reduced survival ≥ 500	Morgan and Levings 1989[1]
		500-8,000 Estuarine, Volcanic Ash	9 days static/72 hr renewal		Reduced hatching ≥ 1,000	Boehlert 1983[1]
			8-9 days		None	
Atlantic herring East Coast	Larvae Feeding	4-20 Estuarine	3 hours	Reduced at 20	None	Johnston and Wildish 1982
		0-80 JTU Diatomaceous earth		Enhanced to 35 JTU, Reduced at 80 JTU	None	Utne-Palm 2004[1]
	Egg Hatching	Egg layers on slides			100% subsurface eggs	Messieh et al. 1981[1]
		Slides coated with sediment			Reduced	Messieh et al. 1981[1]
	Egg Hatching, Larvae Survival	5-300 Estuarine	11 days	None	None	Kiorboe et al. 1981[1]
		500 Estuarine	11 days	None	None	Kiorboe et al. 1981[1]
		10-7,300 Fine grained	15 days	Delayed hatch time, Reduced fish length at 7,300	None	Messieh et al. 1981[1]
		700-19,000 Fine grained	14 days 48 hr renewals		Reduced at 6,000, 100% at 19,000	Messieh et al. 1981[1]
	Egg Hatching	1 cm burial			100%	Messieh et al. 1981[1]
Blueback herring East Coast Freshwater	Egg Hatching	50-5,000	Not stated	None	None	Auld and Schubel 1978[2]

[1] – Cited in Pacific EcoRisk 2005, [2] Cited in LaSalle et al. 1991

Recovery from Disturbance:

Most equipment-related disturbance effects would end with cessation of dredging activities.

Turbidity effects generally would be limited to the construction period, but actual exposure duration would vary depending on project- and site specific conditions. It is unknown to what extent turbidity may interfere with behavior of Pacific herring and potential approach of spawning areas (LFR 2004). Ogle (2005) reviewed that delays in spawning up to two weeks had no detrimental effects on fertilization, embryo development, or hatching (cited Hays 1986). Therefore, impacts would not be expected to span more than one season. Avoidance of turbid areas or enhancement and/or interference with feeding would be expected to last as long as the turbidity plume. Pacific herring larvae may exhibit reduced survival if exposed to high suspended sediment concentrations. Turbidity effects would depend on magnitude of effect, and could range from no effects, displacement, to sublethal or lethal effects depending on concentration.

Direct burial of spawning habitat would not occur. Sedimentation impacts that made an area unsuitable for spawning would be detrimental, and recovery would depend on magnitude of effect. Generall, impact would not be expected to last more than a season unless there was loss of attachment substrate such as eelgrass. Loss of eelgrass habitat from dredging could take years to recover (see Section 3.3.8).

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	After cessation of activities		If eelgrass loss		
Burial					X
Sedimentation	X	If eelgrass degraded	If eelgrass loss		
Turbidity	After cessation of activities			X	
Spawning Habitat Loss		If eelgrass degraded	If eelgrass loss		

Critical Impact Thresholds:

Turbidity levels of concern for larvae may range between 500 to 1,000 mg/L; however additional study is warranted since effects data is primarily based on non-native sediment and no information is available for juveniles and adults.

Data Gaps:

The relationship between turbidity and herring foraging is not well understood (Ogle 2005), but potentially important to survival of early life stages (Lassuy 1989). Because of the conflicting nature of available experimental studies, additional study is warranted.

The effects of turbidity on adult Pacific herring approaching a spawning area and/or on juvenile and larval herring are unknown. Studies to examine this subject were identified as

priorities to increase effectiveness of protective dredging measures in San Francisco Bay (LFR 2004).

Reports indicate sedimentation can adversely affect habitat suitability for spawning and may be detrimental to early life stages (Messieh et al. 1981, Barnhart 1988, Lassuy 1989). Additional data on sedimentation effects could be useful for developing critical impact thresholds. Field characterization of sedimentation gradients associated with dredging activities using different equipment under different environmental conditions could be particularly useful for developing appropriate buffer distances from spawning areas. Laboratory studies, field experiements, and/or characterization of suspended sediment plumes during dredging outside the spawning season and ambient conditions during Pacific herring spawning season have been recommended to increase effectiveness of protective dredging measures in San Francisco Bay (LFR 2004).

Pacific herring spawn on virtually any type of hard substrate to depths of 60 ft (18 m), although depths < 30 ft (9 m) are more common. Spawning areas associated with eelgrass beds generally are better known because of port and harbor management plans; however, potential spawning areas in deeper waters may be less well known. Studies to determine the distribution of herring and larvae, and spawning areas deeper than wadeable depths in San Francisco Bay were identified as priorities to increase effectiveness of protective dredging measures in San Francisco Bay (LFR 2004).

Restoration:

Dredge removal and/or extensive sedimentation of herring spawning substrate could adversely affect spawning activities. Loss of eelgrass habitat would require replacement mitigation, which would be guided by the Southern California Eelgrass Mitigation Policy (see Section 3.3.8).

Summary:

Although direct damage to herring eggs from sediment management activities has not been documented in the literature, equipment such as dredges and/or anchors within a herring spawning area has the potential to remove and/or damage eggs. Turbidity from dredging also has the potential to result in sediment resuspension and deposition of silt in a spawning area before and/or after dredging, both of which could be detrimental either by reducing suitability of substrate for egg attachment or causing mortality of laid eggs.

Early life stages of Pacific herring may be sensitive to turbidity. Reduced larval survival has been reported between 500 and 1,000 mg/L. At concentrations at or below 500 mg/L, larval feeding may be enhanced or reduced. It has been suggested that moderate turbidity may provide some protection of larvae from visual predators. Adult and possibly juvenile herring may display avoidance behaviors to turbidity based on limited available information for Atlantic herring. Little is known regarding effects of turbidity on juveniles and adults, although mortality of more mobile life stages would not be expected. Turbidity effects are expected to be short-term for individual fish; however, turbidity effects will influence an area until in-water construction activities cease. The potential for turbidity to affect adult movements relative to approach of spawning sites is unknown. Different experimental designs and sometimes conflicting results regarding effects concentrations for Pacific and Atlantic herring suggest additional study of turbidity effects is warranted.

Pacific herring may be disturbed by noises produced by dredging activities (Section 5.3.2.6); however, noise freqeuencies are below the frequency range of most sounds produced for social mediation (Reine et al. 1998, Wilson et al. 2003). Pacific herring may be attracted to lights associated with nighttime dredging operations, which could result in loss due to predation. No information is available on the counteracting effects of light and noise on Pacific herring during nighttime dredging operations.

Potential impacts to Pacific herring from dredging activites is avoided with environmental windows, which range from November 1 to March 1 along the north coast and from December 1 through February 28 in San Francisco Bay (USACE et al. 2001, http://el.erdc.usace.army.mil/tessp/windows.cfm).

If herring spawning substrate such as eelgrass was lost from dredging, eelgrass would require mitigation replacement consistent with the Southen California Eelgrass Mitigaiton Policy (NMFS et al. 2005). The functional value of a restored eelgrass bed as spawning habitat would likely be lower for a couple of years until the bed developed (see Section 3.3.8).

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on Pacific herring.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Documented	NA	Relevant reports	Relevant reports
Critical Impact Thresholds	NA	Loss of nursery eelgrass habitat, substantial entrainment	NA	Loss of eelgrass nursery habitat, sedimentation of eggs	Impair migration, and/or spawning
Impact Responses	NA	Loss and/or damage to eggs or spawning substrate	NA	Habitat unsuitable for egg attachment, mortality early life stages	Attraction or avoidance, impair feeding, sublethal to lethal effects at high levels
Duration of Impacts	NA	Minutes-months	NA	Months-years	Minutes-months
Potential for Restoration	NA	Yes, if eelgrass loss	NA	Yes, if eelgrass loss	Unnecessary

NA = not applicable

4.3.3 Salmonids

Species Scientific Name	**Salmonids**

Juvenile Coho salmon
Photo credit: Danny Heilprin, SAIC

Several species of salmonids occur in California (CDFG 2001). The salmon species that regularly occur along the California coast are Chinook salmon (*Oncorhynchus tshawytscha*), Coho salmon (*Oncorhynchus kisutch*), and steelhead (*Oncorhynchus mykiss*).

Small numbers of cuttthroat trout (*O. clarkii*) occur in northern California streams, lagoons, and estuaries. Sockeye salmon (*O. nerka*), chum salmon (*O. keta*), and pink salmon (*O. gorbushcha*) are much less common. Recovery and/or restoration and management plans are available for Coho salmon and steelhead (http://www.CDFG.ca.gov/nafwb/pubs.html).

Regulatory Status:

Federal Endangered (FE) State Endangered (SE)	Chinook: Winter run – FE, SE Coho: Central California ESU (south of San Francisco Bay) – SE Steelhead: Southern California ESU (coastal basins from Santa Maria River south) – FE
Federal Threatened (FT) State Threatened (ST)	Chinook: Spring run - ST Central Valley ESU (spring run) – FT California coastal ESU (naturally spawned coastal spring and fall Chinook between Redwood Creek and Russian River) – FT Coho: Central California ESU (naturally spawning populations from Punta Gorda and San Lorenzo River) - FT Southern Oregon/California coastal ESU (populations from Punta Gorda north) – FT, ST Steelhead: Northern California ESU (naturally spawned populations residing below impassable barriers in coastal basins from Redwood Creek to Gualala River) - FT Central California Coast ESU (all runs in coastal basins from Russian River to Soquel Creek, excluding Sacramento-San Joaquin River basins) – FT South/central California ESU (all runs in coastal basins from Pajaro River to Santa Maria River) – FT Central Valley ESU (all runs in Sacramento and San Joaquin Rivers and their tributaries) – FT
CDFG Managed	Chinook: Klamath and Trinity ESU (spring run) Central Valley ESU (fall and late-fall runs) Coho: Southern Oregon/California coastal ESU Steelhead: Klamath Mountains Province ESU (summer run) Northern California ESU (summer run) South/central California ESU Southern California ESU

Description and Distribution:

Chinook salmon are distributed along the California coast, but are more common in central and northern California (Moyle 2002). There are four distinct runs of Chinook in California (fall, late-fall, winter and spring), corresponding to the time of years when each of the four stocks migrate upstream to spawn (CDFG 2001). The National Marine Fisheries Service (NMFS) recognizes five Evolutionary Significant Units (ESUs) of Chinook salmon in California, based on genetic and life history similarities (Moyle 2002):

- Southern Oregon and California coastal ESU
- Upper Klamath and Trinity Rivers ESU
- Central Valley fall-run ESU
- Central Valley spring-run ESU
- Sacramento River winter-run ESU

Coho salmon are known to occur in the coastal waters all along the California coast, but are more common in central and northern California (Moyle 2002). There are two Coho salmon ESUs recognized in California by NMFS (CDFG 2001):

- Central California coastal Coho ESU
- Southern Oregon/northern California Coho ESU

Steelhead salmon are known to occur throughout the California coastal waters (Moyle 2002). The NMFS determined six distinct steelhead ESUs in California using genetic and life history data (Moyle 2002):

- Klamath Mountains Province steelhead ESU
- Northern California steelhead ESU
- Central Valley steelhead ESU
- Central California coast steelhead ESU
- South/Central California coast steelhead ESU
- Southern California steelhead ESU

Revised Critical Habitat for Pacific salmon and Steelhead in California was recently designated (NMFS-NOAA 2005). Critical Habitat for California salmonids includes streams all along the California coast as far south as San Juan creek in southern Orange County.

Life Stage and/or Function	California			Inland	Inter-tidal	Nearshore < 30 feet	Offshore > 30 feet	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X			X	X	E, P
Juvenile	X	X	X			X	X	E, P
Primary Habitat	X	X	X			X	X	E, P
Foraging Habitat	X	X	X			X	X	E, P
Spawning Habitat				Rivers				

Functions:

Studies have shown that estuaries are important rearing habitats for salmonids, and eelgrass is an important foraging habitat (Nightingale and Simenstad 2001, LFR 2004). However, only limited inforation is available regarding salmonid use of habitats in embayments. Studies have been proposed to obtain information of salmonid distribution and habitat use paterns in large estuaries such as San Francisco Bay and the Columbia River to improve long-term sediment management strategies in those embayments with respect to appropriate protection of migration and nursery habitat functions for salmonids (e.g., NMFS 2002, LFR 2004).

Associated Species	Forage/ Prey	Eaten By
Invertebrates	X	
Fish	X	X
Birds		X
Vegetation		
Marine Mammals		X
Terrestrial Animals		X
Humans		X

After entering the ocean, juvenile Chinook salmon feed on a variety of small pelagic fish and crustaceans, including crab larvae and amphipods, while larger Chinook feed primarily on pelagic fish (Moyle 2002). Immature Coho salmon feed on pelagic marine invertebrates when they enter the ocean. As they mature, Coho shift their diet to pelagic fish, but crustaceans and pelagic invertebrates are also eaten in some areas (Moyle 2002). When juvenile steelhead salmon enter the ocean, they feed primarily on pelagic invertebrates; adults feed primarily on pelagic fish, but also eat squid and crustaceans (Moyle 2002). Each of the three salmon species will shift their diet seasonally to correspond to the most abundant prey choice available. Salmonids are eaten by larger fishes, birds and marine and terrestrial mammals. They are fished both commercially and recreationally.

Life History Facts:

The seasonal runs of Chinook salmon differ in their timing of migration and spawning. Juveniles also enter the ocean at different times of the year. Chinook spend 2 to 5 years in the ocean before returning to their parent streams to spawn and subsequently die (CDFG 2001). The following describe the life history of each of the four runs of Chinook salmon (CDFG 2001; Moyle 2002):

Fall run
Migration period up the river occurs from June through December and spawning ranges from October through December. Juveniles enter the ocean as smolts between April and July. This is the major run in California.

Late-fall run
Migration period up the river takes place from October through April with spawning occurring between January through April. Juveniles enter the ocean as smolts between November and April.

Winter run
Migration period up rivers occurs from December through August with spawning occurring between April and August. Smolts enter the ocean between December and May. Unlike the other runs that spawn between the ages of 2 and 5, the winter run Chinook mature and spawn as three-year-old fish. This run is unique to the upper Sacramento River.

Spring run

Migration period up rivers takes place between March and September with spawning occurring between late-August and October. The timing of juvenile emigration to the ocean varies.

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg	Spawning Runs: Chinook: Fall: Oct-Dec Late-fall: Jan-Apr Winter: Apr-Aug Spring: late-Aug-Oct Coho: November-February Winter Steelhead: January-June Summer steelhead: winter or spring	Age at Sexual Maturity: Chinook: 2-5 years old Coho: 2-3 years old Steelhead: 2-5 years old	NA	Chinook: Fall run: Jun-Dec Late-fall run: Oct-Apr Winter run: Dec-Aug Spring run: Mar-Sept Coho: enter rivers late-fall through winter Winter Steelhead: enter rivers Dec-Mar Summer steelhead: enter rivers in spring, early summer and fall	Chinook: 2-5 years old Coho: 3 years old Steelhead: 5-7 years	Mobile

Coho salmon begin their spawning migrations up coastal streams when heavy rains in late-fall or early winter breach the sandbars at the mouths of their natal rivers (CDFG 2001). There is one run in California, corresponding to the spawning period that occurs between September and March, peaking in November and February (Love 1996, CDFG 2001). Most Coho migrate back to the ocean, usually at night, between March and May at one year of age, although some are two years of age. They initially remain nearshore close to the parent stream and gradually move northward and further from the coast as they get older (Moyle 2002). Most Coho are mature by the end of their third year and most return to their parent stream to spawn and die (Moyle 2002).

Steelhead have two seasonal “races”, summer and winter steelhead (CDFG 2001). Summer steelhead enter streams as immature individuals following the spring rains, migrate to deep pools in headwater tributaries to mature over the summer, and spawn in winter and spring. Winter steelhead enter streams in winter when rains breach sandbars of lagoon mouths, as well as provide cold water for migration and spawning. Mating occurs at the spawning sites in fresh water streams.

Steelhead spawning occurs from January through June, mainly March to early May. Winter steelhead return to the ocean after spawning, whenever possible (Moyle 2002). Unlike Chinook and Coho salmon, steelhead salmon are capable of repeat spawning (CDFG 2001). Steelhead do not migrate back to the ocean at a specific age, ranging from less than a year old to never returning to sea (CDFG 2001).

Most steelhead return to streams to spawn after spending 2 to 6 years in the ocean, but some have returned after spending less than a year in the ocean (CDFG 2001). The age at

sexual maturity depends on the combination of years spent in fresh water and in the ocean, but generally ranges from 2 to 5 years old (Moyle 2002). There is evidence that distribution and abundance of steelhead in the ocean is influenced by thermal regimes, and population dynamic phases appear to last 20 to 30 years that may coincide with Pacific Decadal Oscillation (Welch et al. 1998).

Adaptations and/or Behaviors to Disturbance:

Adult and juvenile salmonids respond to disturbance by swimming away. Laying eggs in isolated mountain streams presumably historically provided some protection for the eggs and young. In recent times, salmon spawning grounds have been threatened by many anthropogenic disturbances including damming of rivers, development, and human water use.

Life Stage	Behavior			Habitat (Nursery)	High Reproductive Output
	Swim	School	Spawning runs		
Adult	X	X	X		
Juvenile	X	X		X	
Egg/ Larvae				X	X

Potential Impacts from Sediment Management Activities:

The primary concern with respect to dredging activities is the potential for equipment and turbidity interference with migration. Entrainment of juveniles is of concern in large embayments such as San Francisco Bay that serve as nursery habitats. At beach nourishment sites near rivers used by salmonids, there is a concern that sediment transport could result in shoaling and/or blockage of a river mouth and impede migrating salmonids. An additional concern is that sediment manangement activities may degrade the food base for salmonids.

Types of sediment management activities and potential impacts to salmonids may include:

- Maintenance dredging of embayments – turbidity.
- Offshore borrow site dredging – turbidity.
- Nearshore placement – turbidity.
- Profile placement – equipment damage, burial, sedimentation, turbidity.
- Beach placement – equipment damage, burial, sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging	X	X			X	X
Growth					X	
Habitat			X			
Reproduction						
Respiration					X	

Equipment

There is some potential that juvenile salmon could be entrained in a dredge working in a bay, estuary or river mouth. La Salle et al. (1991) summarized studies reporting low levels of entrainment of chum and pink salmon fry by hydraulic dredges working in the Fraser River with losses equivalent to between 0.04 and 0.00004 percent of the total migration in the river. La Salle et al. (1991) also listed an entrainment rate for chum salmon as 0.0008 fish per cy for dredging in Grays Harbor, Washington. The NMFS (2002) reviewed that studies of entrainment during dredging in the Columbia River revealed that salmonids generally were not entrained because dredging occurred below the depth where salmonids migrate (Larson and Moehl 1990, Carlson et al. 2001); however, entrainment did occur during an experiment when the hopper dredge draghead was purposely operated while elevated in the water column instead of within the substrate to determine presence/absence of fish (R2 Resource Consultants 1999).

LaSalle et al. (1991) reviewed recommendations of restrictions to minimize entrainment effects on salmonids, including limitation of dredging in waters at least 15 ft (4.6 m) deep during the migratory period of salmonid fry and activation of the cutterhead pump no more than 5 ft (1.5 m) from the bottom. NMFS (2002) recommended that during use of cutterhead and/or hopper hydraulic dredges that pumping operations be limited to below the substrate surface to the maximum extent possible, and pumping operations be stopped when the cutterhead and/or hopper dredge dragarm is raised more than 3 ft (1 m) off the bottom.

A concern has also been expressed that the physical presence of dredge equipment in a channel used for salmonid migration may impede the migration both by the physical presence of the operations as well as the associated turbidity (Reine et al. 1998). However, there appears to be no conclusive, documented evidence that dredging operations impede fish migration (Reine et al. 1998). Noises from dredges are within ranges that could disturb fish (Hastings and Popper 2005); however, noise disturbance would be expected to be limited to close to dredging activities (Section 5.3.2.6).

Nightengale and Simenstad (2002) reviewed several studies that indicate that artificial lighting may attract juvenile salmonids, resulting in delayed outmigration and/or increased loss from predation; adult migration was less vulnerable to disruption.

Embayment dredging that resulted in removal of eelgrass could adversely affect nursery habitat for salmonids, if present.

Burial/Sedimentation

There is a concern that burial or sedimentation from beach nourishment projects could reduce the prey base for salmonids, particularly in areas frequented by outmigrating juveniles (Hiss et al. 1988). Monitoring of the invertebrate community following a beach nourishment project on Lincoln Park Beach in Seattle found that the overall density of important salmonid prey items along the nourished beach was similar to a control beach (USACE 2002b). The project placed 18,000 cubic yards of sand and gravel along the seaward side of an existing seawall.

There is also a concern that sediment placed on the beach could be transported into the mouth of rivers used for salmonid spawning (Chambers Group 2001c). Monitoring following nourishment of Goleta Beach did not detect closure of the inlet to Goleta Slough as a result of sand transport from the beach nourishment project (Moffatt & Nichol 2005).

Turbidity

Laboratory studies of effects of suspended sediment on juvenile salmonids generally have found lethal effects at exposures of 488 to 1200 mg/L for an extended period of time (96 hours) (Bash et al. 2001). Higher concentrations were required to induce mortality in adults (39,000 mg/L over 24 hours). Sublethal effects may include gill trauma, changes in blood physiology and interference with osmoregulation, but, again, these effects generally occurred at exposures to high suspended sediment concentrations in laboratory tanks for days (Bash et al. 2001).

A number have studies have found that turbidity can decrease feeding efficiency in salmonids (Bash et al. 2001, Madej 2004, Barrett et al. 1992, Vogel and Beauchamp 1998). Reduced feeding in juveniles has been reported at concentrations ranging from 100 to 300 mg/L (Appendix C.3-2). The effectiveness of salmonids in obtaining food may be reduced by turbidity levels as low as 20 NTU (Bash et al. 2001). Salmonids may avoid turbid waters (Bash et al. 2001). Other studies indicate that juvenile Coho salmon, steelhead and Chinook salmon appear to prefer moderately turbid water for foraging (Sigler et al. 1984). Gregory and Levings (1998), in a study of predation on migrating juvenile salmon in British Columbia rivers, found that juvenile salmon were less likely to be eaten by fish piscivores in turbid water (27 to 108 NTU) than in clear water. The effects of moderate turbidity on salmonids may represent a trade-off between feeding efficiency and predation risk (Bash et al. 2001, Gregory and Northcote 1993). Turbidity concentration and exposure duration are important considerations (Newcombe and Jensen 1996, Berry et al. 2003).

The long-term management strategy for the placement of dredged materials in San Francisco Bay requires consultation for sediment management activities outside specified work windows to protect the various species and runs of salmonids (USACE, USEPA, BCDC, SFBRWQCB 2001).

Recovery from Disturbance:

If juvenile salmon were entrained in a dredge or if equipment interfered with migration, recovery might not occur until the next season. However, entrainment losses, if any, would

be expected to be small and probably not discernible on a population level. Other equipment-related disturbance effects would end with cessation of dredging activities.

Turbidity effects would depend on magnitude of effect, and could range from no effects, displacement, to sublethal or lethal effects depending on concentration. High levels would not be expected unless there was dredging in the immediate vicinity of nursery habitat. Turbidity effects generally would be limited to the construction period, but actual exposure duration would vary depending on project- and site specific conditions.

Studies of beach nourishment projects have documented that the invertebrate community is temporarily reduced but re-establishes often in a matter of months and in most cases within a couple of years. Direct burial of spawning habitat would not occur. Sedimentation impacts that made an area unsuitable as a nursery area would be detrimental, and recovery would depend on magnitude of effect. Generally, impact would not be expected to last more than a season unless there was loss of eelgrass nursery habitat. Loss of eelgrass habitat from dredging could take years to recover (see Section 3.3.8).

Closing of an inlet to a stream used by salmonids by would be expected to last until a storm generated enough flow to force the inlet open again, unless mechanically opened.

	Recovery Rates				
Impact	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	X		If eelgrass loss		
Burial					X
Sedimentation	X	If eelgrass degraded	If eelgrass loss		
Turbidity	After cessation of activities			X	
Forage Reduction	X	X			
Access to Habitat Loss		Inlet closure			

Critical Impact Thresholds:

Laboratory experiments have identified lethal and sublethal effects on salmonids at various levels of turbidity or suspended solids concentrations. No critical impact thresholds have been established.

Data Gaps:

Additional information on the reaction of salmonids to turbidity at levels that might be encountered from a sediment management project would help to determine whether concerns related to salmonids are realistic.

Restoration:

Dredge removaland/or extensive sedimentation of eelgrass nursery habitat would require replacement mitigation, which would be guided by the Southern California Eelgrass Mitigation Policy (see Section 3.3.8).

Summary:

Juvenile salmon have the potential to be entrained by dredges, although low levels of entrainment have been documented. It has been hypothesized, but not documented, that dredging and associated turbidity could interfere with migration if the activities were in a channel used by salmonids.

It has also been hypothesized that direct burial or subsequent sedimentation from sand placement could reduce the prey base for salmonids. Numerous studies have documented that benthic invertebrate recovery following beach nourishment is within 1 year unless there is a change in sediment characteristics (Section 4.2.6).

Turbidity effects are expected to be short-term for individual fish; however, turbidity effects may influence a local area until in-water construction activities cease. Early life stages of salmonids appear to be more sensitive than adults to turbidity. Low to moderate turbidity may provide some protection of larvae from visual predators. The potential for turbidity to affect adult migration is unknown.

Localized noise disturbance may occur during dredging (5.3.2.6). Salmonids may be attracted to lights associated with nighttime dredging operations, which could result in loss due to predation. No information is available on the counteracting effects of light and noise on salmonids during nighttime dredging operations.

If eelgrass, which may be used as salmonid nursery habitat, was lost from dredging, eelgrass would require mitigation replacement consistent with the Southen California Eelgrass Mitigaiton Policy (NMFS et al. 2005). The functional value of a restored eelgrass bed as nursery habitat would likely be lower for a couple of years until the bed developed (see Section 3.3.8).

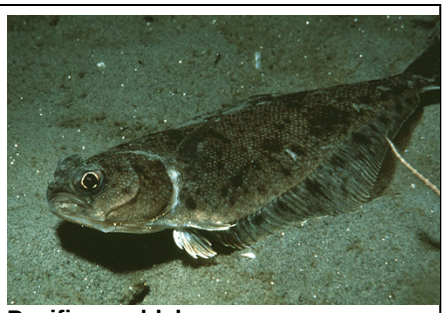
The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on salmonids.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Documented to protective conservatism	NA	Protective conservatism	Documented
Critical Impact Thresholds	NA	Loss of eelgrass nursery habitat, substantial entrainment	NA	Loss of eelgrass nursery habitat	Impair migration
Impact Responses	NA	Entrainment mortality, interference with migration	NA	Displace due to forage reduction or habitat loss	Attraction or avoidance, impair feeding, sublethal to lethal effects at high levels
Duration of Impacts	NA	Minutes-months	NA	Months-years	Minutes-months
Potential for Restoration	NA	Yes, if eelgrass loss	NA	Yes, if eelgrass loss	Unnecessary

NA = not applicable

4.3.4 Bottom-Dwelling Fish

Species Common Name	**Bottom-Dwelling Fish**
Species Scientific Name	**Various species and families**



Pacific sanddab
Photo credit: Daniel Gotshall

Regulatory Status:

Endangered	
Threatened	
CDFG Managed	California Corbina, California Halibut

Distribution:

Life Stage and/or Function	California			On Land	Intertidal	Nearshore < 30 feet	Offshore > 30 feet	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X		X	X	X	E, P
Juvenile	X	X	X		X	X	X	E, P
Egg	X	X	X		X	X	X	E, P
Primary Habitat	X	X	X			X		E, P
Foraging Habitat	X	X	X		X	X	X	E, P
Nesting/ Spawning Habitat	X	X	X		X	X	X	E, P

A variety of bottom fish inhabit the nearshore California sand bottom environment. Common bottom fish species in California shallow sand bottom habitats include barred sand bass (*Paralabrax nebulifer*), California halibut (*Paralichthys californicus*), California corbina (*Menticirrhus undulatus*), California lizardfish (*Synodus lucioceps*), diamond turbot (*Hypsopsetta guttulata*), hornyhead turbot (*Pleuronichthys verticalis*), round stingray (*Urolophus halleri*), speckled sanddab (*Citharichthys stigmaeus*), shovelnose guitarfish (*Rhinobatos productus*), starry flounder (*Platichthys stellatus*) and spotted turbot (*Pleuronichthys ritteri*) as well as a variety of other species (Cross and Allen 1993, Schultze 2001, Chambers Group 1994).

Nearshore sand bottom species differ in their depth distribution and distribution along the coast. Some species such as speckled sanddab are common along the entire California coast while others are more common from central California south (corbina, barred sand bass) and others such as starry flounder are most abundant from central California north. Most shallow water sand bottom species have a depth distribution out to at least a hundred feet, but species such as those listed above as typical of nearshore soft bottoms are most common in shallower water.

Most of these fish species release eggs and larvae to the water column (Cross and Allen 1993). Spawning of nearshore species is limited to the coastline and to offshore islands and

banks. Eggs and larvae of nearshore fishes are dispersed by currents, and must either remain nearshore or return to the coast in sufficient numbers to maintain adult populations. Thus, eggs and larvae of most inshore soft bottom fish species tend to be distributed over a wide depth range but their abundance increases nearshore (Cross and Allen 1993). Older larvae of California halibut are concentrated in the epibenthic layer close to shore. Juvenile halibut use protected waters such as bays and estuaries as nursery habitat (Allen 1988).

Functions:

Depending on their trophic level, bottom fishes of the shallow sand bottom environment feed on invertebrates, other fishes or both (Love 1996, Cross and Allen 1993). Turbots, for example, with their small mouths feed primarily on benthic invertebrates, while adult California halibut are mainly piscivores. Barred sand bass are an example of a species that feeds on fishes, and benthic and water column invertebrates. The diets of most species change as they grow (Cross and Allen 1993). For example, juvenile halibut eat mostly invertebrates but switch to fishes as they mature. Nearshore bottom fishes are eaten by larger fishes, marine mammals, and birds (CDFG 2001, Love 1996).

Associated Species	Forage/ Prey	Eaten By
Invertebrates	X	
Fish	X	X
Birds		X
Vegetation		
Marine Mammals		X
Terrestrial Animals		
Humans		X

Nearshore soft bottom fishes are popular targets for recreational fishermen from piers, shore, and boats (CDFG 2001). California halibut is an important flatfish species in both the commercial and recreational fisheries of central and southern California.

Life History Facts:

Most nearshore bottom-dwelling fish species release eggs and larvae to the water column (Cross and Allen 1993). Sharks and rays are an exception; they release their young alive (Love 1996). Reproductive periods vary depending on species. For example, barred sand bass spawn from spring to fall; summer spawners include California corbina, round stingray, speckled sanddab, and spotted turbot; wnter to spring spawners include California halibut and starry flounder (Love 1996). Horneyhead turbot spawn year-round in southern California and spring to summer off central California (*ibid.*). Recruitment of nearshore bottom fish occurs throughout the year, but is greatest in winter through spring (Cross and Allen 1993).

Typically, nearshore soft bottom species reach maturity at 2 to 3 years old (CDFG 2001). Speckled sanddabs mature at 1 year old and barred sand bass mature at 3 to 5 years. Life spans of nearshore sand bottom species very from as short as 3 years for speckled sanddabs to as old as 30 years for California halibut (CDFG 2001).

Migration patterns depend on the species. Many bottom fishes make inshore/offshore migrations (Cross and Allen 1993). California halibut, for example, migrate inshore in late winter and early spring to spawn and feed, stay throught the sumer and fall, then disperse in offshore in late fall and winter (Love 1996).

Many bottom-associated fish use bays and estuaries as nursery habitats (e.g., California halibut, bat rays, round stingrays) (Kramer 1991, MEC 2000b, Allen et al. 2002, Valle et al. 1998). Female round stingrays move into bays to give birth, and juveniles move out into deeper water when they are 6 to 7 inches long (Love 1996). There is some evidence that diamond turbots move out of estuaries to to the open coast to spawn (Love 1996). Some species also may migrate along the coast. Love conducted a tagging study that suggested that California halibut may migrate north (Love 1996).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Spawn	Throughout the year, varies with species	Most species reach maturity in 2 to 3 years.	N/A	Variable	3 years to 30 years	Mobile

Adaptations and/or Behaviors to Disturbance:

In general, nearshore soft bottom fishes react to disturbance by swimming away. Some species such as the flatfishes and spotted cusk-eels (*Chilara taylori*) burrow into the sediment and thus hide from potential predators (Love 1996). Juveniles of some species, including California halibut and southern stingray, spend their early years in bays and estuaries. This behavior may reduce predation.

Life Stage	Behavior			Habitat (Nursery)	High Reproductive Output
	Swim	Burrow	Migration		
Adult	X	X	X		
Juvenile	X			X	
Egg/ Larvae				X	X

Potential Impacts from Sediment Management Activities:

Because of the wide distribution of nearshore sand bottom habitat, sand bottom species (with the exception of grunion) have generally not been a focus of concern for sediment management projects. Potential impacts are primarily from turbidity or reduction in the benthic invertebrate prey base. Sand bottom fishes and their prey have been monitored for some sediment management projects. Potential impacts and the results of monitoring studies are discussed below.

Types of sediment management activities and potential impacts to bottom-dwelling fish may include:

- Maintenance dredging of embayments – equipment, turbidity.
- Offshore borrow site dredging – equipment, turbidity.
- Nearshore placement – sedimentation, turbidity.
- Profile placement – sedimentation, turbidity.
- Beach placement – sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging		X	X	X	X	X
Growth						
Habitat			X			
Reproduction						
Respiration						

Equipment

Demersal fishes may be disturbed by dredges, barges, anchoring, pipepline placement/removal, and/or vessel noise during dredging, nearshore placement, profile placement, and/or vessel movement and mooring at a mono buoy to discharge sands through a pipeline during beach placement. Noises from dredges are within ranges that could disturb fish (Hastings and Popper 2005); however, noise disturbance would be expected to be limited to close to dredging activities (Section 5.3.2.6). Generally, these types of disturbances would be expected to result in temporary displacement, avoidance behaviors (Suzuki et al. 1980, Chambers Group 1992, Hastings and Popper 2005).

Several reports suggest that demersal fish may be attracted to borrow sites during and/or after dredging. Greene (2002) reviewed five citations from studies conducted in the 1970s and 1980s at borrow sites off Florida that reported an increase in fish abundance attributed to release in nutrients and infauna when sediment was removed during dredging. She also cited a review by Grober (1992), who suggested that studies had short post-sampling times that did not allow determination if fish abundance remained high after benthic organisms were consumed. Insufficient information is available to determine if effects were more than temporary attraction. Fish attraction was reported during a sand mining operation off Hawaii (Maragos et al. 1977 cited by Navqi and Pullen 1982). Naqvi and Pullen (1982) cited a report by Gustafson (1972), who noted that borrow pits in San Franciso Bay were a haven for many game fish such as striped bass (*Morone saxatilis*).

Temporary avoidance during dredging also may occur. Van Dolah et al. (1994) reported an initial reduction in the number of fish and crustacean species, but pre-dredge conditions were restored within one year following borrow site dredging for the Folly Beach, South Carolina beach nourishment project. Although changes in species composition were detected, they were attributed to normal seasonal and yearly variability rather than the effects of dredging (cited in Greene 2002).

No substantial changes in fish species composition and/or catch were reported in association with dredging at borrow areas used to support the 8.1 million cy Asbury Park to Manasquan Inlet, New Jersey beach nourishment Project (Burlas et al. 2001). Surveys were conducted at three borrow areas during spring and fall over a five year period

encompassing prre-project, dredging, and one-year post-dredging periods. The authors concluded that there was no evidence of any large-scale change in the composition or abundance of demersal fish in relation to dredging of the borrow areas. Surveys of food habits and gut contents of selected species indicated no appreciable change in the food habits of winter flounder, a benthic omnivore, and summer flounder, an epibenthic feeder between baseline, dredging, and post-dredging periods. The study also showed that some food items (anemones) taken by winter flounder were not common at the borrow areas, indicating selective feeding and/or some foraging outside the borrow areas.

Localized changes in the abundance (enhanced, depressed) of some species have been reported over longer time frames after cessation of borrow site dredging or commercial marine aggregate dredging.

- Courtenay et al. (1980) conducted a survey seven years after borrow site dredging off Hallandale, Florida and noted an increase in fish species, except for the dusky jawfish (cited in Naqvi and Pullen 1982).
- Although there was an overall reduction in numbers and densities of epifauna taxa, enhanced abundances of some species including gobiidae fish were reported at sites surveyed several years after cessation of marine aggregate extraction compared to reference areas in the North Sea and eastern English Channel off the United Kingdom (Boyd et al. 2004, Cooper et al. 2005). In general, sediments tended to contain proportionately more sand and less gravel in areas previously exposed to high levels of dredging intensity (Boyd et al. 2004).
- A reduction in catch of smooth hound shark (*Mustelus mustelus*) by charter anglers was reported off the United Kingdom in an area affected by marine aggregate extraction dredging that also overlapped with the locality of a mussel bed, a food source for the species (Cooper 2005).

Anchoring and/or pipeline placement would be expected to have temporary disturbance effects on demersal fish (Lissner et al. 1991). Mobile fish would be capable of swimming over the pipe.

There is the potential for dredge entrainment of demersal fish. Low entrainment rates have been reported for starry flounder, English sole, sand sole, slender sole, Pacific sanddab, speckled sanddab, and range from 0.001 to 0.035 per cy (Reine and Clark 1998).

Embayment dredging that resulted in removal of eelgrass nursery habitat would be of concern.

<u>Burial/Sedimentation</u>

Burial and/or sedimentation have the potential to reduce the prey base for benthic foraging sand bottom fishes.

Reilly and Bellis (1983) monitored ecological impacts associated with a 1.18 million cy beach nourishment project at Boque Banks, North Carolina. Although the monitoring focus was on invertebrates, fish were opportunistically netted in the shallow surf zone and gut content analysis of more than 100 fish established that mole crabs and *Donax* clams were primary prey items.

Nearshore fish in the surf zone were monitored with beach seines before, during, and for two years after a 4.7 million cy phase of a large beach nourishment project in New Jersey (Burlas et al. 2001, Wilber et al. 2003). The project dredged sand from an offshore borrow site and placed the sand on the beach. The northern kingfish (*Menticirrhus saxatilis*), which is a benthic-feeder, displayed short-term attraction to the beach nourishment area during fill operations, possibly because of the resuspended benthic material. However, based on analysis of stomach contents, kingfish did not exhibit any dietary changes associated with beach nourishment, and northern kingfish abundance was not significantly higher off the nourished area one and two years after nourishment. Bluefish (*Pomatomus saltatrix*), which is a visual predator, displayed avoidance of the beach nourishment area (Section 4.3.5). Other differences in surf zone fish abundance patterns appeared to be related more to proximity to groins and interannual variability than to beach nourishment. The authors reported that partial burial of the rock groins by the nourishment operation may have temporarily reduced their habitat value, but there was no evidence that this effect significantly affected feeding habits of examined surf zone fish. Species number was significantly higher near groins at the reference area and in the vicinity of beach nourishment (treatment area) before and two years after nourishment; however, the difference at the treatment area was less pronounced or non-signifcant during and one year after nourishment.

Versar (2004) studied the impacts to surf zone and nearshore fish of a beach nourishment project in North Carolina.that project removed sand from the lower portion of the Cape Fear River navigation channel and used it to replenish the sands of four beaches. One beach was reconstructed per season. The nearshore and surf zone fish community included both bottom dwelling and water column species. No significant depression in abundance and diversity was detected one year after beach construction. When significant differences were observed either an enhancement was indicated or seasonal differences between the nourished beach and the reference beach were inconsistent. The fish community's ability to migrate caused a highly variable community in both a temporal and spatial aspect but also indicated that fishes could move in and out of beaches impacted by the replenishment operations.

Chambers Group (1994) studied the nearshore fish community near Oceanside Harbor before and after the beginning of operations of a sand bypass system. The sand bypass system dredged sediment from the Oceanside Harbor entrance and discharged it onto a a downcoast beach. No effect of the discharge was detected on the nearshore fish community. Fish community characteristics did not differ near the discharge point compared to controls away from the influence of the discharge.

<u>Turbidity</u>

Fish associated with the sand-water interface may be relatively tolerant of high suspended sediment concentrations (Wilber and Clarke 2001). In coastal areas outside bays and estuaries, fish species in the surf zone are exposed to turbidity from wave action, the effects of which diminish offshore. Although relatively tolerant, there also is evidence that bottom fishes may move to avoid turbid waters. Greene (2002) cites a study in which winter flounders were observed leaving shallow coastal waters to avoid turbulence during storms. The author speculated that because adult winter flounder were sight feeders, it is likely that increased turbidity affects their success rate for capturing prey. Colby and Hoss (2004) demonstrated that flounders fed when TSS concentrations were low (≤ 200 mg/L) and prey concentrations were high, but not with the reversed condition.

De Robertis et al. (2003) found that comparatively low turbidity (5 to 10 NTU) decreased both the rate at which bottom-living sablefish pursued prey and the probability of successful prey capture.

Recovery from Disturbance:

Beach nourishment projects have resulted in short-term declines in the abundance and biomass of nearshore benthos (Burlas et al. 2001, Versar 2004) suggesting nearshore fishes could be impacted by a decline in their prey base. However, actual effects of decreased prey resources on nearshore soft bottom fishes have not been demonstrated. Fish mobility and foraging over a broader area than the impacted area may be influential. Intertidal invertebrates generally recover within months unless recruitment is impaired or substrate altered (Section 4.2.6). Recovery of subtidal fauna after borrow site dredging may take two or more years depending on project- and site-specific conditions (Section 4.2.7). Turbidity effects generally would be limited to the construction period, but actual exposure duration would vary depending on project- and site specific conditions. Habitat loss generally is not an issue, with the possible exception of potential loss of eelgrass as a result of embayment dredging.

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	After cessation of activities	X	If loss of eelgrass		
Burial					X
Sedimentation					X
Turbidity	After cessation of activities				
Habitat Loss			If loss of eelgrass		
Forage Reduction	X	X	X		

Critical Impact Thresholds:

No critical impact thresholds are available for impacts to California nearshore soft bottom fish species.

Data Gaps:

It is unknown to what extent California species avoid turbidity plumes or experience decreased foraging efficiency. Limited information is available regarding the impact of reductions in benthic invertebrate forage on demersal fish activity patterns. Few data are available on demersal spawning grounds (locations, time of year) and/or nurseries. Such information would improve project planning to avoid and/or minimize potential dredging, and/or entrainment impacts.

Restoration:

Because impacts to soft bottom fishes from sediment management activities appear to be short term, restoration should not be necessary. Any eelgrass habitat loss would require

mitigation replacement consistent with the Southen California Eelgrass Mitigaiton Policy (NMFS et al. 2005).

Summary:

There is some evidence that bottom-feeding fishes may be attracted to areas of beach nourishment, presumably to feed on resuspended benthic material. The invertebrate forage base for demersal fish may be reduced after sediment management activities. Recovery rates of benthic forage generally are < 1 year after beach nourishment and 2 to 3 years after borrow site dredging unless there is substantial change in sediment and/or hydrodynamics (Section 4.2.6, 4.2.7). Monitoring studies have not demonstrated obvious differences in fish composition, abundance, or gut contents in the vicinity of beach nourishment or borrow site dredging. It has been suggested that fish may forage over broader areas than represented by local sediment management activities. The highly mobile nature of fish populations also apparently contribute to lack of detection of effects.

Demersal fish may be relatively tolerant of high suspended sediment concentrations; however, visual feeders exhibit reduced foraging at elevated turbidity and may move away from turbid waters. Demersal fish have the potential to be entrained by dredges, although low levels of entrainment have been documented. Dredge noises may result in localized disturbance.

Demersal fish may use eelgrass as nursery habitat; therefore, any dredging-related losses would be of concern. Any eelgrass habitat loss would require mitigation replacement consistent with the Southen California Eelgrass Mitigaiton Policy (NMFS et al. 2005). The functional value of a restored eelgrass bed as nursery habitat would likely be lower for a couple of years until the bed developed (see Section 3.3.8).

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on bottom dwelling fish.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Documented	Protective conservatism	Relevant reports	Documented
Critical Impact Thresholds	NA	Damage to spawning grounds, loss of eelgrass nursery habitat, substantial entrainment	Prolonged reduction in forage prey	Prolonged reduction in forage prey, loss of eelgrass nursery habitat	Unknown
Impact Responses	NA	Possible minor impact from offshore equipment	Displace due to forage reduction	Displace due to forage reduction	Decreased feeding efficiency, avoidance of turbidity
Duration of Impacts	NA	Minutes-months	Months-year	Months-year	Minutes-months
Potential for Restoration	Not necessary	Yes, if eelgrass loss	Not necessary	Yes, if eelgrass loss	Not necessary

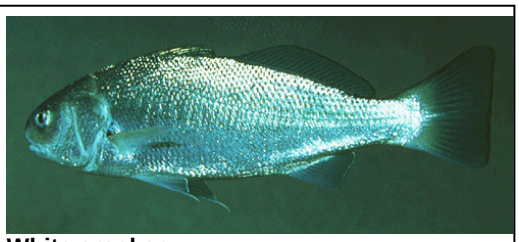
NA = Not applicable

4.3.5 Nearshore Water Column Fish

Species Scientific Name	**Various species and families**

Regulatory Status:

Endangered	
Threatened	
CDFG Managed	Grunion (discussed in Section 4.3.1)



White croaker
Photo credit: Daniel Gotshall

Distribution:

Common water column species of nearshore soft bottoms include jacksmelt (*Atherinopsis californiensis*), topsmelt (*Atherinops affinis*), California grunion (*Leuresthes tenuis*) (refer to Section 4.3.1), queenfish (*Seriphus politus*), walleye surfperch (*Hyperprosopon argenteum*), white seaperch (*Phanerodon furcatus)*, northern anchovy (*Engraulis mordax*), and white croaker (*Genyonemus lineatus*) a bottom feeder that lives in the water column (Cross and Allen 1993, Chambers Group 1994). A number of other water column species including Pacific bonito (*Sarda chilensis*), jack mackerel (*Trachurus symmetricus)*, and brown smoothhound (*Mustelus henlei*) also sometimes occur in nearshore waters. Most of the water column species found in California nearshore waters are widely distributed from bays and estuaries out to ocean depths of 100 feet or more (Love 1996).

Most of the common nearshore water column species are distributed along the California coast from northern through southern California (Love 1996). Queenfish are only abundant in southern California.

Life Stage and/or Function	California			On Land	Inter-tidal	Nearshore < 30 feet	Offshore > 30 feet	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X		X	X	X	E, P
Juvenile	X	X	X		X	X	X	E, P
Egg	X	X	X			X	X	E, P
Primary Habitat	X	X	X		X	X	X	E, P
Foraging Habitat	X	X	X		X	X	X	E, P
Nesting/ Spawning Habitat	X	X	X		X	X	X	E, P

Functions:

The majority of nearshore water column fishes eat zooplankton, algae, and small fishes (Love 1996). Some of the larger species like Pacific bonito eat the smaller nearshore fish species like anchovy (CDFG 2001). Some water column fishes, like white seaperch and white croaker, feed on the benthos.

Nearshore schooling fishes like the silversides, anchovies, and queenfish are eaten by a wide variety of higher predators including larger fishes, seabirds and marine mammals (Love 1996). Northern anchovy are fished commercially.

Associated Species	Forage/ Prey	Eaten By
Plankton	X	
Invertebrates	X	
Fish		X
Birds		X
Vegetation		
Marine Mammals		X
Terrestrial Animals		
Humans		X

Life History Facts:

The majority of nearshore water column fishes are broadcast spawners with pelagic eggs (Love 1996). However, jacksmelt and topsmelt lay their eggs on marine vegetation (Love 1996). Surfperches are livebearers. Recruitment of white croaker and queenfish is close to shore (Cross and Allen 1993). Spawning occurs throughout the year, but is generally greater from winter through spring, although some species (e.g., queenfish) primarly spawn in spring to summer (Cross and Allen 1993, Love 1996). Northern anchovy display gonadal activity throughout the year, but most spawn from winter to spring (*ibid.*). Some species exhibit south to north differences in spawning periods; e.g., topsmelt spawn from winter-spring in southern California and spring-fall in San Francisco Bay (Love 1996).

Pelagic fish may display seasonal and/or daily onshore and offshore migratory patterns related to feeding and reproduction (Cross and Allen 1993). For example, jack mackerel, queenfish, and walleye surfperch remain in schools in shallow wates near the day but disperse to deeper waters at night to feed on plankton. Anchovy schools move offshore to spawn in winter-spring and are more abundant inshore in summer-fall. White croaker move inshore in summer and offshore in winter (Love 1996). Many species use bays as nursery areas (e.g., California grunion, jacksmelt, northern anchovy, Pacific sardine) (Allen et al. 2002).

Most nearshore water column fish species mature at 1 to 2 years of age (CDFG 2001). The life span of most nearshore water column fishes is 6 to 11 years (Love 1996). Jack mackerel, however, live for 35 years.

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Livebearer Egg/Spawn	All months but particularly winter-spring	Mature at 1 to 2 years	N/A	All year for migratory species	Most live 6 to 11 years: jack mackerel live 35 years.	Mobile

Adaptations and/or Behaviors to Disturbance:

Nearshore water column fishes react to disturbance by swimming away. Most of these species are schooling. Schooling behavior helps to protect fish from predation (Moyle 1993). Livebearing by surf perches protects from losses of eggs in the ocean environment. Laying eggs on vegetation by jacksmelt and topsmelt keeps eggs from being carried by currents and insures that eggs will hatch in a suitable environment.

Life Stage	Behavior			Habitat	High Reproductive Output
	Swim	School	Migration		
Adult	X	X	X		
Juvenile	X	X	X		
Egg/ Larvae				X	X

Potential Impacts from Sediment Management Activities:

Because they are wide-ranging, nearshore water column fishes generally are not a focus of concern for sediment management projects. Potential impacts most likely would be related to turbidity or reduction in their food base. Nearshore water column fishes and their prey have been monitored for some sediment management projects.

Types of sediment management activities and potential impacts to nearshore water column fish may include:

- Maintenance dredging of embayments – equipment, turbidity.
- Offshore borrow site dredging – equipment, turbidity.
- Nearshore placement – sedimentation, turbidity.
- Profile placement – sedimentation, turbidity.
- Beach placement – sedimentation, turbidity..
- Dune placement – sedimentaton.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging	X	X		X	X	X
Growth						
Habitat						
Reproduction					X	
Respiration						

Equipment

Equipment on the beach would not be expected to affect water column fishes. Barges or dredges working offshore potentially could have a localized impact related to light and noise. Visual predators, including large fishes and marine mammals, have been observed to concentrate foraging on schooling fishes around lighted vessels, presumably because the light illuminates their prey (N. Davis, personal observation). Therefore, lights on vessels could increase predation on water column fishes. In addition, noise potentially could cause fishes to avoid the immediate area of the offshore activity.

Burial/Sedimentation

Available reports suggest that beach nourishment may result in short-term attraction of pelagic fish that include benthic prey in their diet. The effects of beach nourishment on diet and abundance patterns of surf zone fish were studied along the northern coast of New Jersey (Burlas et al. 2001, Wilber et al. 2003). The beach nourishment project dredged sand from an offshore borrow site and placed it directly on the beach. Beach nourishment resulted in short-term attraction and/or increase in stomach biomass of some water column species that include benthic prey in their diets, but had no long-term affect on stomach prey biomass or distribution. During beach nourishment, Atlantic silversides (*Menidia menidia*) had a greater prey biomass in their stomachs than fish at reference areas. The authors suggested that prey availability may have increased at the beach nourishment stations because prey were more rapidly suspended by wave action in the newly deposited sand and thus more vulnerable to predators. The relative composition of prey items in Atlantic silversides did not differ between reference and beach nourishment areas one and two years after the completion of the beach nourishment project suggesting that impacts of beach nourishment on diet were short-lived.

Versar (2004) studied the impacts to surf zone and nearshore fish of a beach nourishment project in North Carolina. That project dredged sand from the navigation channel of the Cape Fear River and placed it on four beaches. One beach was reconstructed per season from spring 2001 through winter 2002. The nearshore and surf zone fish community included both water column and bottom dwelling species. No impacts to fish abundance and diversity were detected during beach nourishment activities and up to 8 weeks following the disturbance. No significant depression in abundance and diversity was detected one year after beach construction. When significant differences were observed either an enhancement was indicated or seasonal differences between the nourished beach and the reference beach were inconsistent. The fish community's ability to migrate caused a highly variable community in both a temporal and spatial aspect but also indicated that fishes could move in and out of beaches impacted by the nourishment operations.

Chambers Group (1994) studied the nearshore fish community, including both water column and demersal species, near Oceanside Harbor before and after the beginning of operations of a sand bypass system. Otter trawls and gill nets were sampled seasonally over multiple years. The sand bypass system dredged sediment from the Oceanside Harbor entrance and discharged it to a downcoast beach. No effect of the discharge was detected on the nearshore fish community based on examination of species composition, abundance, and biomass). Fish community characteristics did not differ near the discharge point compared to controls away from the influence of the discharge.

Turbidity

Laboratory studies of on estuarine and coastal fishes have observed lethal effects at dosages as low as several hundred milligrams per liter for 24 hours to no effect at concentrations above 10,000 mg/L for 7 days (Clarke and Wilber 2000). Response varies considerably by species and life stage.

DeRobertis et al. (2003) found in laboratory experiments that planktivorous fishes (juvenile chum salmon and walleye pollock) were less sensitive to elevated turbidity than piscivorous fish (sablefish). Planktivorous feeding in the turbidity range tested (0-40 NTU) was reduced at high light intensity, but not at low light intensity. Comparatively low turbidity (5 to 10 NTU) decreased both the rate at which sablefish pursued prey and the probability of successful prey capture. These results suggest that turbid environments may be advantageous for planktivorous fish because they will be less vulnerable to predation by piscivores, but will not experience a substantial decrease in their ability to capture zooplankton prey.

Other studies suggest that water column fishes may suffer reduced foraging efficiency in turbid water. Utne (1997) found that reaction distance of a marine planktivore (*Gobiusculus flavescens*) decreased significantly with increased turbidity. Wilber and Clarke (2001) cited data that showed the feeding rate of silversides were reduced at high turbidity concentrations (120 NTU) and that reaction distance to prey was reduced at turbidity as low as 28 NTU.

Peterson et al. (2002) studied feeding efficiency of Florida pompano exposed to different turbidity levels and prey in wave tank mesocosms; i.e., coquina clams (*Donax variabilis*) (101 versus 9 NTU) and mole crabs (*Emerita talpoida*) (74 versus 7 NTU). Results suggest some lowering of prey consumption by pompano under higher turbidity, but the results were not statistically significant.

Short-term (30-minute), feeding experiments by Colby and Hoss (2004) demonstrate that larval croaker, pinfish, and spot were able to feed at all test concentrations, ranging from 20 to 20,000 mg/L, but was best when prey concentration also was high. Turbid water reduced feeding in adult Atlantic croaker (Wilber and Clarke 2001).

There is some evidence suggesting that water column fishes may avoid turbid discharges. Water column fishes including northern anchovy, white croaker, and shiner perch were observed to move away from the discharge area in response to sediment disposal at the Alcatraz Dredged Material Disposal Site in San Francisco Bay, but returned to the site within an hour or two after the disposal event (O'Conner 1991).

Chason (1993) documented increased activity of rainbow smelts at sediment concentrations greater than 10 mg/L in laboratory experiments. He interpreted this increased swimming behavior as an alarm response.

Monitoring of surf zone fish response to beach nourishment operations off New Jersey indicated localized attraction by some species (northern kingfish) to the nourishment areas and avoidance by other species (bluefish) (Burlas et al. 2001, Wilber et al. 2003). The investigators thought that the kingfish may have been attracted to increased prey in the disposal area, while the turbidity (70 NTU) may have reduced the suitability of the disposal sites for visually feeding bluefish.

These data suggest that turbidity associated with sediment management activities may have adverse (if fishes avoid the turbid area and have a reduced foraging efficiency), attraction, or beneficial effects (if turbidity protects fish from predation) on water column fishes depending on concentration and duration.

Recovery from Disturbance:

Most equipment-related impacts of sediment management activities on water column fishes are expected to be limited to the construction period. Turbidity effects generally would be limited to the construction period, but actual exposure duration would vary depending on project- and site specific conditions.

Benthic forage for bottom-feeding, water column species may be reduced after sediment management activities. Intertidal invertebrates generally recover within months unless recruitment is impaired or substrate altered (Section 4.2.6). Recovery of subtidal fauna after borrow site dredging may take two or more years depending on project- and site-specific conditions (Section 4.2.7). However, effects on fish after sediment management activities have not been demonstrated. Effects on bottom-feeders may be limited due to wide foraging range and/or difficult to detect due to fish mobility (Section 4.3.4). No effects on planktivores or piscivores would be expected outside the construction period.

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	After cessation of activities				
Burial					X
Sedimentation					X
Turbidity	After cessation of activities				
Habitat Loss					X

Critical Impact Thresholds:

In most cases no direct effects of total suspended solids have been observed for coastal and estuarine fish species at concentrations below 500 milligrams per liter (Clarke and Wilbur 2000).

Data Gaps:

For large scale beach nourishment projects, it would be useful to document the extent to which nearshore water column fishes avoid turbidity plumes.

Restoration:

Because no long term effects of beach nourishment on nearshore water coumn fishes would be expected, no restoration is necessary.

Summary:

Most effects from sediment management activities on water column fishes appear to be temporary. Localized noise disturbance may occur during dredging (5.3.2.6). Attraction to lights may occur with nighttime dredging operations, which could result in increased feeding and/or losses due to predation depending on species. No information is available on the the counteracting effects of light and noise on water column fish during nighttime dredging operations. Turbidity during construction may result in temporary displacement, reduced feeding efficiency in piscivores, and/or protection of planktivores from predation. Fish may move away from turbid waters.

Benthic forage for bottom-feeding, water column species may be reduced after sediment management activities. Forage reduction may span months to years depending on project- and site-specific conditions. However, effects on fish after sediment management activities have not been demonstrated. Effects on bottom-feeding water column fish may be limited due to wide foraging range and/or fish mobility. No effects on planktivores or piscivores would be expected outside the construction period.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on water column fish.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	None	Documented	Protective conservatism	Relevant reports	Documented
Critical Impact Thresholds	NA	NA	NA	NA	Mortality
Impact Responses	NA	Disturbance, increased vulnerability to predation	Displace due to forage reduction	Displace due to forage reduction	Attraction or avoidance, impair feeding, sublethal to lethal effects at high levels
Duration of Impacts	NA	Minutes to hours	Months-years	Months-years	Minutes-months
Potential for Restoration	NA	Not necessary	Not necessary	Not necessary	Not necessary

NA = not applicable

4.3.6 Subtidal Reef Fish

Species Scientific Name	**Various Species and Families**

Regulatory Status:

Endangered	
Threatened	
CDFG Managed	California Nearshore Fisheries Management Plan
Fully protected	Garibaldi

Rockfish
Photo by: D. Heilprin, SAIC

The California Nearshore Fisheries Management Plan manages the following 19 nearshore reef fishes:

- Monkeyface Prickleback (*Cebidichthys violaceus*),
- Kelp Greenling (*Hexagrammos decagrammus*),
- California Sheephead (*Semicossyphus pulcher*),
- Cabezon (*Scorpaenichthys marmoratus*),
- Black Rockfish (*Sebastes melanops*),
- Blue Rockfish (*Sebastes mystinus*),
- Olive Rockfish (*Sebastes serranoides*),
- California Scorpionfish (*Scorpaena guttata*),
- Qullback Rockfish (*Sebastes maliger)*,
- Calico Rockfish (*Sebastes dalli*),
- Rock Greenling (*Hexagrammos lagocephalus*),
- Brown Rockfish (*Sebastes auriculatus*),
- Copper Rockfish (*Sebastes caurinus*),
- Treefish (*Sebastes serriceps*),
- Gopher Rockfish (*Sebastes carnatus*),
- China Rockfish (*Sebastes nebulosus*),
- Black-and-yellow Rockfish (*Sebastes chrysomelas*),
- Kelp Rockfish (*Sebastes atrovirens*),
- Grass Rockfish (*Sebastes rastrelliger*)

The garibaldi (*Hyosypops rubicunda*) was named the state's "marine fish" and given fully protected status in 1995 (AB 77, 1995, http://info.sen.ca.gov/pub/95-96/bill/asm/ab_0051-0100/ab_77_cfa_950824_162154_sen_floor.html)

Description and Distribution:

Shallow subtidal reefs support a considerable diversity of fishes (Cross and Allen 1993). Fish abundance on reefs is related to the presence or absence of giant kelp and substrate

relief, although bottom relief > 3 ft (> 1 m) has little effect on fish species diversity and abundance (Cross and Allen 1993). The abundance of water column fishes such as kelp surfperch (*Brachyistius frenatus*), kelp bass (*Paralabrax clathratus*), giant kelpfish (*Heterostichus rostratus*) and kelp rockfish, is directly correlated with kelp density. Kelp is an important nursery area for kelp bass, giant kelpfish and kelp surfperch (Cross and Allen 1993). Shelter-seeking species such as blacksmith (*Chromis punctipinnis*), garibaldi. grass rockfish, brown rockfish and gopher rockfish are abundant on high-relief reefs but rare or absent on low relief reefs.

Some characteristic reef species are more abundant in southern California than northern California. Reef fish species most abundant south of Point Conception include California sheephead, California scorpionfish, garibaldi, blacksmith, rock wrasse (*Halichoeres semicinctus*), and treefish (Schultze 2001). Reefs in northern California tend to be dominated by a variety of rockfishes. Other species more common in northern than southern California include monkeyface prickleback, rock greenling and kelp greenling. Many reef-associated fish species are site tenacious and move little during their adult lives (Love 1996).

Juvenile Garibaldi
Photo credit: Danny Heilprin, SAIC

The distribution of eggs and larvae of reef fishes vary widely. Many species such as seniorita (*Oxyjulis californica*) and kelp bass release their eggs to the open ocean where eggs and larvae may drift relatively far from the coast before settling in the nearshore (Love 1996, CDFG 2001). Other species such as cabezon lay their eggs on rocky surfaces on the reef. Similarly, garibaldi build nests on the reef in which to deposit and tend eggs. Rockfishes develop the eggs inside their body and then release the larvae to the ocean. Surfperches are live bearers.

Life Stage and/or Function	California			On Land	Inter-tidal	Nearshore< 30 feet	Offshore > 30 feet	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X			X	X	E, P
Juvenile	X	X	X			X	X	E, P
Egg	X	X	X			X	X	E, P
Primary Habitat	X	X	X			X	X	E, P
Foraging Habitat	X	X	X			X	X	E, P
Nesting/ Spawning Habitat	X	X	X			X	X	E, P

Functions:

Several factors affect the diversity and abundance of fish associated with subtidal hard bottom habitats. Generally, higher relief reefs support more diverse communities than low relief reefs that experience excessive siltation or sand scour (Ambrose et al. 1989; also see

Section 3.2.5). Consequently, hard bottom areas within littoral depths (to beach depth of closure) are often less diverse due to greater disturbance from waves, sedimentation, turbidity than sublittoral reefs. Resource development is higher for vegetated than non-vegetated reefs; macroalgae provides food, structural complexity, refuge from predation, and spawning/nursery sites for fish (Foster and Schiel 1985, Levin and Hay 2002).

Reef fishes forage on vegetation, invertebrates and smaller fishes (Love 1996, CDFG 2001). Reef fishes, in turn, are prey for larger fishes, seabirds and marine mammals. Many reef fishes are popular sportfish for recreational fisherman and also are the target of commercial trap and hook and line fisheries (Schultze 2001).

Associated Species	Forage/ Prey	Eaten By
Invertebrates	X	
Fish	X	X
Birds		X
Vegetation	X	
Marine Mammals		X
Humans		X

The following reef descriptions provide examples of the range of fish resource development associated with nearshore reefs in California. Generally, relatively few species of fish have been reported from shallow nearshore waters (< 30 ft, < 9 m), as follows:

- 1 species - low-relief (< 3 ft, < 1 m) patch reefs surrounded by sand, 3 to 4 species - low relief reefs with surfgrass, 6 species - reef heights varied from low to high (> 3 ft, > 1m) with surfgrass at depths < 20 ft (6 m) offshore Cardiff and Solana Beach in San Diego County (MEC 1995 cited in MEC 2000a).
- 15 species - reconnaissance surveys of low to high-relief subtidal reefs at water depths ranging from 10 to 30 ft (3 to 9 m) offshore several beaches in San Diego County (USDN 1997a,b)

A greater variety of fish has been reported at sublittoral depths (e.g., > 30 ft, > 9 m). Over 100 species of fish have been reported to inhabit rocky reefs and kelp beds off California, however, the number of species associated with particular reef areas may vary depending on reef characteristics, presence of kelp, and location. The following examples provide relevant examples:

- 12 fish species - sand bottom in giant kelp bed at depths > 35 ft (11 m) offshore Corral Canyon, Santa Barbara, southern California (Chambers Consultants 1982).
- 22 fish species - mixed bottom, high-relief (maximum height 23 ft) siltstone reef, which lacked kelp, in 31 to 59 ft (9.5 to 18 m) depths offshore Corona Del Mar, southern California (Pequegnat 1964);
- 28 species - low relief (< 3 ft) cobble with kelp reefs at depths ranging from 33 to 49 ft (10 and 15 m) offshore San Onofre, southern California (Larson and DeMartini 1983);
- 23 to 26 species - giant kelp and bull kelp beds associated with high relief reefs (3 to 13 ft) off central California (Bodkin 1986);
- 46 species - high relief Naples Reef with kelp at depths ranging from 52 to 65 ft (16 to 20 m) approximately 1 mile offshore Santa Barbara, southern California (Ebeling et al. 1980);

- 17 species – Bureaucrat artificial reef made of large quarry rock, located at 40 ft (12 m) offshore Torrey Pines, southern California (Wilson et al. 1984 cited in Ambrose 1986).

Life History Facts:

Reef fishes display different reproductive modes depending on the species. Many species release pelagic eggs to the ocean. Some species such as garibaldi lay eggs in nests on the reef substrate. Rockfishes develop their eggs inside their bodies and release larvae to the ocean. Surfperch are livebearers. Considering all the different species of reef fishes, spawning occurs year round, although several species of fish display seasonal patterns of distribution and abundance related to kelp occurrence (Cross and Allen 1993, Love 1996, CDFG 2001). Depending on the species, the age of reproductive maturity can vary between 1 and 8 years. Many of the rockfish species do not reach maturity until they are 5 or 6 years old (CDFG 2001). The lifespan of reef fish ranges between about 7 years for senorita to as much as 50 years for sheephead (Love 1996, CDFG 2001).

Although some species of reef fishes are migratory, many are site tenacious and move little in their adult lives (Love 1996, CDFG 2001).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Nest Egg/Spawn	All year, peak coincides with kelp	All months Mature at 1 to 8 years old depending on species	N/A	Depends on species, many species don't migrate	From 7 to 50 years depending on species	Mobile

Adaptations and/or Behaviors to Disturbance:

Adult and juvenile fishes tend to react to disturbance by swimming away. However, some reef fishes are closely associated with the substrate and some such as giant kelp fish are cryptic. Therefore, if they leave their protected habitat in reaction to a disturbance they may become more vulnerable to predation. A variety of transient species also may frequent kelp/reef habitats such as albacore (*Thunnus alalunga*), dolphinfish (*Corphaena hippurus*), Pacific bonito (*Sarda chiliensis*), Pacific barracuda (*Sphyraena argentea*), skipjack tuna (*Katsuwonus pelamis*), and yellowfin tuna (*Thunnus albacares*).

The eggs of species that are pelagic spawners have no adaptations to disturbance. However, eggs deposited in nests on substrate would be protected from some disturbances. Finally, species such as rockfishes and surfperch that develop eggs inside their bodies provide considerable protection from disturbance.

Life Stage	Behavior			Habitat	High Reproductive Output
	Swim	Shelter	Transient migrants		
Adult	X	X	X	X	
Juvenile	X	X		X	
Egg/ Larvae				X	X

Potential Impacts from Sediment Management Activities:

Because subtidal reef fishes are so closely associated with reef habitat, the primary concerns are damage to habitat by equipment working offshore or burial of reef habitat. Damage to reefs from equipment can be avoided by pre-construction surveys and placement of equipment to avoid subtidal hard bottom habitat. Burial is addressed through pre-construction surveys to identify reef habitat and adjustment of sediment management activities to reduce the chances of sedimentation of reefs. After construction, there is often a requirement that reefs be monitored to determine whether any sediment burial has occurred. Impacts to subtidal reefs are discussed in more detail in Section 3.2.5.

Types of sediment management activities and potential impacts to subtidal reef fish may include:

- Maintenance dredging of embayments – equipment, turbidity.
- Offshore borrow site dredging – equipment, turbidity.
- Nearshore placement – equipment, burial, sedimentation, turbidity.
- Profile placement – equipment, burial, sedimentation, turbidity.
- Beach placement –sedimentation, turbidity..
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging		X		X	X	X
Growth						
Habitat			X	X		X
Reproduction /Recruitment		X		X		X
Respiration					X	

<u>Equipment</u>

Reef fishes could be affected by damage to rocky subtidal habitat and/or kelp beds from offshore sediment management activities. No reports of damage to habitats used by reef fish have been reported with sediment management projects in California. However, temporary movement of fish was reported from localized damage to coral reefs during offshore borrow site off the southeastern coast of the United States (Courtenay et al. 1972, see Section 4.2.8). Temporary fish displacement also was likely associated with localized damages to kelp or reef habitats from anchoring and/or pipeline placement involved in offshore oil development and construction projects off California (Chambers Planning Group 1982, Lissner et al. 1991, MEC 1995). Temporary displacement of reef fish may increase

vulnerability to predation, particularly early demersal stages (Lindeman and Snyder et al. 1998).

Damage to reef habitats by offshore equipment can be avoided by pre-construction surveys to identify mooring, anchor, and pipeline locations as well as vessel access routes that avoid sensitive habitat. For example, prior to the Goleta beach nourishment project an underwater survey was conducted to identify pipeline and mooring locations that would avoid significant subtidal habitat (Moffatt & Nichol 2005c).

Reef fish may be sensitive to noise disturbance. Relevant reports indicate reef fish use noise as a cue for orientation and recruitment to reefs. Hammer et al. (2005) stated that change in noise levels may mask sounds that reef fish otherwise use for feeding and reproductive activities (Stobutzki and Bellwood 1998, Tolimieri et al. 2000, Myrberg and Fuiman 2002, Montgomery et al. 2006). The effects of noise from dredge operations on reef fish have not been studied; however, noise levels produced by dredges may disturb fish depending on distance from the source (Section 5.3.2.6). University of California at Santa Barbara divers have observed reef fishes to scatter briefly in response to vessel noise (Chambers Group 1988). Experiments investigating fish response to very loud noise (seismic air guns) indicate that reef fish are site tenacious (Wardle et al. 2001 cited in Hastings and Popper 2005). Therefore, permanent displacement of reef fish would not be expected from dredging operations. A concern with dredging near reefs would be exceedance of noise thresholds that may interfere with reproduction and/or recruitment. This may be more of concern with anchored dredging than trailing suction dredging. However, no information is available with respect to adverse noise thresholds for reef fish.

Burial/Sedimentation

Nearshore and/or profile placement has the potential to bury subtidal reef, if present. Beach placement potentially could result in sedimentation of nearshore reefs, if present, from erosion of the beach fill and littoral transport of placed sands. Limited information is available on impacts to subtidal reef fish from burial and/or sedimentation effects.

No studies of impacts to reef fish after California sediment management projects have been conducted. Two relevant monitoring studies of hard bottom habitats in the vicinity of beach nourishment projects off Goleta Beach, Santa Barbara County and off San Diego County suggest that potential impacts to fish were probably limited.

Subtidal reefs with kelp beds were monitored before and quarterly for 1 year after the Goleta Beach Nourishment Demonstration project, which placed 79,000 cy on the beach; results indicated no obvious sedimentation impacts (see Section 3.2.6).

AMEC (2005) monitoried kelp and reef habitat before and for four years following the 2001 San Diego Regional Beach Sand Project and did not report any significant effects on nearshore reef or kelp habitat or indicator species (several species of kelp, algae, invertebrates) attributed to the project (AMEC 2005). Approximately 2 million cy of sand was placed at 11 San Diego beaches; volumes ranging from 101,000 to 225,000 cy were placed at some beach sites in areas of coastline with nearshore reefs and offshore kelp beds. Changes in sand cover following the sand replenishment project were similar to natural sand movement for the area. Nearshore reefs included low to high relief (< 3 to > 3 ft, < 1 to > 1 m) substrate that was discontinuous; i.e., separated by sand channels that ran perpendicular to shore. AMEC (2005) suggested that the sand channels may have provided

avenues for sand movement, decreasing the likelihood of impacts from sand scour and burial of nearshore reefs. No substantial sedimentation was observed in offshore kelp beds, which experienced increased recruitment after sand placement, probably in response to oceanographic conditions.

In contrast, Lindeman and Snyder (1999) documented substantial impact to nearshore fish from sedimentation that resulted in substantial burial of hard bottom outcrops offshore a beach nourishment project at Carlin Park, Florida. More than 457,800 cy (350,000 cm) of beach-compatible sediments were excavated by a cutterhead dredge from an offshore borrow site and hydraulically pumped along 1.1 mi (1.8 km) of shoreline. Bulldozers extended the fill seaward to an estimated width of 197 ft (60 m). It was estimated that the project impacted 12 to 14 acres (4.9 to 5.7 ha) of nearshore with hard bottom outcroppings. Hard bottom consisted of limestone outcrops (also termed *Anastasia* formation outcroppings, coquina reefs, worm reefs) between depths of 0 and 13 ft (0 and 4 m), some of which extended 5.7 ft (1.75 m) above the bottom; sand comprised approximately 35% of the area within all surveyed transects.

Visual surveys (transects) of nearshore fish were conducted for 12 months prior and 15 months after construction at depths ranging from 3.2 to 13 ft (1 to 4 m) offshore the beach fill and at a physically similar site approximately 2.5 mi (4 km) north (Lindeman and Snyder 1999). Transects were randomly selected during each survey. Fish were counted by species and life stage (adult, juvenile, early juvenile and newly settled). The project was conducted in March-April, and hard bottom was substantially buried throughout the spring-summer and only partially exposed after winter erosion. Burial of the nearshore hard bottom habitat significantly lowered both the number of fish species and the number of individuals. After one year, fish abundance was reduced by 30 times and the number of species by 10 times compared to before project and a control site.

Lindeman and Snyder (1999) concluded that although some buried outcroppings were uncovered by the following winter erosion, structural support for two years of larval recruitment, shelter from post-settlement predation, and food for growth were probably eliminated from the impacted site. Impacts were considered exacerbated by limited alternate nearshore hard bottom in the vicinity of the impact site; the closest natural reef was at depths of at least ft 33 ft (10 m), the nearest shallow water hardbottom was at least 4 km to the south, and artificial hard bottom (jetties) was located 1.2 mi (2 km) to the north. A total of (1.6 ha) of mitigation reefs were constructed three years later to compensate for impacts. The authors concluded that dredging effects of sand placement on reef fish populations may be amplified by burial prior to and during spring and summer periods of peak larval recruitment. They also suggested that in areas where hard bottom is limited, construction of mitigation reefs prior to construction may provide refuge for displaced fish as well as sites for recruitment; however, even with prompt construction, many factors can limit artificial reef net productivity and biomass. A risk-averse approach to hard bottom burial was recommended.

Lindeman and Snyder (1999) reviewed that the monitoring study did not support many of the impact assumptions stated in the project EIS. Primary predicted impacts to fish included (1) short-term displacement during construction, and (2) temporary loss of food resources. The EIS also reported that impacts would be reduced by (1) the fishery value of impacted species being low, (2) some hard bottom would remain or would be constructed for mitigation if needed, and (3) construction would take place when fish populations were at their lowest. The monitoring study showed that many of the fish associated with the

hardbottom habitat were early life stages of economically and ecologically valuable species, displacement was considered permanent for most individuals because of the substantial reduction in hardbottom habitat and distance from other alternate hard bottom that probably contributed to high mortalities, and project timing during a seasonal low was insignificant since habitat was buried during the spring-summer recruitment period. In addition, loss of reef-associated food resources from burial was considered substantial.

Turbidity

Limited information is available on response of reef fish to turbidity. Courtenay et al. (1972) reported displacement of reef fish during offshore borrow site dredging off Florida.

Reef fishes may be more vulnerable to turbidity than water column and soft bottom fishes, because they tend to be site tenacious and many species are cryptic, relying on their resemblance to vegetation or rocks for protection. Ebeling (personal communication to N. Davis, July 2005) has noted that fishes on southern California reefs become skittish under turbid conditions. If reef fish have to leave their protective habitat to avoid turbidity, they may become more vulnerable to predation.

No laboratory studies of turbidity effects on reef fish have been conducted. Laboratory studies on other estuarine and coastal fishes have observed lethal effects at dosages as low as several hundred mg/L for 24 hours to no effect at concentrations above 10,000 mg/L for 7 days (Clarke and Wilber 2000). Indirect effects might include interference with feeding, protection from predation, and avoidance of turbid areas (DeRobertis et al. 2003, Wilber and Clarke 2001).

Recovery from Disturbance:

Recovery of the reef fish community from the effects of equipment, burial and sedimentation will depend on the extent of habitat damage and the recovery of the reef itself. Recovery from any temporary disturbance from the noise and lights of offshore vessels would be expected to occur as soon as the equipment leaves the area. If rocks are broken or damaged by anchors, moorings, pipelines or chains, a portion of the reef may be of lower value to reef fishes until recovered. Studies after artificial reef construction indicate colonization ranges from rapid (days) for the less site-tenacious fish species to up to two years for most, typical species (Davis et al. 1982). Recovery from damage would be expected to be less than that required for colonization of newly created habitat.

Sedimentation impacts would depend on magnitude of effect. Direct burial of sensitive reef habitat would not be expected, but could indirectly occur from sand transport sedimentation. Sedimentation effects could range from no effect, reduction in vegetation, to loss of shelter and/or damage to eggs. Burial of ephemeral reefs may occur. The duration of sedimentation and/or burial effects would depend on magnitude of effect and coastal processes, and could range from one to several years.

Turbidity effects generally would be limited to the construction period, but actual exposure duration would vary depending on project- and site specific conditions. High levels would not be expected unless there was dredging or discharge in the immediate vicinity of a reef. No significant impacts would be expected unless prolonged turbidity resulted in a decline in vegetation and associated invertebrates. Recovery rates of marine vegetation may be fairly rapid once water quality improves.

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	After cessation of activities	X			
Burial	X	X	X		
Sedimentation	X	X	X		
Turbidity	After cessation of activities			X	
Habitat Loss		X	X		

Critical Impact Thresholds:

No critical impact thresholds have been established for reef fish. Burial and/or substantial sedimentation that resulted in habitat loss could displace reef fish and increase their vulnerability to predation and/or result in reduction in local populations.

Data Gaps:

Field studies of the sensitivity of reef fishes to turbidity would be helpful to determine whether reef fishes actually are more vulnerable to turbidity than fish species not closely tied to a particular location.

Restoration:

Loss of reef habitat can be addressed through creation of artificial reefs. Lost kelp may be restored successfully through transplants although sand based kelp has proved difficult to restore. Restoration of surfgrass has proved difficult.

Summary:

Because reef fishes are strongly associated with the physical attributes of their reef, they are vulnerable to physical damage to the habitat either by offshore equipment or sedimentation. Relevant reports indicate damage to hard substrate and kelp may occur from the activities associated with dredging, anchoring, and pipeline placement (Courtenay et al. 1972, Chambers Group 1982, Lissner et al. 1991, MEC 1995). Recovery from localized damage depends on extent of impact and existing conditions, but generally would be expected over days to months. Equipment damage can be avoided by pre-construction surveys and placement of equipment to avoid sensitive habitat.

Indirect burial of reefs from beach nourishment has been demonstrated with some projects in Florida. Minimization of effects below significant levels also has been demonstrated in California and Florida. Project location and size appear to be important considerations for avoiding significant impacts. Recovery from sedimentation effects would depend on magnitude and duration of effect, ranging from < 1 year if sedimentation was not persistent to several years if there was habitat loss. Artificial reefs generally have been constructed on the East Coast to compenstate for buried reefs and lost reef functions.

Turbidity associated with sediment management activities generally is limited to the period of construction, ranging from days to months. Turbidity effects would depend on magnitude

of effect, and could range from no effects, displacement, to sublethal or lethal effects depending on concentration. High levels would not be expected unless there was dredging or discharge in the immediate vicinity of a reef. Turbidity may result in lower foraging efficiency of reef fish. If turbidity caused cryptic reef fishes to abandon protective habitat, they could become more vulnerable to predation. No significant impacts would be expected unless prolonged turbidity occurred and resulted in reduction in marine vegetation and associated invertebrates.

Reef fish may be more susceptible because of their high site fidelity to noise disturbance from dredging activities than pelagic or demersal fish. Relevant reports indicate that reef fish are sensitive to change in noise level. Noise levels produced by dredges are below thresholds that cause injury, but noise disturbance may be a concern if prolonged.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on subtidal reef fish.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Relevant reports	Protective conservatism	Documented	Relevant Reports
Critical Impact Thresholds	NA	Impair recruitment	Habitat loss	Degrade food base, habitat loss	Impair recruitment
Impact Responses	NA	Displacement, increased predation risk	Displacement, increased predation risk	Displacement, increased predation risk, reduction in forage	Displacement, impair feeding, sublethal to lethal effects at high levels
Duration of Impacts	NA	Days-years	Months-years	Months-years	Hours-months
Potential for Restoration	NA	Unnecessary	Artificial reef, kelp transplant	Artificial reef, kelp transplant	Unnecessary

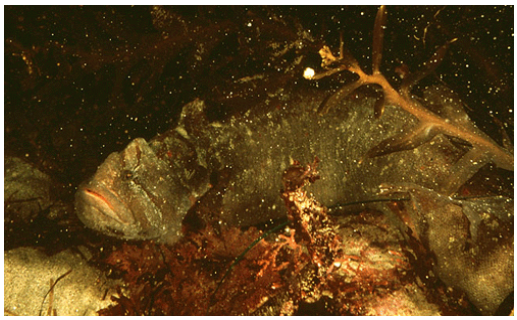
NA = not applicable

4.3.7 Tidepool Fish

Species Scientific Name	**Various Species and Families**

Regulatory Status:

Endangered	
Threatened	
CDFG Managed	Monkeyface prickleback



Monkeyface prickleback
Photo credit: Daniel Gotshall

The monkeyface prickleback (*Cebidichthys violaceus)*, a shallow subtidal and intertidal fish, is managed under the California Nearshore Fisheries Management Plan.

Description and Distribution:

The rocky intertidal is a stressful environment for fishes which most cope with the turbulence of wave shock and the physiological stresses associated with the ebb and flow of the tide (Cross and Allen 1993). Because of the rigorousness of the intertidal environment, a limited number of fish species are true residents of the rocky intertidal.

Life Stage and/or Function	California			On Land	Inter-tidal	Nearshore < 30 feet	Offshore > 30 feet	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X		X	X		E, P
Juvenile	X	X	X		X	X		E, P
Egg	X	X	X		X	X		E, P
Primary Habitat	X	X	X		X			E, P
Foraging Habitat	X	X	X		X			E, P
Spawning Habitat	X	X	X		X			E, P

Only six species are residents of the rocky intertidal in southern California (Cross and Allen 1993, Cross 1982). These species are California clingfish (*Gobiesox rhessodon*), wooly sculpin (*Clinocottus analis*), rookpool blenny (*Hypsoblennius gilberti)*, reef finspot (*Paraclinus integripinnis*), spotted kelpfish (*Gibbonsia elegans*) and juvenile opaleye (*Girella nigricans*). These species are mainly common from central California south (Love 1996, Eschmeyer et al. 1983). Several species tend to be habitat specialists (Cross 1982).

The diversity of tidepool fishes increases in central and northern California with 14 resident species typical of central California (Cross 1982). Tidepool fishes more common from central California north include crevice kelpfish (*Gibbonsia montereyensis*), black prickleback (*Xiphister atropurpureus*), ribbon prickleback (*Phytichthys chirus*), rock prickleback (*Xiphister mucosus),* fluffy sculpin *(Oligocottus snyderi*) and monkeyface

prickleback (*Cebidichthys violaceus*) (Chambers Group 1980, Love 1996, Eschmeyer et al. 1983).

Functions:

Associated Species	Forage/ Prey	Eaten By
Invertebrates	X	
Fish		X
Birds		X
Vegetation	X	
Marine Mammals		
Terrestrial Animals		
Humans		

Most intertidal fishes eat invertebrates and algae (Love 1996). Intertidal fishes are eaten by birds and larger fishes.

Life History Facts:

Most resident intertidal fishes have adhesive eggs that they lay on rock or vegetation (Love 1996). Some species have nests that are tended. Primary residents of the intertidal spend all but their larval existence in the intertidal (Cross 1982). Opaleye shed eggs into the water column (Love 1996). Opaleye spend their first 1 to 2 years of life in tidepools and then move out into the subtidal. Considering the various species, spawning by tidepool fishes occurs year round.

The age that tidepool fishes mature ranges from 1 year for wooly sculpin, fluffy sculpin and tidepol sculpin to 4 to 7 years for monkeyface prickleback (Love 1996). With the exception of opaleye, resident tidepool fishes spend all of their lives except their larval stage in tidepools and some species have been found to have the ability to return to specific tidepools (Cross and Allen 1993). The life span of tidepool fishes ranges from about 1.5 years for fluffy sculpin to 18 years for monkeyface prickleback (Love 1996).

Tidepool fish are mobile and may move among rockpools during high-tide excursions (Griffiths et al. 2004). However, movement may be within a limited home range. One study showed that monkeyface prickleback are site tenacious, with movement less than 15 ft (3 m) (cited in Love 1996).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Nest Egg/Spawn	All Year	Mature at 1 to 5 Years	N/A	None	1.5 to 18 years	Mobile

Adaptations and/or Behaviors to Disturbance:

Tidepool fish have morphological and physiological adaptations for life in a harsh environment and to temporarily cope with adverse conditions (Gritffiths et al. 2004). Juvenile and adult tidepool fishes generally swim away and/or seek shelter among crevices and/or vegetation (*ibid.*). Tidepool fishes are adapted to living and depositing their eggs in a rigorous habitat that many species cannot tolerate.

Life Stage	Behavior			Habitat	High Reproductive Output
	Swim	Shelter			
Adult	X	X	X	X	
Juvenile	X	X		X	
Egg/ Larvae				X	X

Because seasonal sand movement is common in California intertidal habitats, it is assumed that tidepool fishes can withstand some degree of sedimentation. However, Cross (1982) noted lower abundance of intertidal fishes associated with sedimentation in Washington.

Potential Impacts from Sediment Management Activities:

The primary concern for tidepool fishes is burial of their habitat. Direct burial of significant rocky intertidal generally is avoided. Rocky intertidal areas in the vicinity of sediment management activities often are monitored, but no program has monitored tidepool fishes following sediment placement.

Types of sediment management activities and potential impacts to tidepool fish may include:

- Maintenance dredging of embayments – not applicable
- Offshore borrow site dredging – not applicable
- Nearshore placement – turbidity.
- Profile placement – equipment, burial, sedimentation, turbidity.
- Beach placement – equipment, burial, sedimentation, turbidity.
- Dune placement – sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging				X	X	X
Growth				X		X
Habitat				X		X
Reproduction				X		X
Respiration					X	

<u>Equipment</u>

Although theoretically tidepool fishes could be disturbed or injured by equipment involved in sediment management activities, it is unlikely that equipment would work in the high relief mid to low intertidal areas inhabited by tidepool fishes. Direct disturbance of well developed rocky intertidal areas with tidepools is unlikely to be permitted in California because of the sensitive status of the habitat. If disturbance were to occur, the effect could range from temporary disturbance (Griffiths et al. 2004) or increased vulnerability to predation.

Pre-construction environmental surveys were used to finalize pipeline routes to avoid direct impacts to sensitive rocky reef resources during the 2001 San Diego Regional Beach Sand Project (AMEC 2002) and 2003 Goleta Beach Demonstration Project (Chambers Group 2003, Moffatt & Nichol 2003). Pre-construction surveys to finalize pipeline routes in areas

with intertidal reefs have been recommended as a beach nourishment mitigation measure (Chambers 1992, 2000b).

Burial/Sedimentation

Beach nourishment could result in burial and/or sedimentation of rocky intertidal habitat, if present within the project area of potential effect. Burial could result in loss of habitat for tidepool fish. Sand transport sedimentation also could result in habitat loss if substantial, reduced habiatat quality, and/or damage to early life stages (e.g., eggs laid on substrate damaged and/or buried by sedimentation). Natural sedimentation and/or substrate instability has been associated with lower numbers of intertidal fish species compared to unaffected sites (Cross 1982).

Direct burial of sensitive rocky intertidal areas is unlikely to be permitted in California. Several California beach nourishment projects have been designed during project planning to avoid direct placement of sand in areas with persistent rocky intertidal (Tekmarine and Analytic Planning Service 1990; Chambers 1992; USDN 1997a,b; SANDAG and USDN 2000; Moffatt & Nichol 2001).

No monitoring studies have examined the effects of sediment management activities on tidepool fishes. Two relevant monitoring studies of hard bottom habitats in the vicinity of beach nourishment projects off Goleta Beach, Santa Barbara County and off San Diego County suggest that the potential to impact tidepool fish would have been temporary and/or limited.

Intertidal reefs were monitored before and quarterly for 1 year after the Goleta Beach Nourishment Demonstration project. Sediment deposition was observed during the first year of monitoring at intertidal sites 6,500 ft (2000 m) to 7,874 ft (2,400 m) downcoast of the Goleta Beach Nourishment Demonstration Project, which placed 79,000 cy of sand onto the beach and was followed by an additional project with 18,600 cy of sand placement (Moffatt & Nichol 2005c). However, increased sand depth and cover was only observed during one survey at each of the two monitoring sites and sand changes were within natural variability shown at the site prior to beach nourishment (also see Sections 3.3.4, 3.3.7). Chambers Group (2004) concluded that the beach nourishment project may have had a temporary impact on rocky intertidal habitat, but does not appear to have caused any long term change. Although no monitoring was done of intertidal fishes, any impact would have been temporary since sand moved out of the area within a few months.

No direct burial of intertidal reefs occurred with the 2001 San Diego Regional Beach Sand Project, although some placement occurred in areas with cobble and/or sand scoured low relief rocks with few biological resources (SANDAG and USDN 2000). No obvious sedimentation impact to rocky intertidal reef attributable to the 2001 San Diego Regional Beach Sand Project was reported based on comparison of pre-construction and four years of post-construction monitoring data (Engle 2005). Monitoring was conducted at an intertidal rocky reef 3,400 ft (1,000 m) downcoast of a receiver site that received 101,000 cy of sand and at comparative locations outside the littoral cell where beach nourishment occurred. Although some changes in densities of target species (algae, invertebrates) were observed and attributed to changes in sand levels, the effects were considered within the range of measured natural variation and no obvious impacts from the beach nourishment project were reported (Engle 2005). Because no significant change in habitat quality of the

intertidal reef was reported, there is no reason to suspect a significant impact occurred to tidepool fish from the project.

Lindeman and Snyder (1999) reported temporary to prolonged burial of low intertidal to shallow subtidal reefs from a beach nourishment project in Florida (Section 4.3.6).

Turbidity

No laboratory studies of turbidity effects on tidepool fish have been conducted. Available laboratory studies indicate a general trend in tolerance with the most tolerant species found near the sediment-water interface and decreasing tolerance as association with the bottom decreases (Wilber and Clarke 2001). Because tidepool fishes live in the turbulent surf zone, where sediments frequently are resuspended, they likely are tolerant of turbidity. Therefore, it is unlikely that tidepool fishes would be killed by suspended sediments from beach nourishment activities. Because tidepool fishes are closely associated with the tidepool habitat, if they left their tidepools to avoid a turbidity plume, they might become more vulnerable to predation.

Tidepool fishes feed on invertebrates or algae associated with the substrate. No adverse effects would be expected from short-term exposures to turbidity. No significant impacts would be expected unless prolonged turbidity occurred and resulted in reduction in marine vegetation and associated invertebrates.

Recovery from Disturbance:

Tidepool fish assemblages have been shown to begin recolonization of rockpools immediately after disturbance with recovery of the pre-disturbance assemblage generally within 1 to 3 months (Griffiths et al. 2004). Recolonization has been showen to be mainly by movment of subadults and adults from adjacent rockpools (within meters of each other), although larval recruitment may sometimes play a significant role in population replenishment. Griffths et al. (2004) found recovery rates to be slower when rockpools were significantly farther apart than a few meters.

No information is available on the rate of recovery of the intertidal fish assemblage from sedimentation. It is likely that the rate of recovery would depend on the extent of burial and the proximity of unburied rocky intertidal habitat with a tidepool fish assemblage to serve as a colonization source. Recovery rates could range from < 1 year for minor sedimentation to > 3 years if it was substantial. Permanent burial would result in habitat loss for tidepool fish.

Turbidity effects generally would be limited to the construction period, but actual exposure duration would vary depending on project- and site specific conditions. No significant impacts would be expected unless prolonged turbidity resulted in a decline in vegetation and associated invertebrates. Recovery rates of marine vegetation may be fairly rapid once water quality improves.

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	After cessation of activities	X			
Burial	X	X	X		
Sedimentation	X	X	X		
Turbidity	After cessation of activities			X	
Habitat Loss		X	X		

Critical Impact Thresholds:

No critical impact thresholds for sedimentation and/or turbidity have been established for tidepool fishes. Burial and/or substantial sedimentation that resulted in habitat loss could displace tidepool fish and increase their vulnerability to predation and/or result in reduction of local populations.

Data Gaps:

Information on the recovery of intertidal fishes from burial/sedimentation would be useful to determine whether temporary burial/sedimentation of tidepool habitat has significant impacts on this community.

Restoration:

It may be possible to create rocky intertidal habitat although successful restoration of tidepools has not been done.

Summary:

Equipment involved in beach nourishment is highly unlikely to be working in the mid to low rocky intertidal areas where tidepool fishes live. If equipment impacts were to occur, they could result in localized habitat disturbance and/or mortality of individual animals. Project design avoidance and/or pre-construction surveys to finalize pipeline routes have been used to avoid direct and minimize indirect impacts to sensitive rocky intertidal habitats.

Tidepool fishes potentially could be impacted by sediment nourishment activities if rocky intertidal habitat is buried either directly or by movement of sediment along the coast. Recovery of tidepool fishes from burial and/or sedimentation has not been studied, but probably would depend on the extent and duration of sedimentation and proximity of unaffected tidepool fish assemblages for colonization. It may be possible to re-create tidepool habitat if it is permanently lost, but restoration of tidepools has not been demonstrated.

Turbidity associated with sediment management activities generally is limited to the period of construction, ranging from days to months. Turbidity effects would depend on magnitude of effect, and could range from no effects, displacement, to sublethal or lethal effects depending on concentration. Because tidepool fishes are adapted to the naturally turbid surf zone, they would be expected to be able to tolerate considerable turbidity. However,

because tidepool fishes tend to be cryptic and closely associated with the substrate, if they left an area to avoid turbidity, they could become more vulnerable to predation.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on tidepool fish.

ssue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Protective conservatism	Protective conservatism	Protective conservatism	Relevant Reports
Critical Impact Thresholds	NA	Rocks overturned Mortality	Habitat loss	Degrade food base, habitat loss	Mortality
Impact Responses	NA	Displacement, increased predation risk	Loss of habitat. Damage to eggs	Displacement, increase predation risk, reduction in forage, damage to eggs	Displacement, impair feeding, sublethal to lethal effects at high levels
Duration of Impacts	NA	Days-years	Months-years	Months-years	Hours-months
Potential for Restoration	NA	Unnecessary	Feasible, but not demonstrated	Feasible, but not demonstrated	Unnecessary.

NA = not applicable

4.4 Review of Bird Species Responses to Natural Disturbance and Sediment Management Activities

4.4.1 California Brown Pelican

Species Scientific Name	***Pelecanus occidentalis californicus***

Regulatory Status:

Endangered	State, Federal
Threatened	
CDFG Managed	
Essential Fish Habitat	
Other	
None	

Public domain credit: NOAA

California brown pelican is a state and federal listed endangered species.

Description and Distribution:

Primary habitat for brown pelicans varies along the coast of California. California brown pelicans breed on Anacapa and Santa Barbara Islands off the coast of southern California, on islands off Mexico, and a few nest at the south end of the Salton Sea, southern California (Patten et al. 2003, CDFG 2005c). Although breeding habitat is limited and localized off southern California, this species forages and rests/roosts throughout California.

Life Stage and/or Function	California			On Land	Intert-idal	Nearshore < 30 feet	Offshore > 30 feet	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X	X	X	X	X	E, P
Juvenile	X	X	X	X	X	X	X	E, P
Egg	X			X				Islands
Primary Habitat	X			X		X		E,P
Foraging Habitat	X	X	X			X	X	E, P
Nesting/ Habitat	X			X				Islands
Resting/ Roosting Habitat	X	X	X	X				E,P

Brown pelicans roost on islands, offshore rocks, breakwaters and other structures (piers, pilings etc), rocky intertidal areas, mudflats, and beaches. Communal roost sites are essential habitat for brown pelicans at all times of year, throughout their range (American Trader Trustee Council 2001).

Brown pelicans do not have wettable plumage and must come ashore regularly to dry and restore their plumage. Roost site selection is based on proximity to prey resources, isolation from potential predators and human disturbance, and microclimate features that aid in thermoregulation. In northern and central California, primary roosting habitat consists of offshore rocks and natural substrates in estuaries (Jaques and Strong 2000).

In southern California, artificial structures support the majority of roosting pelicans (Jaques and Strong 2000). Particularly important brown pelican roosting areas in southern California include the Zuniga Point jetty, man-made structures in Aqua Hedionda Lagoon, the Dana Point Harbor jetty, the Los Angeles and Long Beach Harbor breakwaters, the Marina del Rey breakwater, the Santa Clara River mouth, the Ventura Harbor breakwater, Rincon Island, an abandoned barge in Santa Barbara Harbor as well as the beach at Point Castillo, and an abandoned oil pier (Bird Island) in the Ellwood Oilfield Complex in Santa Barbara. Large numbers of brown pelicans also roost at Mugu Lagoon (Jaques et al. 1996).

Long Beach Harbor
Photo credit: Karen Green

Important roosting sites in central and northern California include the Farallon Islands in San Francisco County, Ano Nuevo Island in San Mateo County, Point Reyes and Point Bonita in Marin County, and Pacific Grove, Carmel and Point Loma in Monterey County (Thelander 1994)

During the late 1960's and early 1970's, the brown pelican population suffered a widespread decline linked to egg shell thinning caused by the pesticide DDT in their food chain. The California population, estimated at approximately 5,000 pairs prior to 1960, declined to 597 pairs in 1973 (Anderson et al. 1975). Following the ban of DDT and protection and management by the National Park Service at the Channel Islands, the population recovered to its former numbers. For example, on West Anacapa Island in 1999 3,020 young were fledged from about 5,300 nest attempts (Gress 2001).

Potential Functions:

California brown pelicans are top predators. Brown pelicans forage primarily in nearshore and offshore waters along the mainland or along the coasts of islands. Pelicans feed primarily on small surface-schooling fishes, particularly northern anchovy and sardines (Jaques et al. 1996). Brown pelicans are plunge divers. They fly above the water until they see accessible prey and then swoop down and capture the prey in their bills (Cogswell 1977). Pelicans primarily forage within 6 mi (10 km) of shore (http://www.natureserve.org).

Associated Species	Forage/ Prey	Eaten By
Invertebrates		
Fish	X	X
Birds		X
Vegetation		
Marine Mammals		
Terrestrial Animals		X
Humans		

Brown pelican adults have few predators, although once in a while a shark will attack when they dive (http://www.fws.gov/sacramento/es/animal_spp_acct/ca_brown_pelican_kf.htm). Eggs are vulnerable to predation from other birds, raccoons, cats, and dogs.

Life History Facts:

California brown pelicans generally arrive on their colonies and begin nest building in January of each year; however, the timing of breeding in this species is highly variable (Hunt et al. 1981). Egg laying usually begins in February and continues through early May. Pelican eggs require approximately 30 days of incubation, so the chicks hatch from late March to June. The young fledge approximately 9 weeks after hatching and most leave the breeding colony by late August. Brown pelicans first breed at 3 to 5 years old (Ehrlich et al. 1988, Brinkley and Humann 2001). Brown pelicans are long-lived, the oldest record is 27 years old (Brinkley and Humann 2001).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Nest	February-August	Females don't breed before third year; males even later	NA	S. CA May-Octr C and N. CA Jul-Oct	Years > 25 years	Mobile

NA = not applicable

Seasonal changes in abundance of brown pelicans in California are due primarily to the migration of birds from the Mexican breeding colonies (Small 1994). Beginning about mid-May, birds from the Mexican colonies (including many immature individuals) increase pelican abundance along the southern California coast and the Channel Islands until about early November, when many pelicans depart for Mexico.

Post-breeding visitors from both the southern California and Mexican colonies disperse to central and northern California from with peak numbers in July through September. Pelicans occur in the Humbolt Bay complex in August through October (http://www.whsrn.org/HumboldtBayComplex/conservation.html). By mid-October, birds start to return to their breeding colonies. Along the southern California coast, numbers are substantial throughout the year (Small 1994).

Adaptations and/or Behaviors to Disturbance:

Brown pelicans protect themselves, their eggs, and their young from disturbance during the breeding season by nesting on steep cliffs of offshore islands. Juveniles spend time between hatching and fledging on remote offshore islands. Brown pelicans prefer to roost in remote locations where they will not be disturbed. Undisturbed natural roosting locations include islands, offshore rocks, remote beaches, and rocky headlands. Brown pelicans also may be observed in areas in closer proximity to human activities on man made structures such as breakwaters, jetties, piers, docks, and pilings.

Although brown pelicans may adapt to a regular level of disturbance, they generally congregate at the ends of jetties or on offshore structures where human disturbance and vulnerability to terrestrial predators are minimized. Brown pelicans may react to disturbance by shifting postion, flushing, or flying away.

Life Stage	Behavior			Habitat
	Flush	Fly	Migrate	
Adult	X	X	X	X
Juvenile	X	X	X	X
Egg/Chick				Steep cliffs

Human disturbance is an important factor in the suitability of roosting and nesting habitat. However, variability in threshold distances of disturbance vary and may be attributed to levels of disturbance to which pelicans are routinely exposed (Anderson 1988). Collazo et al. (1995) reviewed that available information suggests human disturbance should be limited within 328 to 1,968 ft (100 to 600 m) of roosting or nesting site.

Potential Impacts from Sediment Management Activities:

The primary concern about the impacts of sediment management activities on California brown pelicans is disturbance to their roosting sites. A secondary concern is that turbidity from sediment management activities could interfere with brown pelican foraging. However, because sediment management activities would not be expected to occur near the island breeding colonies of brown pelicans, turbidity in a small portion of non-breeding foraging habitat is unlikely to have a significant adverse impact.

Types of sediment management activities and potential impacts to pelicans may include:

- Maintenance dredging of embayments – equipment, turbidity.
- Offshore borrow site dredging – turbidity.
- Nearshore placement – turbidity.
- Profile placement – equipment, turbidity.
- Beach placement – equipment, turbidity.
- Dune placement – not applicable.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging					X	
Growth						
Habitat						
Reproduction						
Resting/ Roosting	X	X				

Equipment

Brown pelicans are sensitive to human disturbance and are particularly sensitive to sudden loud noises or direct light. The USFWS required that brown pelican behavior be monitored during dredging within 270 ft (80 m) of an important roosting site on the Marina Del Rey Breakwater. Punctuated events such as dredge start-up after periods of inactivity, illuminating the breakwater by the dredge after long periods of inactivity, and a tugboat passing between the dredge and the breakwater to retrieve the haul barge caused disturbance to the colony including movements of occasionally large numbers of birds (Varanus 1999). These impacts resulted in pelicans shifting positions or flushing and returning to the breakwater after several minutes. Pelicans otherwise did not appear to be disturbed by more continuous dredging operations.

Other unusual, sudden, or infrequent events of a dramatic nature (fireworks, spotlighting the colony by a boat closely approaching the breakwater) displaced roosting pelicans from the breakwater for several minutes. The largest reaction to disturbance observed during the monitoring was to an earthquake. All the pelicans left the breakwater in reaction to the event and did not return for 45 minutes (Varanus 1999).

Monitoring of the reaction of brown pelicans to disturbance at Mugu Lagoon found results similar to the Marina del Rey study (Jaques et al. 1996). The most pronounced reaction to disturbance was generated by gunshots from duck hunters. Gunshots from blinds in the interior of the estuary caused pelicans to flush from and depart from their night roosts. Approach by persons, especially those walking dogs, caused pelicans to flush. Most pelicans flushed by pedestrians or dogs relocated a short distance to other nearby roost sites. On the other hand, heavy equipment operation and rip-rap installation to control erosion on the north side of a parking lot near a roost site did not seem to cause disturbance to pelicans within 328 ft (100 m) of the operation.

In San Francisco Bay, the long-term management strategy for the placement of dredged materials requires consultation for sediment management activities if within 300 ft (91 m) of large, communal pelican roost sites between July and September when pelicans are most abundant in the area (USACE et al. 2001).

Turbidity

Pelicans are visual feeders. They fly above the water at a height up to 20 to 40 ft (66 to 131 m) until accessible prey (usually schooling fish) are sighted, then plunge dive to capture the fish (Cogswell 1977). Because pelicans need to see their prey to catch it, turbidity could interfere with pelican foraging. However, the level of turbidity that would impede pelican feeding has not been documented.

Recovery from Disturbance:

Observations of pelicans on the Marina del Rey breakwater indicated that the reaction to activities associated with dredging was short-term (Varanus 1999). In most cases the pelicans flew away from the breakwater or moved to another part of the breakwater but returned within a few minutes. No impacts to roosting brown pelicans from beach nourishment activities have been documented.

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	After cessation of activites				
Burial					X
Sedimentation					X
Turbidity	After cessation of activites				
Habitat Loss					X

Information is sparse regarding response of brown pelicans to turbidity associated with beach nourishment projects. AMEC (2002) monitored bird behavior in response to offshore dredging and beach nourishment during the 2001 San Diego Regional Beach Sand Project. Turbidity plumes characterized by Secchi disk depths of ≤ 3 ft (1 m) were required to not extend more than 2.47 ac (1 ha) to avoid significant impacts to brown pelican and least tern foraging. Temporary sand dikes were used to control turbidity of return water at the beach and plume criteria were rarely exceeded. No obvious impacts to seabird or shorebird behaviour during sediment management activities were reported.

Critical Impact Thresholds:

No thresholds for activity, noise, or light disturbance have been established for brown pelicans. A buffer distance of 300 ft (91 m) is specified between dredge operations and communal roosts when pelicans are present in San Francisco Bay (USACE et al. 2001). Collazo et al. (1995) suggests disturbance distances should be on the order of 300 to 1,968 ft (100 to 600 m) of roosting and nesting sites, and points out that thresholds appear to vary depending on disturbance levels routinely experienced by the birds. No thresholds have been established for turbidity.

Data Gaps:

Limited studies of brown pelican behavior to dredging and/or beach nourishment activities have been conducted. Available studies were conducted at large roost sites in busy harbors. Addition information on brown pelican response may be warranted if sediment management activites are conducted in areas with less human disturbance so that information is available to support science-based decisions with respect to appropriate buffer distances in less urbanized settings.

Restoration:

Because impacts of beach nourishment on brown pelicans appear to be short term, restoration is not necessary.

Summary:

The potential impacts of beach nourishment on California brown pelicans would be expected to be temporary. Turbidity generated from sand placement activities generally affects a limited extent of coastline (Section 5.5). Pelican foraging along the mainland, where beach nourishment is likely to occur, is by non-breeding adults and older juveniles; therefore, there

is no issue associated with potential foraging interference of nesting birds. Because pelicans forage over a relatively large, turibidty plumes may respresent only a small portion of their daily foraging excursions.

Noise, light, and activity from sediment management operations may disturb roosting brown pelicans, if present. Available information suggests that buffers and control of sudden noises and changes in lighting may be effective for minimizing impacts. Because brown pelican response to disturbance relates in part on previous exposure levels, additional monitoring may be warranted, particularly if activities near large roosts in less urbanized areas.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on California brown pelican.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Documented	NA	NA	Protective Conservatism
Critical Impact Thresholds	NA	Prolonged disruption of roosting	NA	NA	Impair feeding
Impact Responses	NA	Displacement	NA	NA	Probably forages elsewhere
Duration of Impacts	NA	Minutes to hours	NA	NA	Hours-weeks
Potential for Restoration	NA	Unnecessary	NA	NA	Unnecessary

NA = not applicable

4.4.2 California Least Tern

Species Scientific Name	***Sterna antillarum browni***

Regulatory Status:

Endangered	State, Federal
Threatened	

Photo credit: Kathy Keane, Keane Biological Consultants

California least tern is a state and federal listed endangered species.

Description and Distribution:

California least terns normally are found along the coast from the greater San Francisco Bay area south to San Diego County (Small 1994). They are very rare north of San Francisco and Contra Costa counties, but there are records as far north as Del Norte County. The northernmost nesting sites are in San Francisco Bay (Keane 2001). Least terns in California are most abundant from Los Angeles County south. In 2004, approximately 57 percent of the breeding pairs were at sites in San Diego County and about 26 percent at sites in Los Angeles and Orange Counties (Keane 2004).

Least terns breed on sparsely vegetated sandy beaches, saltflats, and dredge spoils in colonies of up to several hundred nesting pairs. Sandy beaches close to estuaries and coastal embayments that have limited human disturbance have historically served as nesting sites for least terns, and in recent years many non-beach sandy surfaces in coastal areas have been used successfully for least tern nesting (USFWS 2000).

Life Stage and/or Function	California			On Land	Inter-tidal	Nearshore < 30 feet	Offshore > 30 feet	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X	X		X	X	E, P
Juvenile	X	X	X	X		X	X	E, P
Egg	X	X	X					E, P
Primary Habitat	X			X		X		P
Foraging Habitat	X	X	X			X	X	E, P
Nesting/ Habitat	X	X	X	X				E, P

Potential Functions:

Least terns forage on small fishes in estuaries, bays, marsh channels, harbors, nearshore ocean waters, and, in some cases, freshwater ponds or lakes near the coast (Collins et al. 1979, Keane 2001). Least terns forage in the ocean from just beyond the surf line to up to 1 to 2 mi (1.6 to 3.2 km) out to sea (Collins et al. 1979), although they have been documented to forage up to five miles from the nesting colony (USFWS 2000). The majority of least tern

foraging in the ocean is within 1 mi (1.6 km) of shore in waters less than 60 ft (18 m) deep (Atwood and Minsky 1983, AMEC 2002). Prior to post-breeding dispersal from breeding colonies, most foraging activity occurs within 2 mi (3.2 km) of the nesting sites.

Least terns appear opportunistic in their foraging behavior, and have been observed on numerous occasions to shift to different feeding areas in response to localized concentrations of suitable prey (Atwood and Minsky 1983). Least terns feed on small surface schooling fishes such as topsmelt, northern anchovy, jacksmelt and mosquitofish (Atwood and Minsky 1983). Least terns hover above the water and then plunge to grab fish; terns are not capable of deep dives (CDFG 2003). Most feeding takes place in the early morning and late afternoon.

Associated Species	Forage/ Prey	Eaten By
Invertebrates		
Fish	X	
Birds		X
Vegetation		
Marine Mammals		
Terrestrial Mammals		X
Humans		

Least terns, especially eggs and chicks, are vulnerable to a number of (mostly terrestrial) avian and mammalian predators including peregrine falcons, American kestrels, crows, ravens, coyotes, dogs, cats, and red foxes (Keane 1999). Marine-associated predators include great blue herons and various species of gulls.

Life History Facts:

California least terns are only present in California during the breeding season of April through September (Atwood et al. 1994). Their winter distribution is not well known, but they are believed to spend winters along the Pacific coast of Central America. The earliest spring migrants arrive in the San Diego area after the first week in April and reach the greater San Francisco Bay area by late April (Small 1994). The bulk of the population tends to arrive in California during the last week in April or the first week in May (Gallagher 1997). Nests with eggs are present May through July (Cogswell 1977).

Fledging typically occurs between the third week in June and the middle of July (Gallagher 1997). Most of the initial nesting attempts are made by experienced breeders and are completed by mid-June (USFWS 2000). A second wave of nesting usually occurs from mid-June through early August and is comprised of re-nests after initial failures and second year birds nesting for the first time. Fall departure begins late in August, most are gone by mid-September, and a few linger to late October.

Females lay their eggs in shallow depressions in flat, open areas with little vegetation (Atwood et al. 1994). Both parents incubate the eggs which hatch in 20 to 25 days, with young able to fly by 28 days (Rigney and Granholm 1990 cited in CDFG 2003). Least terns first breed at 2 years old (Brinkley and Humann 2001). Mean longevity after attaining adulthood is 5 to 12 years for small gulls and terns (Brinkley and Humann 2001).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Nest	April through September	Breeds at 2 years	N/A	September - April	5-12 years	Mobile

Adaptations and/or Behaviors to Disturbance:

Because least terns nest in open areas, their eggs and chicks are extremely vulnerable to predators and to direct disturbance such as being run over by vehicles. Essentially the only protection least tern nests and eggs have is the colonial nesting behavior of the adults, and many nest sites in California are actively managed to deter predators and human disturbance (CDFG 2003).

Historically, least terns nested in huge colonies along long expanses of sandy beach. Because the nesting birds were spread along a long strand of beach, they were much less vulnerable to predators than the discreet colonies of today are, and their sheer numbers diluted the impact that a single predator could have on the total population (Gallagher 1997). Adults and fledged young can fly away to avoid disturbance but during the nesting season, if adults fly away to avoid disturbance, eggs and chicks are left vulnerable to predators.

Life Stage	Behavior			None
	Flush	Fly	Migrate	
Adult	X	X	X	
Juvenile	X	X	X	
Egg/Chick				X

Potential Impacts from Sediment Management Activities:

The primary concern of sediment management activities to California least terns is direct and/or indirect disturbance in the vicinity of nesting sites. Types of sediment management activities and potential impacts to California least terns may include:

- Maintenance dredging of embayments – turbidity.
- Offshore borrow site dredging – equipment, turbidity.
- Nearshore placement – turbidity.
- Profile placement – equipment, turbidity.
- Beach placement – equipment, turbidity.
- Dune placement – equipment.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging					X	
Growth						
Habitat						
Reproduction	X	X	X	X		
Resting/ Roosting	X	X	X			

Equipment

Equipment potentially could crush least tern eggs or chicks. However, least tern colonies are well defined and most colonies on beaches are fenced. Earthmoving equipment would not be allowed in or near a least tern nesting area during the breeding season (Kathy Keane personal communication 2005; Jack Fancher, personal communication, 2005).

If beach nourishment equipment did work in the general vicinity (but not within) a least tern nesting site or an area where least terns roost, least terns may be disturbed by the noise, activity, and lights (if night-time operations occurred).

Little information was found about the reaction of least terns to equipment. Least terns do nest successfully on busy beaches (for example, Venice Beach and Huntington State Beach) near areas where there is activity from beach grooming machinery and lifeguard vehicles. However, Obst and Johnson (1990) noted that pedestrians, vehicles, and pets disturbed terns at 10 or more sites in their report of the 1990 California least tern breeding survey. Human disturbance was regarded by monitors as an important factor contributing to failure of pairs at Pismo Dunes, Mussel Rock Dunes, the Santa Clara River, Ormond Beach, Batiquitos Lagoon and the Tijuana River.

Fancher et al. (1988) suggested that an absence of nests in the north central part of the Huntington Beach least tern colony might be explained by an actively used park maintenance building next to the fence in the north central part of the colony. Worden et al. (2002) monitored beach use by California least terns and snowy plovers near nesting areas near the Santa Clara River mouth in Ventura County and found a negative correlation between disturbance and bird use with fewer birds in the more disturbed areas.

California least terns nest on islands in estuaries and therefore could be disturbed by sediment management dredging activities. Terns may be affected by ancillary marine fishing activities (e.g., vessel proximity, motor noise, generators, lights, etc.) near rookeries and roosting sites (CDFG 2003b).

Burial/Sedimentation

Eggs or chicks could be buried if sediment were placed directly on a least tern nesting site. However, least tern nesting sites are well defined and no beach nourishment activities would be allowed within a colony during the nesting season (Kathy Keane personal communication 2005; Jack Fancher, USFWS, personal communication 2005).

Sediment compatibility of substrate for least tern nesting is an imporant consideration relative to potenital benefits or impacts from beach nourishment. Substrate should be “beach quality”, consisting of sand, sand-gravel, and shell (Golder et al. 2005). Beach nourishment has enhanced nesting areas for least terns on the Atlantic coast of the United States; however, values may decline due to vegetation and predator encroachment a few years afer nourishment if the site is not managed (Jedrey 2005, Melvin 2005).

Turbidity

California least terns are visual foragers. They fly above the water until they spot small schooling fish and then plunge down to grab their prey. Because least terns rely on finding their prey visually, turbidity plumes that obscure forage fish from sight would interfere with

tern foraging success. During the breeding season, California least terns are dependent on an adequate supply of small fishes near their breeding colonies. When the adults are foraging away from their nests, the young are left unprotected and vulnerable to predation. Therefore, if turbidity plumes generated during sediment management activities near least tern nesting sites inhibited tern foraging, terns might have to travel farther from their nests to feed. The concern would be either that the terns would not procure adequate food to feed themselves and their young or that the young might be killed by predators when the adults were away from the nests.

Review of available monitoring reports suggests that least tern reaction may vary depending on level of turbidity; however, information on critical thresholds is lacking. Collins et al. (1979) studied the foraging behavior of the Huntington Beach least tern colony and noted that terns foraged much less in the consistently turbid Talbert flood control channel than in clearer water bodies in the vicinity of the colony.

Least tern foraging activity was monitored during beach nourishment activities between Seal Beach Pier and Warner Avenue in Orange County (MEC 1997). Material was dredged by cutterhead dredge at an offshore borrow site and pumped directly to a diked area on the beach. Three silt fences were placed perpendicular to flow in the sedimentation pond to reduce the turbidity plume. The observations did not provide any evidence that the activities adversely affected least tern foraging. Least tern foraging and diving behavior occurred in the vicinity of the entrance to Anaheim Bay and downcoast beaches, but was highest offshore the beach where beach nourishment activites occurred; i.e., the “fringe areas of the turbidity plume”.

Least tern foraging was monitored during offshore dredging and beach nourishment near breeding colonies in San Diego (AMEC 2002). Dredging was by a hopper dredge, and dredged material was pumped onto the beach behind a dike. The biological opinion for the project resulted in a permit requirement that turbidty could not be less than 3 ft (1 m) over a 2.47 ac (1 hectare) area and qualified monitors were to record observations of birds and their behavior during water quality monitoring and halt or adjust operations as necessary (USFWS 2000). Turbidity plumes rarely exceeded the compliance requirement (AMEC 2002).

Least terns, Forster’s terns, royal terns, and brown pelicans were observed foraging in turbid and non-turbid areas during dredging operations for the NIMITZ Homeporting Project in San Diego Bay (USDN 1996 cited in USFWS 2000).

To protect tern breeding season foraging activity, the standard recommendation by the USFWS has been to avoid discharging turbid tailwater into the nearshore zone within 1 to 2 miles of a California least tern nest site during the breeding season of April 1 to September 15 (J. Fancher, USFWS, personal communication 2005). An environmental restricted period ranging between March 15 and September 7 may be specified by the USACE, San Francisco Distsrict depending on location. Any dredging in San Francisco Bay requires consultation if conducted in eelgrass areas, which represent important foraging habitat (USACE et al. 2001).

Projects permitted within environmental restricted periods have required consultation with the USFWS, implementation of measures to control turbidity, and monitoring (e.g., MEC 1997, AMEC 2002). Additional predator control also was specified if beach nourishment

occurred in the vicinity of least tern and snowy plover nest sites during the breeding season for the 2001 San Diego Regional Beach Sand Project (USFWS 2000).

Recovery from Disturbance:

Least terns are unlikely to be directly injured by equipment because no beach nourishment equipment would be allowed within a least tern nesting colony. Very little information exists about the reaction to least terns to machinery working in the vicinity of a colony and the recovery of terns from such disturbance. If the disturbance caused the adults to abandon their nests, eggs and chicks could be destroyed by predation. Thus, the disturbance might result in breeding failure for some or the entire colony. Unless pairs that lost eggs or chicks were able to successfully raise a second brood that season, recovery would not occur until the following breeding season. Similarly, if eggs were buried by sand used for beach nourishment (a highly unlikely event because beach nourishment would not be allowed within a tern colony), recovery likely would not occur until the following breeding season.

If turbidity from sediment management activities required least terns to forage farther from nest sites, increased vulnerability of eggs and/or chicks to predation would be of concern. Similar to equipment impact considerations, recovery could be short-term or persist until the following season depending on actual impact.

	Recovery Rates				
Impact	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	After cessation of activites	X			
Burial		X			
Sedimentation					X
Turbidity	After cessation of activites	X			
Habitat Loss					X

Critical Impact Thresholds:

No thresholds for turbidity or noise and light disturbance have been established for California least terns.

Data Gaps:

It would be useful to have more specific information about California least tern response to equipment, noise and turbidity. Presently, resource agencies take a cautious approach and generally prohibit beach nourishment activities in the general vicinity of a California least tern colony. Greater understanding about least tern response to turbidity and disturbance might allow some limited beach nourishment nearer to tern colonies during the breeding season, as long as disturbance and turbidity were kept well below thresholds documented to affect tern behavior.

Restoration:

If beach nourishment activities caused a serious disturbance to a least tern colony, appropriate restoration might be to fund measures that would contribute to the success of

the colony in the future or to the success of other colonies. These measures could include predator control and/or vegetation removal.

Summary:

The standard recommendation has been to avoid sediment management activities within 1 or 2 mi (1.6 to 3.2 km) of a least tern breeding colony during the breeding season. In the instances in which beach nourishment activities were allowed within this radius during the breeding season, measures were taken to reduce turbidity and least tern foraging activity was monitored (MEC 1997, AMEC 2002). These measures appear to have been successful as neither extensive turbidity plumes nor adverse impacts to least tern foraging were observed.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on California least tern.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Relevant reports	NA	NA	Relevant Reports
Critical Impact Thresholds	NA	Disruption of nesting, egg/chick predation	NA	NA	Impair feeding
Impact Responses	NA	None, May move away, nest abandonment	NA	NA	None, Forage elsewhere, impair breeding and/or feeding of chicks
Duration of Impacts	NA	Hours to weeks	NA	NA	Hours to weeks
Potential for Restoration	NA	Unnecessary or enhance success of tern colony by contributing to predator control or vegetation removal.	NA	NA	Unnecessary or enhance success of tern colony by contributing to predator control or vegetation removal.

NA = Not applicable

4.4.3 Western Snowy Plover

Species Scientific Name	***Chardrius alexandrinus nivosus***

Photo credit: Callie Bowdish

Regulatory Status:

Endangered	
Threatened	Federal
CDFG Managed	Species of Special Concern
Essential Fish Habitat	
Other	
None	

Distribution:

Life Stage and/or Function	California			On Land	Inter-tidal	Nearshore < 30 feet	Offshore > 30 feet	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X	X	X			E, P
Juvenile	X	X	X	X	X			E, P
Egg	X	X	X	X				E, P
Primary Habitat	X			X				P
Foraging Habitat	X	X	X	X	X			E, P
Nesting/ Spawning Habitat	X	X	X	X				E, P

The coastal population of western snowy plover breeds from southern Washington to southern Baja California; it breeds along the entire California coast (Miller et al. 1999). Most breeding occurs from southern San Francisco Bay south. The areas with the largest numbers of nesting plovers include San Francisco Bay, Moss Landing Wildlife Area, Morro Bay, Nipomo Dunes, Vandenberg Air Force Base, Mugu Lagoon, San Nicolas Island, the Santa Margarita River mouth, and Silver Strand Beach (K.Keane, 2004). Following the breeding season western plovers disperse for the winter. During the winter, the California coastal snowy plover population is augmented by an influx of breeders from the north and possibly from inland California (Small 1994).

Critical Habitat for western snowy plovers has been designated and includes nesting and wintering areas (Miller et al. 1999). Critical Habitat includes beaches in northern, central and southern California. Wintering snowy plovers are found on many of the beaches used for nesting but also on beaches not used for nesting (Miller et al. 1999).

A number of beaches are particularly important to wintering snowy plover and have been designated Critical Habitat for wintering birds (Miller et al. 1999). Sites that supported the largest number of wintering snowy plover in the winters of 2003/2004 and 2004/2005 were Dillon Beach in Marin County, Salinas State Beach in Monterey County, San Simeon State

Beach, Oceano Dunes, and Morro Strand State Beach in San Luis Obispo County, Vandenberg Air Force Base and Coal Oil Point Reserve in Santa Barbara County, Ormond Beach and San Nicolas Island in Ventura County, Zuma Beach in Los Angeles County, and Camp Pendleton, the Naval Amphibious Base and Tijuana Estuary in San Diego County (J. Fancher, USFWS, pers. comm. 2005).

Western snowy plovers nest along the Pacific Coast on sparsely vegetated beaches backed by dunes, sand spits, beaches at creek and river mouths, dredge spoils, flats of salt evaporation ponds, river bars, bluff-backed beaches, and salt pans in lagoons and estuaries (Miller et al. 1999). Nests are depressions in the substrate lined with bits of debris or shells. Human use of nesting beaches has been the greatest factor in the decline of the western snowy plover (Bruce et al. 1994).

Snowy plovers feed above and below the high tide line on beaches, tidal flats, and in saltflats or salt ponds. Their diet consists of sand crabs, sand hoppers, flies, beetles, brine shrimp and other aquatic and terrestrial invertebrates. In beach areas snowy plovers probe for crustaceans and worms in the low-tide zone, search for insects and other small invertebrates among debris (especially drift kelp) along the high-tide line, or probe the sand under low foredune vegetation (Lafferty 2000).

Functions:

Western snowy plovers tend to be "run and peck" predators (Bruce et al. 1994). They scan the ground until they spot an appropriate prey item and then dart over to capture it. The prey of snowy plovers on the upper beach includes beach hoppers, beetles, and other insects attracted to kelp wrack and other drift (Cogswell 1977). In the lower intertidal they feed on sand crabs, worms and other marine invertebrates. In salt ponds they feed on brine flies. Snowy plovers are vulnerable to a wide range of predators including gulls, crows, ravens, American kestrels, red foxes, coyotes, opossums, raccoons, and skunks as well as dogs and cats (Zeiner et al. 1990, Lafferty 2000).

Associated Species	Forage/ Prey	Eaten By
Invertebrates	X	
Fish		
Birds		X
Vegetation		
Marine Mammals		
Terrestrial Animals		X
Humans		

Life History Facts:

The breeding season for western snowy plovers extends from early March to Late September, with birds at more southerly locations beginning to nest earlier in the season than birds at more northerly locations (Miller et al. 1999). Activities that define the nesting season are courtship, copulation, nest scraping, egg laying, incubation, and rearing of the young to the fledgling stage. Young fledge after 29 to 47 days (Zeiner et al. 1990). Snowy plovers may renest if a clutch is lost (USFWS 2000). The winter season generally extends roughly from October to February but often overlaps the nesting season with birds arriving on wintering areas as early as midsummer (Miller et al. 1999). Birds in the plover family first breed when 1 to 3 years old (Petersen 2001). Plovers tend to be long-lived. Some species of plover (black-bellied plover, Mongolian plover) have been documented to live more than 20 years (Petersen 2001).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Nest	March - September	Young fledge after 29-47 days. First breed at 1-3 years old	N/A	September - February	Up to 20 years	Mobile

Adaptations and/or Behaviors to Disturbance:

Snowy plovers tend to rely on their cryptic coloration for protection. Snowy plovers are very hard to notice unless they move (Lafferty 2000). They crouch motionless on sandy substrate and rely on camouflage for cover (Zeiner et al. 1990). Snowy plovers tend to select nest sites that allow incubating adults good visibility, yet afford them some camouflage from predators (Powell and Collier 2000). Snowy plovers construct nests in cryptic, lined scrapes associated with beach debris (Lafferty 2000). Plover chicks are cryptically colored and often react to predators by running into cover and crouching.

Life Stage	Behavior			Habitat
	Flush	Fly		
Adult	X	X		X
Juvenile	X	X		X
Egg				X

Snowy plovers' reliance on camouflage for protection may be an effective way to escape animal predators, but it makes them extremely vulnerable to human disturbance. Snowy plovers have been reported to shift from beaches with vehicular activity to more protected sites (Powell and Collier 1994 cited in USFWS 2000). Snowy plovers, particularly flightless young are vulnerable to being run over by vehicles or trampled due to their crouching behavior in depressions, such as footprints and tire tracks (James et al. 1992 cited in USFWS 2000). Lower densities of snowy plover nests have been documented at beaches with high off-road vehicle activity (Page and Stenzel 1981 cited in USFWS 2000).

Worden et al. (2002) monitored summer beach use by California least terns and snowy plovers near snowy plover and least tern nesting areas near the Santa Clara River mouth in Ventura County. They found a negative correlation between human disturbance and bird use of the beach. Fewer birds were present in the more disturbed areas. When disturbed snowy plovers will run or fly away, but few disturbances may occur at distances greater than 98 ft (30 m) (Lafferty 2000, 2001a).

Potential Impacts from Sediment Management Activities:

Concerns regarding the impact of sediment management activities on snowy plovers include injury or death to a bird or egg from equipment and personnel as well as disturbance to nesting or foraging snowy plovers from sediment management activities. Unlike least terns that nest in well-defined colonies, snowy plover nests may be scattered throughout an area. The nests, depressions in the ground, are hard to see and the birds themselves, when hunched down on a beach, are cryptic. Snowy plovers may forage and nest on beaches, sparsely vegetated coastal strand backed by dunes, and in lagoons and estuaries.

Types of sediment management activities and potential impacts to western snowy plover may include:

- Maintenance dredging of embayments – equipment.
- Offshore borrow site dredging – not applicable.
- Nearshore placement – not applicable.
- Profile placement – equipment.
- Beach placement – equipment, burial, sedimentation.
- Dune placement – equipment, burial, sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging	X	X	X	X		
Growth						
Habitat						
Reproduction	X	X	X	X		
Resting/ Roosting	X	X	X			

Equipment

Because western snowy plovers, and especially their eggs and chicks, are hard to see, they are vulnerable to being directly injured by beach nourishment activities. Earthmoving vehicles could run over a nest, chick, or even a crouching adult (Miller et al. 1999). Snowy plovers tend to hide in depressions and have been observed to crouch in the ruts made by vehicles (L. Hays, USFWS, pers. comm., 2005). Thus, snowy plovers could hide directly in the path of vehicles involved in beach nourishment activities. Mortality of snowy and piping plovers as a result of vehicular activity on beaches has been documented (Melvin et al. 1994, Persons 1994, Copper 1997 cited in USFWS 2000). Snowy plover eggs potentially could be damaged by the laying of pipelines to transport beach nourishment material, if present (Miller et al. 1999).

In addition to being directly injured by beach nourishment activities, snowy plovers are vulnerable to disturbance. Human disturbance may cause nesting plovers to abandon their nests, thus leaving eggs or chicks more vulnerable to exposure and/or predation (Lafferty 2000). In addition, disturbance may interfere with foraging by either breeding or wintering snowy plovers. The feeding rates of wintering snowy plovers have been observed to decline as human activity increases (Lafferty 2000). Foraging plovers flushed by disturbance suspend feeding and may expend extra energy in flight or avoidance. A study of the ecologically similar piping plover on the east cost showed that the time breeding plovers devoted to foraging decreased as vigilance increased and that reproductive success was lower in areas with higher levels of human disturbance (Burger 1991). Most studies of the relationship between human disturbance and plover behavior were focused on recreational

beach users (Lafferty 2000, Burger 1991). However, human activity associated with beach nourishment clearly has the potential to disturb snowy plovers.

Sediment management activities on beaches used by snowy plovers require consultation with the USFWS. For sediment management activities on beaches heavily used by snowy plovers, snowy plover monitoring generally is required. Usually the USFWS recommends that beach nourishment activities be avoided near snowy plover nesting sites during the nesting season. However, there has been sediment management operations conducted in snowy plover nesting habitat during the nesting season when monitoring and other protective measures have been implemented (USACE 2001).

Chambers Group (2005) monitored dredging of a sand bar in the Talbert Channel inlet in Huntington Beach and placement of the dredged sand in the upper intertidal zone on the adjacent beach. The dredging and disposal operations were monitored because they occurred in an area heavily used by wintering snowy plovers. Snowy plovers avoided the immediate areas where the dredging and disposal activities were occurring, but foraged undisturbed in the neighboring intertidal beach areas.

Several years of beach disposal activities in Santa Barbara Harbor did not result in noticeable impacts to roosting or foraging plovers, which tended to congregate near the disposal site perhaps due to limited public access at that point (USACE 2001). Chambers Group (2001a) observed snowy plovers foraging in the vicinity of the beach discharge of dredged material from Santa Barbara Harbor. The plovers did not react adversely to beach nourishment activities but were flushed by joggers and people with dogs.

Several beach and surf-zone disposal operations have been implemented within snowy plover habitat at Morro Bay, during both nesting and wintering seasons, without any observed negative impacts (USACE 2001). Surf-zone disposal occurred on the Morro Bay sand spit from February to June 1987. Plovers and nests were monitored closely during disposal activities and through the rest of the nesting season. Plovers were observed using the entire length of the ocean beach for roosting and foraging. The clutch-hatching rate could not be determined accurately, but estimates were comparable to, or significantly higher than those at other plover nesting locations. There was no evidence that the dredging operation (including pipeline removal) decreased the snowy plover's breeding success at the sand spit (Hutchinson et al. 1987). Approximately 46 to 50 nests were observed on Morro Strand State Beach in months following the 1993, 1995, and 1997 disposal operations.

Worden and Smith (2004) monitored snowy plover activity near the Santa Clara River mouth during dredging of Ventura Harbor and surf zone disposal off McGrath State Beach. The dredge materials were piped across the mouth of the Santa Clara River and then discharged in the surfline. Foraging and roosting snowy plovers on the Santa Clara River estuary bar were observed moving to avoid the heavy equipment driven on the beach during installation and removal of the dredge pipe. Birds also moved from roosting positions to avoid pickup trucks driving to and from the pipe discharge point during dredging. The investigators concluded that dredging operations appeared to have a less than significant, short-term impact on wintering snowy plovers by temporarily disrupting the activity of birds using the beach.

An additional indirect impact to snowy plovers of beach nourishment may be the removal of seaweed and other debris when the sand placed on the beach is spread out by earthmoving

equipment. Drift kelp and other debris support a high abundance of prey for foraging snowy plovers. Dugan et al. (2003) found that the mean abundance of western snowy plovers on various sandy beaches in southern California was positively correlated with the amount of macrophyte wrack on the beach.

Avoidance and minimization measures have been used to reduce potential equipment impacts on snowy plover. Projects have been restricted to outside the snowy plover breeding season to avoid impacts (e.g., USACE 1993, 1994a, b, 1998a, 1998b, 2000, 2001, 2002; Chambers Group 1992, 2000, 2001). Impact minimization measures have included use of monitors to determine presence of plover nests and responsibility to either halt work or implement other protective measures (e.g., USACE 1994a, 1998a,b, 2000). Generally, the Corps has specifieid single-point surf zone or diked discharge if beach nourishment extends into the nesting season (e.g., USACE 1993, 1994a, 1998a, 2001). In addition, removal of pipelines has been scheduled after the nesting season (USACE 1998b).

Protective measures recommended for piping plovers during beach nourishment on the Atlantic coast of the United States include a 300 ft (91 m) buffer from nests or chicks, and seasonal restriction of placement activities, pipeline storage, and pipline removal between April 1 and August 31, unless work will enhance habitat (Melvin 2005).

Burial/Sedimentation

Beach nourishment potentially could bury snowy plover nests if conducted during the snowy plover breeding season. However, no reports of nest burial during sediment management activities were identified with the literature review. Avoidance and minimization measures described above to reduce potential equipment impacts also reduce the potential for burial impacts.

Burial of invertebrate fauna and/or removal of wrack vegetation during beach nourishment activities have the potential to temporarily reduce the invertebrate prey base for snowy plovers.

Beach nourishment may benefit snowy plovers by providing additional habitat. A 1992-1993 beach disposal operation in Ventura was followed by the first plover nesting in that area in years (USACE 2001). Beach nourishment was recognized as likely providing a temporary benefit to critical habitat for snowy plover at Mission Beach, San Diego County (USFWS 2001). Snowy plovers were found on beach sites that changed from cobble to sandy habitat after nourishment in the City of Encinitas (SAIC 2006).

Beach nourishment has benefited piping plover habitat along the Atlantic coast of the United States (Melvin et al. 1991, Brandreth 2005, Burlas 2005, Fraser and Cohen 2005, Kumar 2005, Melvin 2005). Important design considerations have included low slope (≤10:1, horizontal:vertical), compatible sediments (grain size and color), sparse vegetation, preservation of wrack vegetation, avoidance of sand fencing, and post-construction management (Fraser and Cohen 2005, Melvin 2005). Seasonal management considerations have included vegetation removal, predator and pet control, and restricted access by beach goers, vehicles, and mechanical beach cleaning equipment (Cohen et al. 2005, Jannsen 2005).

Turbidity

Turbidity does not affect western snowy plovers, because this species does not forage in the water.

Recovery from Disturbance:

Western snowy plovers would be expected to recover from minor disturbance within minutes. Chambers Group (2001a) observed that foraging snowy plovers flushed by joggers and dogs on a beach in Santa Barbara returned to their foraging activities within minutes after the disturbance had passed. Worden and Smith (2004) similarly observed that disturbances to snowy plovers near the Santa Clara River mouth from pipeline installation and vehicles were short-term. Signigicant impacts involving direct mortality or indirect reproductive failure due to nest abandonment and/or persistent interruption of foraging and lack of nutrition would require a year or more for recovery, if they occurred.

Potential impacts associated with burial of forage prey (invertebrates, wrack-associated invertebrates) would likely depend on proximity to other suitable foraging areas. Invertebrate recovery of sandy beach habitat generally begins as soon as beach nourishment activities cease, with recovery rates on the order of weeks to months (Section 4.2.6). Impacts to snowy plover could range from minor if adequate prey was available nearby to significant if substantially more time was spent in search of food and adversely affected reproductive success.

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	After cessation of activites	X			
Burial		X			
Sedimentation					X
Turbidity					X
Habitat Loss					X
Forage Reduction	X	X	X		

Critical Impact Thresholds:

No critical thresholds have been established for western snowy plover disturbance. Lafferty (2000) observed few disturbances to snowy plovers from activities at distances greater than 100 ft (30 m). A buffer distance of 300 ft (91 m) to nests or chicks has been recommended during beach nourishment for piping plover (Melvin 2005).

Data Gaps:

Additional information on the effects of noise and disturbance on foraging or roosting snowy plovers would help to define precautions to be taken if beach nourishment activities are planned for beaches regularly used by western snowy plovers. Few studies have examined the benefits of beach nourishment to plovers at erosive beaches. Limited information is

available regarding the temporary impact of reduced invertebrate forage prey on plover foraging patterns.

Restoration:

If beach nourishment activities are found to have resulted in harm to western snowy plovers, restoration could take the form of creating new nesting habitat or protecting existing nesting or foraging habitat. Sand placement in areas protected from heavy public use potentially could create new nesting habitat. Protection of existing nesting areas can include fencing, signs, restriction of public use during the breeding season, and predator control.

Summary:

Because western snowy plovers and their nests are cryptic and difficult to see, they are extremely vulnerable to injury from equipment involved in beach nourishment activities. In addition, sand placed on snowy plover nesting beaches during the breeding season has the potential to bury nests, although this impact has never been documented to occur. The USFWS generally recommends avoiding sediment management activities on snowy plover nesting beaches during the breeding season, although sediment management activities have been conducted in snowy plover breeding habitat without apparent adverse effects (USACE 2001). Sediment management activities on beaches regularly used by snowy plovers generally are required to be monitored.

Snowy plovers and similar species (piping plover) have been documented in the scientific literature to be sensitive to disturbance (Lafferty 2000, Burger 1991, Burger 1994). They also have been documented to be momentarily disturbed by pipe-laying and vehicular activities associated with sediment disposal (Worden and Smith 2004). However, sensitivity to disturbance decreases with distance (Lafferty 2000), and snowy plovers have been documented by monitors to avoid the immediate vicinity of sediment removal and placement activities but to forage undisturbed nearby (Chambers Group 2005). The U.S. Army Corps of Engineers has monitored snowy plovers during beach nourishment operations and has not documented any adverse effects (USACE 2001). Therefore, in general, it appears that disturbance to snowy plovers from beach nourishment activities is limited to a short-term response and avoidance of the immediate working area.

Snowy plovers have been documented to be more abundant on beaches with a higher mount of macrophyte wrack (Dugan et al. 2003). Beach nourishment may remove wrack by directly burying it with sand or by removing it in the process of spreading out sand placed on the beach. Removal of wrack associated with beach nourishment would be a short-term effect. Subsequent grooming of the beach is a beach management not a sediment management impact.

By placing sand on cobble or rocky beaches or by widening narrow sand beaches, beach nourishment may have a beneficial effect on western snowy plovers by creating nesting and/or foraging habitat. Snowy plovers were observed foraging at beach sites nourished in the City of Encinitas, San Diego County from the 2001 Regional Beach Sand Project (SAIC 2006). Increase in available nesting habitat from beach nourishment was documented for ecologically similar piping plovers on the East Coast (Melvin et al. 1991).

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on western snowy plover.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	Documented	Documented	Protective conservatism	Protective conservatism	NA
Critical Impact Thresholds	Unknown	Disruption of nesting, egg/chick predation, displaced from overwintering habitat, mortality	Incompatible substrate that degrades foraging habitat	Incompatible substrate that degrades foraging habitat	NA
Impact Responses	May nest or forage on beach with more sand	May move away or may crouch in path of equipment and get injured	If nest is buried may attempt to renest. If wrack is buried may forage elsewhere	NA	NA
Duration of Impacts	As long as adequate sand remains on beach	Days to weeks	Days to > 1 year	NA	NA
Potential for Restoration	Unnecessary	Unnecessary or enhance success of colony by contributing to predator control or vegetation removal.	Unnecessary or enhance success of colony by contributing to predator control or vegetation removal.	NA	NA

NA = not applicable

4.4.4 Gulls, Skimmers, and Terns

Species Scientific Name	**Laridae**

Regulatory Status:

Endangered	Endangered- California least tern (discussed in Section 4.4.2).
Threatened	
CDFG Managed	Species of Special Concern California gull, black skimmer, and elegant tern

Photo credit: Karen Green, SAIC

Distribution:

Gull species that regularly occur along the California coast include Bonaparte's (*Larus Philadelphia*), Heermann's (*L. heermanni*), mew (*L. canus*), ring-billed (*L. delawarensis*), California (*Larus californicus*), herring (*L. argentatus*), Thayer's (*L. thayeri*), western (*L. occidentalis*) and glaucous-winged (*L. glaucescens*).

Of, these species, the western gull breeds on offshore islands in northern and southern California, islands in San Francisco Bay, and in rocky areas along the coast (Baird 1993, http://en.wikipedia.org/wiki/Western_Gull). California gulls breed on dredge spoil islands in San Francisco Bay (Carter et al. 1992).

Western gulls nest on the ground in solitary pairs, small colonies, and in large colonies involving thousands of birds (Carter et al. 1992). The largest western gull colonies are on South Farallon Island in central California and Santa Barbara and Anacapa Islands in southern California (Carter et al. 1992).

Ring-billed, California, western and herring gulls are common on the coast throughout the state (Small 1994). They are most abundant in the winter when breeding birds disperse from their colonies. Mew gulls and glaucous-winged gulls are more common in northern and central California than southern California and are most abundant during the winter. Heermann's and Bonaparte's gulls are most common in southern and central California. Bonaparte's gulls winter in southern and central California from November through April. Heermann's gulls breed early (March through May) in Mexico (Cogswell 1977). They are present in California from June through March.

Coastal tern species include Caspian (*Sterna caspia*), royal (*S. maxima*), elegant (*S. elegans*), Forster's (*S. forsteri*). The State and federal endangered California least tern is discussed in a separate section. In coastal California, Caspian, elegant, Forster's, and royal terns breed in bays in colonies on bare ground, on islands, dredge spoils, or saltworks. Caspian terns breed in San Francisco Bay, Elkhorn Slough, the Port of Los Angeles, Bolsa Chica Ecological Reserve, and San Diego Bay. Royal terns nest at Bolsa Chica Ecological Reserve in Orange County and San Diego Bay. Elegant terns nest in San Diego Bay, Bolsa Chica and the Port of Los Angeles. Forster's terns nest in San Francisco Bay, Bolsa Chica,

Upper Newport Bay, Batiquitos Lagoon, and San Diego Bay. The terns are most abundant from San Francisco Bay south.

Black skimmer (*Rynchups niger*) nests at the Port of Los Angeles, Bolsa Chica, Newport Bay, Batiquitos Lagoon, and San Diego Bay.

Life Stage and/or Function	California			On Land	Inter-tidal	Nearshore< 30 feet	Offshore > 30 feet	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X	X	X	X	X	E, P
Juvenile	X	X	X	X	X	X	X	E, P
Egg	X	X	X	X				E, P Islands
Primary Habitat								
Foraging Habitat	X	X	X	X - gulls	X	X	X	E, P
Nesting/ Spawning Habitat	X	X	X	X				E, P Islands

Functions:

Gulls are known for being opportunistic feeders (Brinkley and Humann 2001). They forage on fish in the ocean and in bays, scavenge from fishing boats, search for invertebrates on land and in the intertidal, and forage on garbage on land. Gulls will also steal food from other birds (kleptoparasitism). Gulls frequently congregate at garbage dumps. The larger gulls may even eat small birds (including eggs) and mammals.

Associated Species	Forage/ Prey	Eaten By
Invertebrates	X	
Fish	X	
Birds	X	X
Vegetation		
Marine Mammals		
Terrestrial Animals		X
Human	Garbage	

Terns feed primarily on small fishes in bays and nearshore coastal waters, some will also eat invertebrates (Brinkley and Hummann 2001). Terns capture prey with their bills by dipping and plunge-diving while in flight. Like gulls, they may steal food by harassing other birds. Gulls and terns (especially eggs and chicks) are vulnerable to a variety of mammalian and avian predators.

Black skimmers fly a few inches above the water with their lower bill trailing in the water to catch fish.

Life History Facts:

Most of the gull and tern species that are common in California coastal waters breed from late April or early May through August but some prolonged nesters like Forster's terns and black skimmers may breed into September (Zeiner et al. 1990, Gallagher 1997). Heermann's gulls are an exception to this seasonal pattern. They are an early nesting species that breeds in large colonies in Mexico from March through May or early June

(Zeiner et al. 1990, Cogswell 1977). Age at first breeding is highly variable depending on the species of gull or tern but typically is at 2 to 5 years old with the smaller species nesting at a younger age than the larger species (Brinkley and Humann 2001).

The migratory and wintering season for most gulls and terns is from October through March. Heermann's gulls, because of their early breeding, are an exception. Heermann's gulls are dispersed from their breeding colonies from June through March and are migratory visitors in California between summer and winter (Brown et al. 1986).

Western gulls forage close to their breeding colonies in spring-summer, but may be seen on mainland beaches during other times of year. Other gull species are migrants and primarily winter visitors along the coast; they may be seen on beaches in fall-winter through March.

Terns primarily nest in estuaries (often on constructed nesting islands) in southern part of the state. Tern species that breed in California include California least tern, Caspian tern, Elegant tern, Forster's tern, and Royal terns (Baird 1993). Most of these species occur along the coast in the southern half of the state,

Forster's terns range further north along the southern 2/3rds of the coast (Brown et al. 1986). California Least terns migrate southward after breeding in Califonria. Other breeding species may be seen (usually in low numbers) along the coast during the non-breeding season (Baird 1993). Common and Arctic terns are migrants that may be seen during the nonbreeding season in Calfifornia during migration to southern overwintering areas (Brown et al. 1986).

Gulls, skimmers, and terns are fairly long-lived birds. Mean longevity for terns and small gulls is 5 to 12 years (Brinkley and Humann 2001). Large gulls live 9 to 25 years. The oldest record for a black skimmer was a few weeks shy of 20 years (http://floridaconservation.org/bba/BLSK.htm).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Nest	Gulls (except for Heermann's) - April-August Heermann's gull March-June Terns - April - September	Age at first breeding varies - generally 2-5 years old	N/A	October - March (except Heermann's gull June - March)	Small gulls and terns 5-12 years; large gulls 9-20 years	Mobile

Adaptations and/or Behaviors to Disturbance:

The response to disturbance of adult and juvenile gulls and terns is to fly away from the threat. The primary protection for eggs is the colonial nesting behavior of most gulls and terns and the fact that nesting colonies tend to be in areas such as islands and offshore rocks (gulls) that

Life Stage	Avoidance Behavior			Habitat
	Flush	Fly	Migrate	
Adult	X	X		
Juvenile	X	X		
Egg				X

are hard to access. If a nesting colony is flushed by disturbance, eggs and chicks may be left vulnerable to predation while the adults are away.

Potential Impacts from Sediment Management Activities:

Gulls are generally not a focus of concern for sediment management activities because they do not nest on or near beaches were sediment management is likely. In addition, gulls tend to be opportunistic feeders that exploit a wide range of foraging opportunities. Concerns about other species of terns and black skimmers primarily relate to disturbance and/or interference with foraging near their nesting sites.

Types of sediment management activities and potential impacts to gulls may include:

- Maintenance dredging of embayments – turbidity, disturbance.
- Offshore borrow site dredging – turbidity.
- Nearshore placement – turbidity.
- Profile placement – equipment, turbidity.
- Beach placement – equipment, turbidity.
- Dune placement – equipment.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging	X	X			X	
Growth						
Habitat						
Reproduction	X	X				
Resting/ Roosting	X	X		X		

Equipment

Gulls are opportunistic omnivores common in urban areas including heavily utilized beaches and, thus, obviously are tolerant to a considerable amount of human disturbance. Gulls have been observed to be attracted to beach nourishment sites when dredge sediment slurries were pumped to the beach. AMEC (2002) observed that gulls were attracted to the sediment discharge area during beach nourishment in northern San Diego County. Gulls also were attracted to the pumped sediment discharge during beach nourishment at Surfside-Sunset beach in 1997 (D. Cannon, photographs). Presumably, birds were foraging on invertebrates in the sediment discharge.

Gulls, black skimmers, and terns nest on islands in bays, some created from beneficial reuse of dredged materials. Nesting colonies have the potential to be disturbed by dredging

activities, if nearby. Disturbance concerns include reduced foraging, nest abandonment, increased predation of eggs or chicks, and/or reduced feed

Gulls may be affected by ancillary marine fishing activities (e.g., vessel proximity, motor noise, generators, lights, etc.) near rookeries and roosting sites (CDFG 2003). Gulls, which are normally diurnal, are known to forage at night where attracted by bright lights (e.g., near squid fishing boats) (CDFG 2003). Artificial lighting may also increase lighting and foraging abilities of western gulls on nesting colonies, resulting in increased levels of predation on sensitive terns and/or plovers.

Observations on least tern nesting colonies (described in Section 4.4.2) indicate that nesting terns may be sensitive to human disturbance (Obst and Johnson 1990, Fancher et al. 1988). Noise and lights from equipment used for beach nourishment may disturb terns if beach nourishment activities occurred near a nesting colony. Reproductive failure could occur if nesting birds abandoned their colony in reaction to disturbance from dredging equipment, and chicks or eggs were eaten by predators.

Burial/Sedimentation

If sand were placed directly on a tern colony during the nesting season, eggs could be buried. Because gulls and terns (with the exception of the California least tern) do not nest on sandy beaches where beach nourishment is likely to occur, it is unlikely that sand placement would bury gull or tern eggs.

In the long term, addition of sand to a beach may benefit gulls and terns by providing more resting habitat. Beach nourishment appeared to have a positive effect on bird use of receiver beaches in northern San Diego County following beach nourishment (SAIC 2006). Prior to beach nourishment few birds were observed on beaches with extensive cobble cover or shallow sand depths in upper and middle intertidal zones. Following beach nourishment total number of bird species and bird abundance (including gulls) increased on receiver sites and was higher than on non-receiver sites. The increase in bird use at sand placement sites following beach nourishment likely is a result of the greater beach widths created by the beach nourishment project. Similarly, CZR (2003) found that resting behavior of laughing gulls and royal terns increased following beach nourishment in North Carolina although feeding behavior by gulls and terns did not change following beach nourishment. The behavioral data suggested that gulls and terns increased the percentage of their time spent resting after beach nourishment probably because of the greater available beach space.

Turbidity

Gulls and terns feed on fishes by flying above the water until they spot fish prey. Therefore, turbidity plumes created by beach nourishment potentially could interfere with foraging. Gulls are extremely opportunistic and will switch to other food sources such as garbage when their preferred fish prey is unavailable (Hunt et al. 1981). Therefore, it is unlikely that temporary turbidity plumes created by beach nourishment would interfere significantly with gull feeding. Terns tend to be more specialized feeders than gulls (Brinkley and Humann 2001) and thus would likely be more vulnerable to interference with foraging from turbidity plumes. Observations on California least terns (described in the California least tern section), suggest that terns may avoid foraging in turbid areas (Collins et al. 1979). On the other hand, observations of least terns during beach nourishment operations did not suggest

that beach nourishment adversely affected tern foraging (MEC 1997). Forster's terns and royal terns were observed foraging within visible turbidity plumes during Navy dredging operations in San Diego Bay (USFWS 2000)

Recovery from Disturbance:

Because gulls and terns (with the exception of the California least tern) do not nest on beaches where beach nourishment is likely to occur, nesting gulls and terns would not be injured or disturbed by beach nourishment equipment. There is a chance that dredging sediment for beach nourishment near a tern colony in a bay could disturb nesting terns. In a worst case, temporary abandonment of eggs or chicks could leave them vulnerable to predation but most likely the adults would return to their nests rapidly following the disturbance. However, significant disturbance could result in reproductive failure for a season. Disturbance by beach nourishment activities to resting gulls or terns or foraging gulls on beaches where beach nourishment is occurring is expected to be temporary. Interference with foraging by turbidity plumes from beach nourishment would only last as long as the turbidity, usually hours to months. Increased sediment on beaches appears to have a positive effect by providing resting habitat for gulls and terns. This benefit would last as long as the sand stayed on the beach. Depending on the winter surf conditions, sand placed on a beach would be expected to stay 1 to 2 years.

	Recovery Rates				
Impact	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	After cessation of activites	X			
Burial					X
Sedimentation		X			
Turbidity	After cessation of activites				
Habitat Loss					X

Critical Impact Thresholds:

No thresholds for turbidity or disturbance have been established for gulls or terns.

Data Gaps:

Limited inforation is available regarding beach nourishment on birds, in general. Better understanding of bird usage patterns of Calfiornia beaches would improve decision-making with respect to regional sediment management strategies.

Restoration:

If dredging near a tern colony significantly interfered with reproduction of that colony, appropriate restoration measures would be increased protection of the colony by human restrictions or predator control (if appropriate), or creation of an alternative, more protected tern nesting area.

Summary:

Beach nourishment has the potential for short term impacts to gulls and terns from disturbance by beach nourishment activities and interference with foraging by turbidity. Because gulls and terns (with the exception of the endangered California least tern) do not nest on beaches where sand placement activities are likely to occur, these impacts are likely to be temporary. Gulls may feed on sandy beach invertebrates; therefore, there may be some reduction in forage prey base associated with recovery rates of invertebrates. Recovery rates may be influenced by project schedule since invertebrate recruitment varies seasonally (Section 4.2.6).

Dredging near tern nesting colonies in bays has additional concerns related to potential disturbance (causing abandonment of eggs or chicks) or interference with foraging of nesting terns by turbidity plumes.

Beach nourishment may result in benefits to gulls and terns by increasing beach width and resting habitat (CZR 2003, SAIC 2006).

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on gulls, other terns, and black skimmers.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	Documented in post-nourishment studies	Relevant Reports	NA	Protective conservatism	Protective conservatism
Critical Impact Thresholds	Unknown	Disruption of nesting, egg/chick predation, displaced from overwintering habitat, mortality	Incompatible substrate that degrades foraging habitat	Incompatible substrate that degrades foraging habitat	Impair feeding
Impact Responses	Documented increased resting	Least terns may move away from disturbance	NA	Increased sand provides increased resting habitat	Probably forages elsewhere
Duration of Impacts	Years depending on sand retention	Minutes to 1 year if reproduction affected.	NA	Years depending on sand retention	Hours to weeks depending on plume characteristics
Potential for Restoration	Not necessary	Unnecessary to Creation or protection of breeding areas	NA	Not necessary	Creation of new nesting area, increased protection of nesting area

NA = not applicable

4.4.5 Shorebirds

Species Scientific Name	**Charadriiformes**

Regulatory Status:

Endangered	
Threatened	Federal - western snowy plover (Section 4.4.3)
CDFG Managed	Species of Special Concern - long-billed curlew

Photo credit: Andrew Lissner, SAIC

The federal threatened western snowy plover is reviewed in Section 4.4.3. The long-billed curlew is a state Species of Special Concern.

Description and Distribution:

Approximately 20 to 30 species of shorebird regularly use sandy beaches in California (Hubbard and Dugan 2003, Colwell and Sundeen 2000, McCrary and Pierson 2002). Five to eight of these species account for most of the shorebird abundance on a particular beach. The most abundant species recorded on California sand beaches include sanderling (*Calidris alba*), willet (*Catoptrophus semipalmatus)*, black-belied plover (*Pluvialis squatarola*), marbled godwit (*Limosa fedoa*), whimbrel (*Numenius phaeopus*), semipalmated plover (*Charadrius semipalmatus)*, western sandpiper (*Calidris mauri*), least sandpiper (*Calidrius minutilla*), long-billed curlew (*Numenius americanus*), and western snowy plover (discussed in a separate section). Common species in the rocky intertidal include black oystercatcher (*Haematopus bachmani*), ruddy turnstone (A*renaria interpres*), black turnstone (*Arenaria milanocephala*), and surfbird (*Aphriza virgata)*. Bays and estuaries have a greater diversity and abundance of shorebirds than ocean shores (Page et al. 1999).

Life Stage and/or Function	California			On Land	Inter-tidal	Nearshore < 30 feet	Offshore > 30 feet	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X	X	X			E, P
Juvenile	X	X	X	X	X			E, P
Egg		X	X	X				E
Primary Habitat	X	X	X	X	X			E, P
Foraging Habitat	X	X	X		X			E, P
Nesting/ Habitat		X	X	X				E

Shorebirds occur throughout California, using protected embayment habitats and exposed sandy and rocky intertidal shores (Baird 1993, Hubbard and Dugan 2003). Shorebird distribution may be affected by prey availability and/or substrate (Peterson et al. 2002). A shorebird's choice of feeding location may be influenced more by mechanical interference of

substrate (e.g., resistance to bill movement) than prey density (Quammen 1982, Baird (1993).

Potential Functions:

With the exception of snowy plover, no shorebirds breed on sandy beaches in California. Black oystercatchers breed on ledges on undisturbed rocky exposed shores primarily north of Point Conception (Zeiner et al. 1990). The vast majority of shorebirds that occur on California beaches breed in northern areas. A few species such as killdeer (*Charadrius vociferus*) and spotted sandpiper (*Actitis macularia*) breed locally, but inland or in coastal wetlands.

Shorebirds forage primarily on invertebrates in the intertidal. Shorebirds forage at all intertidal levels, including the swash zone, damp sand, in and around macrophyte wrack, in pools, and on and around exposed rocks (Hubbard and Dugan 2003). Species have different bill shapes and foraging methods that permit a variety of species to forage within an area, because each species is exploiting different prey. Shorebirds such as red knot have a pressure-sensitive bill that senses hard objects buried in the sand and a shell-crushing gizzard (van Gils 2005). Sandpipers, on the other hand, use their bills to probe for food in the substrate. Because different sandpiper species have different bill shapes and lengths, they exploit different prey items (Warnock and Warnock 2001). Plovers are "hunt and peck" predators (Petersen 2001). They use their large eyes to detect prey on the sand surface or in wrack and run over and peck at the item.

Prey availability and composition may be key determinants of habitat use by shorebirds, which have been shown to have high feeding rates (e.g., 19 to 20 sand crabs and talitrid amphipods per minute) (Hubbard and Dugan 2003). At high abundance, shorebirds may substantially affect invertebrate resources (Baird et al. 1993). Shorebirds, in turn, may be prey for avian predators such as peregrine falcons and a variety of mammals.

Associated Species	Forage/ Prey	Eaten By
Invertebrates	X	
Fish		
Birds		X
Vegetation		
Marine Mammals		
Terrestrial Animals		X
Humans		

Life History Facts:

Shorebirds breed in the spring and summer from approximately mid-April to mid-September with a peak in May and June (Zeiner et al. 1990). With the exception of the western snowy plover (discussed in a separate section), the only shorebird species that breeds on the California coast is the black oystercatcher, which lays its eggs on inaccessible ledges on remote rocky shores (Zeiner et al. 1990). Several species of shorebirds breed in California estuaries (Baird 1993).

The majority of shorebird use of California beaches occurs during the migration and overwintering periods of July through April (Baird 1993, Hubbard and Dugan 2003). The lowest numbers of shorebirds on California beaches are during May and June when shorebirds are on their breeding grounds (Baird 1993, McCrary and Pierson 2002). The greatest number of shorebirds on California beaches occurs during fall migration (September through November). Many shorebirds overwinter on California beaches from November through February (Hubbard and Dugan 2003). Spring migration back to their

breeding grounds occurs from March to May. Thus, there is a general pattern of shorebird abundance on beaches that is highest in fall-winter, moderate in summer, and lowest in spring (Lafferty 2001). The period of greatest competition among shorebirds for prey is in midwinter when there are more shorebirds present and a concomitant decline in their invertebrate prey (Baird et al. 1993).

Age at first breeding for plovers is 1 to 3 years old (Petersen 2001). Small species of sandpipers first breed at 1 year old, and larger species breed at 2 or 3 years old (Warnock and Warnock 2001). Some species of plover, including the black-bellied, are known to live more than 20 years (Petersen 2001). Sandpipers also have a long life span of up to 30 years or more (Warnock and Warnock 2001). A marbled godwit is on record as having lived 29 years.

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Nest	April - September with peak in May and June	Age at first breeding at 1 to 3 years old	N/A	July-April	May live 20 to 30 years	Mobile

Adaptations and/or Behaviors to Disturbance:

Shorebirds have high metabolic rates and relatively large daily energy expenditures (Hubbard and Dugan 2003). Because of the high energy demand of shorebirds, disturbance during foraging and, to a lesser extent, resting, can result in a significant energy shortage. Human activity has been documented to disturb shorebirds (Burger and Gochfeld 1991, Mc Crary and Pierson 1999, Lafferty 2001b). Shorebirds react to the presence of nearby humans by spending more time watching the potential human threat, walking away from approaching humans, or by flying and moving to a nearby undisturbed section of beach (McCrary and Pierson 1999). Lafferty (2001b) found that birds move or fly away, particularly when people are within 65 ft (20 m). These reactions tend to result in less foraging time by the disturbed birds. In a survey of shorebirds on Ventura County beaches, McCrary and Pierson (1999) found that the beaches with the greatest numbers of shorebirds were the beaches with the lowest number of humans. Lafferty (2001b) also found that the proportion of birds disturbed increased with the amount of activity on a beach.

Some species such as sanderlings and plovers also may derive some protection from disturbance by their tendency to flock.

Life Stage	Behavior			Habitat
	Flush	Fly	Migrate	
Adult		X		
Juvenile		X		
Egg				X

Shellfish-feeding species of shorebirds have a flexible digestive system with a gizzard than expands and contracts to balance daily food intake and energy needs (van Gils et al. 2005). Biomass of flesh-to-shell ratio in mollusks varies with size and may vary seasonally. For example, some bivalves lose up to 40% of their weight during winter (Baird et al. 1993). Van Gils et al. (2005) found that commercial dredging of intertidal cockles in the Dutch Wadden Sea resulted in reduced prey quality (i.e., lower flesh-to-shell ratio) with adverse effects on the red knot population. Red knots initially increased gizzard mass to

compensate for a gradual loss in shellfish quality, but this compensation was not sufficient and led to decreases in local survival and size of European wintering population (*ibid.*).

Potential Impacts from Sediment Management Activities:

Concerns related to sediment management activities on shorebirds are disturbance and reduction of their invertebrate prey base. With the exception of the federal threatened snowy plover (discussed in a separate section), specific measures to reduce impacts on shorebirds have not been required. Shorebirds and/or their invertebrate prey have sometimes been monitored during and after beach nourishment.

Types of sediment management activities and potential impacts to shorebirds may include:

- Maintenance dredging of embayments – not applicable.
- Offshore borrow site dredging – not applicable.
- Nearshore placement – not applicable.
- Profile placement – equipment, burial, sedimentation.
- Beach placement – equipment, burial, sedimentation.
- Dune placement – equipment, sedimentation.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging	X	X	X	X		X
Growth						
Habitat						
Reproduction						
Resting/ Roosting	X	X	X	X		X

Equipment

Little information is available on the reaction of shorebirds to vehicles and other equipment in general or to beach nourishment activities in particular, but based on their vulnerability to human disturbance, shorebirds would be expected to avoid areas of high activity.

Chambers Group (2005) monitored dredging of a sand bar in the Talbert Channel in Huntington Beach and placement of the dredged sand in the upper intertidal zone of the adjacent beach. Western snowy plovers avoided the immediate areas where the dredging and disposal activities were occurring but foraged undisturbed in the neighboring intertidal beaches. Worden and Smith (2004) documented short term disturbance to snowy plovers from pipeline installation and vehicular activity associated with disposal of dredged materials. AMEC (2002) noted that during a beach nourishment project in northern San

Diego County some shorebirds (sandpipers, godwits, curlews) were present on the receiver sites during beach discharge of sediments. For this project sand was pumped ashore behind temporary sand dikes that were constructed from existing and/or placed sands to control turbidity.

Relevant studies indicate that shorebirds typically move a short distance away (walk, fly) from human approach (Burger and Gochfeld 1991, Mc Crary and Pierson 1999); however, these movements may cumulatively result in significant energy deficiencies (Hubbard and Dugan 2003).

Shorebirds are cryptically colored and potentially could be crushed by equipment moving or spreading sand on the beach. The flocking behavior of most shorebirds and their ability to move away from disturbance would be expected to reduce the potential for direct injury from equipment involved in beach nourishment.

Shorebird foraging habitat potentially could be affected by dredging of intertidal habitat associated with embayment enhancement and/or restoration projects, depending on project design. Potential impacts would be expected to relate to size of affected area, invertebrate recovery rates, and proximity to alternate forage locations.

Burial/Sedimentation

Placement of new sand on a beach that impacts the intertidal invertebrate community can result in forage reduction for shorebirds for the period associated with benthic invertebrate recovery (Section 4.2.6).

Substrate characteristics of placed sands may impact shorebird foraging. Sediment too coarse or high in shell content can inhibit a bird's ability to extract food from the substrate (Greene 2002). Coarse sediment that is similar in size to target prey may interfere with prey detection and capture (Baird 1993) and soil resistance to bill movement apparently inflluece shorebird distribution (Quammen 1982).

Peterson et al. (2002) reported reduced use of the beach by sanderlings and willets during nourishment at Boque Banks compared to a control beach, North Carolina. Invertebrate prey was reduced and sediment incompatibility (substantially higher shell hash, fines) may have been influential.

Some shorebirds, especially plovers, forage on invertebrates associated with macrophyte wrack (Dugan et al. 2003). The mean abundance of black-bellied plovers and snowy plovers on southern California beaches was positively correlated with the standing crop of macrophyte wrack and the abundance of wrack-associated macrofauna and taxa (Dugan et al. 2003). Burial of wrack, if present, could potentially reduce foraging opportunities for plovers.

Sand placed on receiver beaches may move along the coast resulting in indirect sedimentation. If sedimentation impacted rocky shore habitat, foraging by shorebirds such as turnstones and surfbirds that feed preferentially in rocky intertidal areas potentially could be affected.

Beach nourishment may benefit shorebirds by creating a sandy beach in cobble areas or by widening an existing sand beach. SAIC (2006) found increased suitability for birds on

receiver beaches in the City of Encinitas two to four years following the 2001 San Diego Regional Beach Sand Project. Beach suitability for shorebirds and gulls was found to be higher at beaches that changed from cobble to sandy beach after nourishment, providing invertebrate forage base and resting habitat. Bird use also was generally higher across tide range at wider, nourished compared to unnourished beaches. In addition, indirect sedimentation of a downcurrent beach with cobble substrate resulted in seasonally improved foraging and resting habitat for shorebirds and gulls. Indirect sedimentation of a sandy beach backed by coastal bluffs had little influence on birds, which had relatively low abundance before and after indirect sand nourishment.

On the other hand, CZR Incorporated (2003) found little evidence that a beach nourishment project in North Carolina affected shorebird abundance. However, increased beach width was considered beneficial to gulls and terns from the stand point of improved energetics since birds were able to increase resting times as a result of increased available beach space. Beach nourishment also increased available nesting habitat of piping plovers on the East Coast (Melvin et al. 1992 cited in NRC 1995).

Turbidity

Because they do not forage in the water column, shorebirds are not affected by turbidity.

Recovery from Disturbance:

Shorebirds would be expected to recover from disturbance by beach nourishment activities within a few minutes or, at most hours. In most cases, shorebirds react to disturbance by running or flying away from the disturbance and then resuming foraging activity in the less disturbed area. Most shorebirds would be expected to avoid the area where people were working as long as activities were occurring in that area.

Sanderlings foraging at Cardiff after beach nourishment
Photo credit: Bill Haas, Varanus

Shorebirds may be impacted by a reduced prey base when clean sand is placed on a sandy beach. The invertebrate prey would be expected to recover within months (see Section 4.2.6). However, if the new sediment is incompatible with natural beach sands, reduction in invertebrate prey could be longer lasting (Peterson et al. 2002).

Shorebirds, such as turnstones, associated with rocky shores may lose rocky habitat if sand from a beach nourishment project is transported into a rocky intertidal area. In most cases, normal cycles of sand movement would be expected to move the sand out of the rocky intertidal during the winter season.

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	After cessation of activities				
Burial	Forage reduction			Altered substrate	
Sedimentation	Forage enhancement	Forage enhancement	Forage enhancement	Altered substrate	
Turbidity					X
Habitat Loss					X

Critical Impact Thresholds:

No critical impact thresholds have been established for shorebirds relating to response to noise and activity or invertebrate diversity and abundance needed to sustain wintering and/or migrating energy needs.

Data Gaps:

It would be useful to have more specific information about shorebird reaction to disturbance from beach nourishment activities and the extent to which shorebirds habituate when beach nourishment is occurring on a beach. Few studies have examined the benefits of beach nourishment to shorebirds at erosive beaches. Limited information is available regarding the impact of reduced benthic invertebrate forage on shorebird foraging patterns.

Limited inforation is available regarding beach nourishment on birds, in general. Better understanding of bird usage patterns of Calfiornia beaches would improve decision-making with respect to regional sediment management strategies.

Restoration:

Because adverse effects of beach nourishment on shorebirds (with the exception of nesting snowy plovers) are short term, restoration is not necessary.

Summary:

Beach nourishment may benefit shorebirds by creating sand beaches in cobble areas that receive little shorebird use.

Shorebirds have been documented to be sensitive to human disturbance (Burger and Gochfeld 1991, McCrary and Pierson 1999). They spend less time foraging when they are disturbed and tend to avoid beaches with high levels of human activity. It is unknown if shorebirds would habituate to an ongoing beach nourishment project on a beach, but disturbance probably would be limited to avoidance of the area where people and equipment were actually working.

Beach nourishment may temporarily reduce foraging opportunities for shorebirds by burying invertebrate forage prey and/or by covering macrophyte wrack with its associated invertebrate population. The effects of beach nourishment on foraging opportunities for

shorebirds may range from a short-term decrease in prey (generally months when source and native sediments are compatible) to a reduction in foraging value if sediments are not compatible (e.g., high shell content).

Documented benefits from beach nourishment include enhanced functional habitat by changing barren cobble beaches into productive sand habitat supporting invertebrate forage prey. Beach nourishment also has been shown to increase beach width and bird use for resting, which can reduce metabolic demands associated with movement and improve energetics.

The effects of indirect sedimentation on birds using downcurrent beaches from beach nourishment have received little attention, but would be expected to depend on type of affected habitat and degree of sediment influence. Available documentation showed little influence at a sandy beach site, but enhanced functional habitat (forgaing, resting) when sedimentation covered barren cobble habitat. Indirect sedimentation could be a concern if productive rocky intertidal habitat used by shorebirds such as turnstones occurred downcurrent from a receiver site and project volumes resulted in persistent habitat burial.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on shorebirds.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	Documented	Documented	Documented	Protective conservatism	NA
Critical Impact Thresholds	Unknown	Displaced from overwintering habitat	Incompatible substrate that degrades foraging habitat	Incompatible substrate that degrades foraging habitat	NA
Impact Responses	Enhanced forage, resting, and/or nesting habitat	Reduced foraging time, displacement	Reduced prey base and foraging opportunities	Displacement or enhanced forage	NA
Duration of Impacts	Years depending on sand retention	Days to weeks	Weeks to months	Months to years	NA
Potential for Restoration	NA	Unnecessary	Unnecessary	Unnecessary unless rocky intertidal impacted	NA

NA = not applicable

4.4.6 Wading Birds

Species Scientific Name	**Ardeidae**

Regulatory Status:

Endangered	
Threatened	
None	X

Photo credit: Karen Green

Description and Distribution:

Wading birds such as herons, egrets, avocets, and stilts are primarily found in estuaries and freshwater bodies (Zeiner et al. 1990). Great blue herons (*Ardea herodias*), great egrets (*Casmerodius albus*) and snowy egrets (*Egretta thula*) are the species most likely to be found along the open coast usually near the mouths of rivers and estuaries and in the rocky intertidal.

They forage in rocky intertidal areas on fishes and invertebrates. Great blue herons sometimes can be seen on top of the canopy in kelp beds. Herons and egrets nest primarily in trees (Zeiner et al. 1990). Great blue herons, great egrets and snowy egrets are found throughout California.

Life Stage and/or Function	California			On Land	Intertidal	Nearshore < 30 feet	Offshore > 30 feet	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X	X	X	X		E, P
Juvenile	X	X	X	X	X	X		E, P
Egg				X				
Primary Habitat	X	X	X	X				Bays, Lakes
Foraging Habitat	X	X	X	X	X	X		E, P
Nesting/ Habitat				X				

Potential Functions:

Herons and egrets feed primarily on fishes and invertebrates (Zeiner et al. 1990). They also eat reptiles, amphibians, small birds, and small mammals.

Herons and egrets are top predators with little risk from predation. Howver, other birds such as ravens may prey on eggs (Kelly 2004).

Associated Species	Forage/ Prey	Eaten By
Invertebrates	X	
Fish	X	
Birds		X
Vegetation		
Marine Mammals		
Terrestrial Animals	X	
Humans		

Life History Facts:

Herons and egrets nest in trees (Zeiner et al. 1990). They tend to be colonial nesters. Snowy egrets also may nest in dense marshes. Great blue herons nest from February through July although some fledglings may not leave the nest until September (Zeiner et al. 1990). Great egrets nest from March to July (Zeiner et al. 1990). Snowy egrets breed from late March to mid-May in southern and central California and late April to late August in northern California (Zeiner et al. 1990).

Most herons and egrets reach maturity at 2 to 3 years old (Davis 2001). Great blue herons, snowy egrets and great egrets are generally non-migratory although they disperse from their nesting colonies after breeding. (Zeiner et al. 1990). Many snowy egrets from central California migrate to Mexico for their first fall and winter but are apparently non-migratory thereafter. Herons and egrets have a life span of over 20 years (Davis 2001). A great blue heron is on record as achieving an age of 23 years and 3 months.

American avocets (*Recurvirostra americana*) and black-necked stilts (*Himantopus mexicanus*) breed in coastal estuaries along the coast with peak activity in April to June.

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Nest	February through September	First breed at 2 to 3 years old	N/A	Generally non-migratory	Up to 23 years	Mobile

Adaptations and/or Behaviors to Disturbance:

Herons and egrets fly away to avoid disturbance. Colonial nesting in high trees protects their eggs and chicks.

Life Stage	Avoidance Behavior			Habitat	None
	Burrow	Fly	Swim		
Adult		X			
Juvenile		X		X	
Egg				X	

Potential Impacts from Sediment Management Activities:

Because their primary habitat is in the shallows of estuaries and freshwater bodies, herons and egrets are rarely a focus of concern for beach nourishment activities. The exception would be in areas such as Goleta Beach where herons or egrets nest in trees near the beach (Chambers Group 1992). In those cases, there is some potential of disturbing a nesting colony if sediment management activities occurred near the nesting trees. Wading birds also have been observed to forage on intertidal reefs in the vicinity of estuaries, where they primarily reside (K. Green, personal observation). However, no beach nourishemnt project has proposed activities close enough to heron or egret nesting trees during the breeding season to potentially disturb a colony.

Types of sediment management activities and potential impacts to wading birds may include:

- Maintenance dredging of embayments – turbidity.
- Offshore borrow site dredging – not applicable.

- Nearshore placement – not applicable.
- Profile placement – equipment, burial, sedimentation.
- Beach placement – equipment , burial, sedimentation.
- Dune placement – not applicable.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging	X	X		X		X
Growth						
Habitat				X		X
Reproduction	X	X				
Resting/ Roosting	X	X				

Equipment

Herons and egrets could be disturbed by the noise, lights and activity of beach nourishment operations. Disturbance to breeding colonies would be the greatest concern. In some places such as Doheny Beach in Orange County and Goleta Beach in Santa Barbara County, birds breed in trees near the beach. Disturbance to nesting colonies can cause nest desertion (Zeiner et al. 1990, Cogswell 1977).

No studies of benthic forage reduction effects on wading birds associated with the types of dredging that may result in materials used for beach nourishment (e.g., maintenance, enhancement and/or restoration) were identified with the literature review. Because of the diet flexibility of wading birds (e.g., fish, invertebrates), potential dredging and/or excavation impacts to shallow water foraging habitat would be expected to be limited to the period of construction and temporary displacement of fish prey.

Burial/Sedimentation

On the open coast wading birds forage for fishes and invertebrates mostly in the rocky intertidal. Foraging habitat of wading birds potentially could be impacted if beach nourishment resulted in burial of functional rocky intertidal habitat or filling in of tidepools.

Turbidity

No adverse turbidity impacts to foraging habitat of herons and egrets from beach nourishment and/or dredging were identified with the literature review.

Turbidity associated with beach nourishment has the potential to result in reduced water clarity in rocky intertidal habitat, if present in the vicinity. Turbidity impacts generally are

limited to the period of sand placement operations (Section 5.55.7). Because herons and egrets forage in rocky intertidal habitat during low tide exposure, potential turbidity interference with their foraging may be limited by tide.

Because of distance considerations, offshore borrow site dredging would not be expected to result in turbidity impacts to heron and egret intertidal foraging habitat. Distance between dredge locations and shallow subtidal wading areas also would be an important consideration with respect to the potential to affect wading birds during embayment dredging and/or excavation. Turbidity plumes associated with dredging sandy materials beneficially resused for beach nourishment generally are localized and decay rapidly from the source (Section 5.5.2.7). Therefore, potential impacts to wading birds from dredging associated with beach nourishment would be expected to be temporary.

Recovery from Disturbance:

Recovery of wading birds from disturbance could range from minutes for a brief response to abandonment of nests and loss of a breeding season. Recovery from burial of rocky intertidal habitat would occur when the sediment moved out of the area. Depending on the littoral process in the area, recovery of rocky intertidal habitat from burial/ sedimentation could range from months for seasonal burial to years.

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	After cessation of activities	X			
Burial		Foraging habitat	Foraging habitat		
Sedimentation	Foraging habitat	Foraging habitat	Foraging habitat		
Turbidity	After cessation of activities				X
Foraging Habitat Loss	X	X	X		

Critical Impact Thresholds:

No critical thresholds relevant to beach nourishment activities have been established for wading birds.

Data Gaps:

More information on the tolerance of nesting colonies to disturbance would help to establish the extent to which beach nourishment activities have to establish a buffer around nesting colonies to avoid impacts.

Restoration:

If a nesting colony is disturbed to the extent that the birds abandon their nests, appropriate restoration would be to provide protection from disturbance and predation to enhance the success of one or more nesting colonies. Long term loss of rocky intertidal habitat may be partially restored by the placement of boulders in the intertidal. Placement of boulders would not, however, restore tidepools.

Summary:

Equipment and activity involved in beach nourishment operations may disturb wading birds. Herons and egrets breed in trees that may be near beaches. The greatest concern would be disturbance of a nesting colony, which could result in nest abandonment (Zeiner et al. 1990, Cogswell 1977). Abandonment of a nesting colony could result in loss of a breeding season for the affected birds. Protection of the colony (and/or other colonies) the following breeding season could restore the lost reproductive output. However, no sediment management program has proposed activities near heron or egret nesting trees during the breeding season, and no protective measures have been required.

Direct burial or sedimentation of tidepools would result in a loss of foraging habitat. If the burial/sedimentation were long-term, placement of boulders in the intertidal may partially restore the habitat.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on wading birds.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Relevant Reports	Protective conservatism	Protective conservatism	Protective conservatism
Critical Impact Thresholds	NA	Disruption of nesting	Loss of foraging habitat	Degrade foraging habitat	Impair feeding
Impact Responses	NA	Momentary disturbance to possible abandonment of nesting colony	Loss or degradation of foraging habitat	Loss or degradation of foraging habitat	Displace
Duration of Impacts	NA	Days-weeks	Duration of burial	Duration of burial	Days-weeks
Potential for Restoration	Not necessary	Protection of breeding colonies	Placement of intertidal rocks	Placement of intertidal rocks	Not necessary

NA = not applicable

4.4.8 Waterfowl and Seabirds

Species Scientific Name	**Gavidae, Podicipedidae, Phalacrocoracidae, Aythyinae, and Alcidae**

Photo credit: Callie Bowdish

Regulatory Status:

Endangered (state)	Marbled Murrelet
Threatened (federal)	Marbled Murrelet
Species of Special Concern	Common Loon, Double-crested Cormorant,

Description and Distribution:

Common waterfowl and seabird species that occur close to shore along the California mainland coast include Pacific loon (*Gavia pacifica*), common loon (*G. immer*), red-throated loon (*G. stellata*), western grebes (*Aechmophorus occidentalis*), double-crested cormorant (*Phalacrocorax auritus*), Brandt's cormorant (*P. pencillatus*), pelagic cormorant (*P. pelagicus*), surf scoter (*Melanitta persipicillata*) and, in central and northern California, white-winged scoter (*M. fusca*), common murre (*Uria aalge*), pigeon guillemot (*Cepphus columba*), and marbled murrelet (*Brachyramphus marmoratus*) (Baird 1993, Ainley and Terrell 1998, Small 1994).

Life Stage and/or Function	California			On Land	Inter-tidal	Nearshore < 30 feet	Offshore > 30 feet	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X			X	X	E, P
Juvenile	X	X	X			X	X	E, P
Egg	X	X	X	X				E, P Islands
Primary Habitat	X	X	X			X	X	E, P
Foraging Habitat	X	X	X			X	X	E, P
Nesting/ Habitat	X	X	X	X				E, P Islands

Sea birds and sea ducks either rest on the water or roost on rocky ledges or islands (Zeiner et al. 1990). They rarely occur on sand beaches.

The loons, scoters, and grebes nest either in the far north (e.g., Alaska, Canada), at inland lakes, and at coastal lagoons and estuaraies.

In California, double-crested cormorants breed in lake, estuarine and coastal habitats (Zeiner et al. 1990, Carter et al. 1992). The largest numbers breed on the Channel Islands, the Farallon Islands, on bridges in San Francisco Bay, and on offshore rocks and islands and Old Arcata Wharf in northern California (Carter et al. 1992).

Brandt's cormorant breeds along the California coast on offshore islands, offshore rocks and mainland cliffs (Carter et al. 1992, Zeiner et al. 1990). The highest abundance of nesting Brandt's cormorants is on the Farallon Islands and the Channel Islands.

Pelagic cormorants breed in small colonies (generally less than 100 birds) on steep cliffs along the northern and central California coast as well as on offshore islands including the Channel Islands (Carter et al. 1992).

The common murre nests on cliff ledges of rocky islands and the mainland coast in northern and central California (Zeiner et al. 1990, Carter et al. 1992). The largest numbers of nesting common murres are on offshore rocks along the northern California coast and on the Farallon Islands.

Pigeon guillemots nest in rock crevices and burrows in inaccessible island and mainland cliffs (Carter et al. 1992). In southern California, all pigeon guillemot nesting colonies are on the Channel Islands. Marbled murrelets nest on the branches of old-growth coniferous trees along the coast in northern and central California (Carter et al. 1992).

Functions:

Most seabirds common in California nearshore waters feed on small fishes (Elphick et al. 2001, Zeiner et al. 1990). Surf and white-winged scoters (sea ducks) feed primarily on bottom dwelling invertebrates (Zeiner et al. 1990). Eelgrass is important to waterfowl such as brandt (*Branta bernicla*) that feed nearly exclusively on the plants and on associated invertebrates (Phillips 1984). Seabirds and sea ducks are not very vulnerable to predators except when they are nesting. Seabird eggs and young are preyed upon by gulls, ravens, and crows (Zeiner et al. 1990).

Associated Species	Forage/ Prey	Eaten By
Invertebrates	X	
Fish	X	
Birds		X
Vegetation	X	
Marine Mammals		
Terrestrial Animals		
Humans		

Life History Facts:

Most seabirds and sea ducks breed between April and August with peak activity from May through August (Zeiner et al. 1990). Age at first breeding ranges from 1 to 5 years, depending on the family ((Elphick et al. 2001). Grebes first breed at 1 to 2 years old. Loons and scoters first breed at 3 years old and alcids first breed at 3. The age of first breeding for cormorants is between 2 and 5.

The sea ducks and seabird species that do not breed along the California coast are present in migration and on their wintering waters from September or October through March. The life span of seabirds and sea ducks is more than 10 years and individuals of some species have been recorded at greater than 20 years of age (Elphick et al. 2001).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Egg/Nest	April to August	Grebes first breed at 1-2 years, loons and scoters at 2-3 years, alcids at 3 years, cormorants at 2 to 5 years	N/A	September to March	More than 10 years	Mobile

Adaptations and/or Behaviors to Disturbance:

Life Stage	Avoidance Behavior			Habitat
	Flush	Fly	Swim	
Adult		X	X	X
Juvenile			X	X
Egg				X

Most seabirds and sea ducks are protected from human disturbance by the fact that they spend the majority of their time either on the water or on remote cliffs, islands, or offshore rocks. With the exception of the double-crested cormorant, which may nest on urban lakes in inshore areas, nesting is in remote, inaccessible locations. When disturbed, seabirds and sea ducks will fly away or they may dive.

Potential Impacts from Sediment Management Activities:

Waterfowl and seabirds seldom are the focus of concern for sediment management activities because sediment management activities generally are not conducted near their breeding areas. During the non-breeding season, seabirds and waterfowl are widely distributed and would not be vulnerable to a particular sediment management operation. Potential impacts are discussed in more detail below.

Types of sediment management activities and potential impacts to waterfowl may include:

- Maintenance dredging of embayments – not applicable.
- Offshore borrow site dredging – equipment, turbidity.
- Nearshore placement – equipment, turbidity.
- Profile placement – equipment, turbidity.
- Beach placement – equipment, turbidity..
- Dune placement – not applicable.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging	X	X			X	
Growth						
Habitat						
Reproduction						
Resting/ Roosting	X	X				

Equipment

Beach nourishment would not be expected to occur near any seabird nesting area or important roosting area. Seabirds and/or sea ducks potentially could be disturbed by a dredge working offshore or in a bay or harbor and by vessels and equipment in nearshore waters if sand were pumped onto a beach by a barge moored in the nearshore area.

Diving ducks have been documented to be sensitive to disturbance from recreational boaters (Korschgen et al. 1985). Wintering canvasback ducks on Lake Onalaska in the Midwest were disturbed an average of 5.2 times per day by recreational boaters on the lake. Ducks flew away from boats with outboard motors from a distance as far away as 0.6 mi (1 km) from the boat. Vessel traffic associated with beach nourishment would be much lower than the 17.2 boats per day documented to be in the study area for the Lake Onalaska study. It is unlikely that more than one or two crewboat trips per day would visit the dredge and/or barge. In addition, seabirds and sea ducks might avoid the immediate area of the dredge or barge. Common murres are fairly tolerant of close vessel approaches but loons, scoters, Brandt's cormorants and marbled murrelets exhibit higher sensitivity to vessel approaches (Strong 2005). Therefore, most seabirds and sea ducks would be expected to avoid areas where dredging or sand pumping activities were taking place.

Foraging habitat of diving ducks has the potential to be affected from dredging operations in embayments. However, no studies of benthic forage reduction effects on waterfowl associated with the types of dredging that may result in materials used for beach nourishment (e.g., maintenance, enhancement and/or restoration) were identified with the literature review. Maintenance dredging potentially could result in localized reduction in area and/or quality of forage habitat. Generally, invertebrate recovery rates are less than 1 year in frequently disturbed navigational channels (see Section 4.2.7). Longer benthic recovery rates may be associated with one-time and/or infrequent dredging of embayment habitats associated with enhancement and/or restoration projects. Potential impacts to waterfowl foraging habitat after enhancement and/or restoration dredging would be expected to relate to size of affected area, invertebrate recovery rates, and proximity to alternate forage locations.

Noise levels associated with dredging activities may disturb sea ducks, if nearby. Disturbance thresholds developed as part of the USFWS biological opinion for the Olympic National Forest program ranged from 70 to 92 dB for disturbance and injury (young missed

feeding due to adult flushed from nest) and a level of 153 dB_{rms} for underwater disturbance of feeding (WSDOT 2006). Measured ranges of dredge noises are below the injury level, but within disturbance thresholds (Section 5.3.3.6).

Burial/Sedimentation

Most seabirds are visual feeders on fishes. Because seabirds and sea ducks rarely use mainland sand beaches, they would not be affected by invertebrate forage reduction associated with burial or sedimentation. Brant distribtution is related to eelgrass occurrence in embayments; therefore, brant have the potential to be affected if equipment or sedimentation from dredging adversely impacted eelgrass habitat (Section 3.3.8).

Turbidity

Most seabirds are visual feeders on fishes. Therefore, a turbidity plume from beach nourishment operations potentially could interfere with foraging. Little information was found that documented the response of seabirds to turbidity. Cormorants have been observed to forage successfully in very turbid waters, and seabirds are known to feed along the edges of river plumes (Strong 2005). Brant distribtution is related to eelgrass occurrence in embayments; therefore, brant have the potential to be affected if turbidity from dredging adversely impacts eelgrass habitat (Section 3.3.8).

Recovery from Disturbance:

Flushing of seabirds and sea ducks by vessels or other offshore equipment would be expected to last a few minutes or at most a few hours. Flushed birds would be expected to resume foraging or resting within a few minutes of settling on the water after being flushed, but may not return to the original area for several hours. Some species may avoid the dredging or pumping area for the duration of the project.

If seabirds avoided foraging within a turbidity plume, they would be expected to return to foraging in the area when the plume subsided. Because turbidity plumes generally last on the order of hours to months, potential response would be expected to be within that time frame depending upon sediment characteristics and volume of nourishment material.

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	After cessation of activities				
Burial					X
Sedimentation					X
Turbidity	After cessation of activities				
Foraging Habitat Loss			If eelgrass loss		X

Critical Impact Thresholds:

No thresholds for turbidity or vessel or equipment disturbance have been established for seabirds.

Data Gaps:

Although seabird and sea duck response to vessels and equipment and turbidity plumes are expected to be of short duration, it would be useful to have more specific information about seabird response to these impacts.

Restoration:

Because impacts of beach nourishment on seabirds and sea ducks is expected to be short term, restoration is not necessary.

Summary:

No beach nourishment projects would be expected to occur in the vicinity of any seabird nesting colonies or important roosting areas. Sea birds and sea ducks are sensitive to vessel disturbance, and may be flushed by vessels working in nearshore coastal waters (Strong 2005, Korschgen et al. 1985). Species sensitive to disturbance may avoid areas of activity such as dredging or pumping sand onto the beach.

Because most seabirds are visual predators, they may avoid foraging within the turbidity plume. However, there is some evidence that some seabirds may forage in turbid areas (Strong 2005).

Impacts to seabirds and sea ducks from beach nourishment are expected to be short term. No residual impacts would be expected once beach nourishment activities are completed.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on waterfowl and seabirds.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Relevant Reports	Protective conservatism	Protective conservatism	Protective conservatism
Critical Impact Thresholds	NA	Unknown	NA	NA	Unknown
Impact Responses	NA	May be flushed by boats or avoid areas where equipment is working	NA	NA	May avoid foraging in turbidity plume.
Duration of Impacts	NA	Minutes to hours	NA	NA	Hours to months
Potential for Restoration	NA	Unnecessary	NA	NA	Unnecessary

NA = not applicable

4.5 Review of Marine Mammal Species Responses to Natural Disturbance and Sediment Management Activities

4.5.1 Sea Otters

Species Scientific Name	**Mustelidae**

Regulatory Status:

Endangered	
Threatened	Southern sea otter – federal threatened
CDFG Managed	Southern sea otter – fully protected

Public domain credit: NOAA.

Distribution:

The sea otter subspecies that regularly occurs along the California coast is the southern sea otter (*Enhydra lutris nereis*). Sea otters occur off of the California coast year-round, primarily along rocky shores that support kelp forest communities, but they are also known to occur along sand shorelines (VanBlaricom et al. 2001). Kelp beds serve as vital resting, foraging, and nursery sites (NOAA 1992).

The home ranges of adult males and females during the principal breeding season (summer and fall) are about a length of ½ mile of coastline, and during the winter the home ranges are about 1 mile of coastline (VanBlaricom et al. 2001). Male otters are capable of seasonal long-range movements among high-use areas on the order of 35-60 miles, while female otters can travel twice this distance (VanBlaricom et al. 2001).

Southern sea otter distribution ranges from Half Moon Bay to Point Conception and the population is estimated to be 2,150 animals (USFWS 2003). In recent years, substantial numbers of southern sea otters were seen south of Point Conception (Estes and Hatfield 1998; USFWS 2003).

Life Stage and/or Function	California			On Land	Inter-tidal	Nearshore < 30 feet	Offshore > 30 feet	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X				X	X	X
Juvenile	X	X				X	X	X
Primary Habitat	X	X				X	X	X
Foraging Habitat	X	X				X	X	X
Nesting/ Spawning Habitat	X	X				X	X	X

Functions:

Associated Species	Forage/ Prey	Eaten By
Invertebrates	X	
Fish	X	X
Birds		
Vegetation		
Marine Mammals		X
Terrestrial Animals		X
Humans		

Sea otters feed on a variety of large-bodied benthic invertebrates in both rocky and soft substrate communities and kelp beds (NOAA 1992, VanBlaricom et al. 2001). Their principal food items include large crabs, sea urchins, abalone, and large clams when they initially use a new foraging area (VanBlaricom et al. 2001). As a foraging area is used for an extended period of time, their diets diversify and will include snails, octopus, squid, and mussels (Orr and Helm 1989; VanBlaricom et al. 2001). Sea otters rarely eat fishes in California (VanBlaricom et al. 2001; USFWS 2003). Sea otters are known to control herbivorous invertebrate abundance and individual size, which can lead to the development of dense algae (e.g. kelps) communities (VanBlaricom et al. 2001).

Sea otters may be preyed upon by sharks, Stellar sea lions, killer whales, bears, and coyotes (http://www.seaotterresearch.org/predators.shtml). However, great white sharks account for most mortalities in California.

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Life History Facts:

The sea otter birthing season in California occurs year-round with a peak in births between late-February and early-April (Orr and Helm 1989; USFWS 2003). Female sea otters may give birth to one pup during each breeding season after a 6-month gestation period (Orr and Helm 1989). Female otters become reproductively active at 3-5 years of age and males become reproductively active at 5 years of age (USFWS 2003). The maximum life span of sea otters is 11-15 years (VanBlaricom at al. 2001).

Male sea otters establish breeding territories in kelp bed habitats, but may vacate these after seasonal deterioration of kelp and may form male groups (Bodkin and Rathbun 1988). Male groups may occupy areas near the ends of the otter's range in areas of abundant food resources, and then return to kelp canopies in spring to early summer to restablish their territories.

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Live birth	Year-round, with a peak from late-February to early April	Age at Sexual maturity: Females: 3-5 years old Males: at least 5 years old	N/A	N/A	11-15 years	Mobile

Adaptations and/or Behaviors to Disturbance:

Sea otters dive and swim away from disturbance.

Potential Impacts from Sediment Management Activities:

Concerns about sediment management related to sea otters focus on potential disturbance or injury from offshore equipment, damage to their kelp bed habitat or reduction in their prey base.

Types of sediment management activities and potential impacts to sea otters may include:

- Maintenance dredging of embayments – equipment, turbidity.
- Offshore borrow site dredging – equipment, turbidity.
- Nearshore placement – equipment, burial, sedimentation, turbidity.
- Profile placement – equipment, burial, sedimentation, turbidity.
- Beach placement – equipment, burial, sedimentation, turbidity..
- Dune placement – not applicable.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging	X	X	X	X	X	X
Growth						
Habitat				X		X
Reproduction	X	X	X			
Resting/ Roosting	X	X	X			

<u>Equipment</u>

Sea otters have the potential to be disturbed by the noise and activity of vessels during sediment management projects. Dredging has the potential to remove forage base. There also is risk of potential collision with dredges and support vessels.

Available information suggests that noise during dredging operations are within Level B harassment levels for continuous noise, 120 dB_{rms} (re 1 μPa) near the source, but may attenuate below harassment levels at distances beyond 500 ft (150 m) (Section 5.3.3.6). Sea otters monitored during a seismic survey showed no disturbance reactions when a full-scale seismic ship passed as close as 0.9 km (0.5 miles) (Richardson et al. 1995). Feeding otters continued to dive and feed successfully at these times. These observations suggest that sea otters would not be sensitive to noise disturbance from dredges or other offshore equipment operating at distances > 500 ft (150 m), and may tolerate closer approach depending on actual noise levels. Richardon et al. (1995) reported that sea otters often allow close approaches by boats, but sometimes avoid heavily disturbed areas).

Bodkin and Rathbun (1988) observed that abundance of a male group of sea otters in Morro Bay declined after harbor maintenance dredging started. Although they could not establish a cause and effect relationship, they speculated that otters may have left the harbor in response to the substantial increase in human activity associated with the project. Sea otters were observed in variable, but lower numbers the following year (Bodkin and Rathbun 1989). Subsequent reports by the USACE (2001) indicate low numbers of both male and female sea otters use the bay, with minimum numbers in summer months.

Sea otters have the potential to be hit by vessels associated with offshore sediment management activities, if present. Harvey (2004) notes that sea otters have been killed by strikes of fast-moving vessels off Elkhorn Slough. Therefore, risk for collision may be higher for fast moving support vessels than slow moving dredges and barges.

Burial/Sedimentation

Burial or sedimentation will not directly affect sea otters. Burial and/or sedimentation of rocky subtidal and/or kelp forest habitat could indirectly result in forage reduction. Sea otters have high energy demands and if direct burial or sedimentation reduced the availability of prey, sea otter food availability and potentially the health of the impacted individuals could be affected. The impacts of dredging on sandy subtidal and rocky subtidal invertebrates are discussed in Sections 4.2.7 and 4.2.9.

Sea otters tend to be most abundant in kelp beds (VanBlaricom et al. 2001). Therefore, if sedimentation resulted in loss of kelp forest habitat (Section 3.2.6), the result would be habitat loss for sea otters, if present.

Turbidity

Turbidity may interfere with the ability of sea otters to see prey, but there is no information on the effects of turbidity on sea otter foraging efficiency.

Recovery from Disturbance:

Recovery from minor disturbance associated with sediment management activities may occur within a few minutes. On the other hand, sea otters may temporarily abandon an area as may have happened in response to maintenance dredging in Morro Bay (Bodkin and Rathbun 1988).

In general, invertebrates recover from burial or sedimentation in a period between a few months and a few years (Section 4.2.7). Because sea otters eat larger invertebrates, recovery of prey items to a size that would be appropriate for sea otters may take 2 or more years. Any effects of turbidity on sea otters would last as long as the turbidity plume, generally hours to months depending on the duration of the project. Burial of kelp and subtidal rock habitat could persist for a few months to years depending on sediment transport processes in the area.

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	After cessation of activities				
Burial	X	X	X		
Sedimentation	X	X			
Turbidity	After cessation of activities				
Habitat Loss	X	X	X		

Critical Impact Thresholds:

No critical impact thresholds relevant to sediment management impacts have been established for sea otters.

Data Gaps:

The sensitivity of sea otters to dredging and other offshore sediment management activities has not been established.

Restoration:

Loss of reef and kelp habitat can be addressed by the creation of artificial reefs and transplant of kelp.

Summary:

Sea otters could be disturbed by offshore sediment management activities. Although sea otters have been found to be relatively tolerant of vessel activity (Richardson et al. 1995), their abundance decreased in Morro Bay Harbor when a maintenance dredging project started (Bodkins and Rathbun 1988). Sea otters also could be injured by a collision with a vessel involved in sediment management activities. Harvey (2004) notes that sea otters have been killed by strikes of fast-moving vessels off Elkhorn Slough. Generally, sediment management involves few high speed support vessels; therefore, the chances of injury to an otter from offshore vessel traffic are low.

Sea otters are closely associated with kelp beds. If a kelp bed were lost because of direct burial or subsequent sedimentation related to beach nourishment, the result would be a loss of habitat for sea otters. Kelp beds and subtidal reefs may recover from burial/sedimentation. If recovery does not occur, the lost habitat could be restored by the creation of artificial reefs and kelp transplants.

Sea otters are highly depended on a large food base of subtidal invertebrates. This food base could be reduced by burial/sedimentation associated with sediment nourishment activities. Although many invertebrates recover from burial/sedimentation within months, the larger individuals favored by sea otters may take several years to re-establish.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on sea otters.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Documented	Protective conservatism	Protective conservatism.	Protective conservatism
Critical Impact Thresholds	NA	> 120 dB_{rms} (re 1 μPa), mortality	Loss of foraging habitat	Degrade foraging habitat	Impair feeding
Impact Responses	NA	Abandonment of area. Injury by vessel strike	Reduction in prey base	Reduction in prey base	Reduced foraging efficiency
Duration of Impacts	NA	Minutes to Months	Months to Years	Months to Years	Hours to Months
Potential for Restoration	NA	Unnecessary	Artificial reef and kelp transplant	Artificial reef and kelp transplant	Unnecessary

4.5.2 Pinnipeds

Species Scientific Name	**Pinnipedia**

Regulatory Status:

Endangered	
Threatened	State & federal Threatened Guadalupe Fur Seal (*Arctocephalus townsendi*), Federal Threatened Stellar Sea Lion (*Eumetopias jubatus*)

.Public domain credit: NOAA

Distribution:

The seal species that regularly occur along the California coast are harbor seals (*Phoca vitulina*) and northern elephant seals (*Mirounga angustirostris*). Harbor seals occur commonly along the California coast, occasionally in bays and estuaries, but are never found in large numbers (Orr and Helm 1989). They tend to haul out on reefs or offshore rocks at low tide and do not venture far from water (Orr and Helm 1989).

Northern elephant seals occur from southern California north to Point Reyes during the breeding season (Orr and Helm 1989). Breeding colonies exist on San Miguel Island, Santa Barbara Island, San Nicholoas Island, San Simeon, Ano Nuevo Island, Southeast Farallon Island and Point Reyes Peninsula (Hanan et al. 2001). They are gregarious during the breeding season, sharing sand and gravel beaches (Reeves et al. 1992). Elephant seals occur all along the California coast waters during the non-breeding season (Reeves et al. 1992). Seasonal peaks in abundance occur in late January (height of breeding season), late April – early May (molting), and October. The northern elephant seal is the largest pinniped in the Northern Hemisphere (Orr and Helm 1989).

Life Stage and/or Function	California			On Land	Inter-tidal	Nearshore < 30 feet	Offshore > 30 feet	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X	X		X	X	E, P
Juvenile	X	X	X	X		X	X	E, P
Egg								
Primary Habitat	X	X	X					E, P
Foraging Habitat	X	X	X			X	X	E, P
Nesting/ Spawning Habitat	X	X	X	X				E, P

The sea lions that regularly occur along the California coast include California sea lions (*Zalophus californianus*) and Steller's sea lion (*Eumetopias jubata*). The California sea lion commonly occurs in the waters along the California coast, including bays, estuaries, and river mouths. The breeding range of the California sea lion ranges from the Channel Islands

south to Baja California. All of the breeding by California sea lions occurs on offshore islands from the Channel Islands south. At the end of the breeding season, adults and immature males begin a migration northward, peaking along the central and northern California coastline in September. A southward migration toward the breeding rookeries begins in early spring, peaking in late March to early April in central California (Orr and Helm 1989).

Steller's sea lions are commonly found in northern and central California. Small rookeries exist on Ano Nuevo Island, Southeast Farallon Island, and Cape St. George in northern California (Reeves et al. 1992). This species hauls out on rugged offshore rocks and rocky islands, but it does not commonly enter bays, estuaries, or river mouths (Orr and Helm 1989).

Functions:

Harbor seals feed largely on pelagic and benthic fish, cephalopods, and crustaceans along the shore and in bays and estuaries (Orr and Helm 1989; Reeves et al. 1992). Northern elephant seals are known to eat mesopelagic cephalopods, fish, and occasionally small sharks (Reeves et al. 1992).

Associated Species	Forage/ Prey	Eaten By
Invertebrates	X	
Fish	X	X
Birds		
Vegetation		
Marine Mammals	X	X
Terrestrial Animals		
Humans		

California sea lions eat a variety of fish and cephalopods, with seasonal and annual variability in their diet based on prey abundance (Reeves et al. 1992). Steller's sea lions feed on various fish, cephalopods, and marine mammals (e.g. small harbor seals and sea otters), and their diet will shift seasonally, reflecting changes in local prey availability (Reeves et al. 1992). Sharks and toothed whales prey on pinnipeds.

Sea lions feed during day and night, but do not appear to feed in the vicinity of the haul-out as their foraging trips are long (often >1 day) in duration (Hodder 2005). In contrast, harbor seals may be nocturnal feeders based on observations that they spend more time in the water at night than during the day (Frost et al. 2001 cited in Hodder 2005).

Life History Facts:

Harbor seals give birth to their young on a reef or sandbar between March and early May. Sexual maturity occurs between three and five years of age. Mating apparently takes place in the water after the young are weaned (Orr and Helm 1989). Northern elephant seals give birth to one pup approximately one week after hauling ashore between December and March (Reeves et al. 1992). Copulation occurs between late-December and late-February because estrus is not synchronized among females (Reeves et al. 1992).

Photo credit: Karen Green

Male California sea lions and Steller's sea lions establish breeding territories in May through July and female sea lions come ashore in May and June. Females give birth to pups at the rookery sites several days later. Estrus and mating take place 3-4 weeks postpartum in California sea lions and 11-14 days postpartum in Steller's sea lions (Reeves et al. 1992). Breeding in Steller's sea lions is polygynous (Orr and Helm 1989).

Pinnipeds are known to live less than 30 years. In general harbor seals live less than 25 years and northern elephant seals live less than 15 years (Reeves et al. 1992). California sea lions may live up to 25 years and Steller's sea lions can live up to 30 years old (Reeves et al. 1992).

Reproduction		Growth Season	Dormancy Season	Migratory Season	Longevity Life Span	Motility
Method	Season					
Live birth	Seals: December-March Sea lions: May-July	Age at Sexual maturity: Seals: 4-8 years old Sea lions: 3-8 years old	N/A	California sea lions: northward at the end of the breeding season; southward in early spring	Seals: 15-25 years Sea lions: 25-30 years	Mobile

Adaptations and/or Behaviors to Disturbance:

Pinnipeds react to disturbance by swimming away. The fact that they breed in remote areas (usually on islands) protects the juveniles.

Potential Impacts from Sediment Management Activities:

Pinnipeds have not been a focus of concern for sediment management activities because such activities have not occurred near breeding or important haul out sites. The greatest potential concern would be disturbance to pinnipeds on land if sediment management did occur near a haul out or breeding site.

Types of sediment management activities and potential impacts to pinnipeds may include:

- Maintenance dredging of embayments – equipment, turbidity.
- Offshore borrow site dredging – equipment, turbidity.
- Nearshore placement – equipment, turbidity.
- Profile placement – equipment, turbidity.
- Beach placement – equipment, turbidity..
- Dune placement – not applicable.

The different types of potential impacts, measures employed to avoid and minimize impacts, and results of relevant monitoring and studies are discussed below.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging	X	X	X		X	
Growth						
Habitat						
Reproduction	X	X				
Resting/ Roosting	X	X	X			

Equipment

Pinnipeds either offshore or on land may be disturbed by the noise, light, and activity of sediment management equipment. In general pinnipeds in the water tend to be tolerant of vessels (Richardson et al. 1995). California sea lions and harbor seals are often seen in busy harbors and near offshore oil activities. Sea lions rarely react unless a vessel approaches within 328 to 656 ft (100 to 200 m) (Bowles and Stewart 1980). Therefore, it is doubtful that offshore sediment management equipment will disturb pinnipeds in the water. Risk for collision may be higher for fast moving support vessels than slow moving dredges and barges.

On the other hand, pinnipeds on land are very sensitive to disturbance (Richardson et al. 1995). Harbor seals hauled out on shore may move into the water in response to boats (Richardson et al. 1995). People walking near or in California sea lion and northern fur seal rookeries and haul-out areas can cause major short-term disturbance (Richardson et al. 1995). If pinnipeds are disturbed on their breeding grounds, pups can be killed or injured by the stampede of animals into the water. Most of the pinniped breeding areas in California occur on offshore islands or other remote areas where sediment management activities would not occur. However, haul-out areas occur on nearshore rocks and breakwaters along the coast.

The potential to affect pinnipeds at haul-out areas may be influenced by existing conditions. For example, Hodder (2005) considered additional vessel trips associated with nearshore dredge disposal unlikely to adversely affect pinnipeds near the south jetty of the Columbia River because the area was already exposed to considerable ship traffic.

Hodder (2005) also considered nearshore dredge discharge unlikely to impact foraging opportunities for pinnipeds based on the wide foraging range of sea lions and limited potential to affect harbor seals if dredge discharge operations occured during daylight hours.

Available information suggests that noise during dredging operations are within Level B harassment levels for continuous noise, 120 dB_{rms} (re 1 μPa) near the source, but may attenuate below harassment levels at distances beyond 500 ft (150 m) (Section 5.3.3.6). Captive seals have been shown to avoid areas where sound pressure levels exceed 107 dB_{rms} (re 1 μPa) (Kastelein et al. 2006). Temporary hearing loss, also termed temporary

threshold shift (TTS), have been reported at much higher sound pressure levels (e.g., >180 dB re 1 μPa^2 s) (Kastak et al. (2005).

Pinnipeds have the potential to be hit by vessels associated with offshore sediment management activities, if present. An average of approximately three California sea lions and three harbor seals are killed or injured by boat collisions in California each year (Carretta et al. 2004). Risk for collision may be higher for fast moving support vessels than slow moving dredges and barges.

Burial/Sedimentation

Burial or sedimentation will not directly affect pinnipeds. Burial and/or sedimentation of rocky subtidal and/or kelp forest habitat could indirectly result in forage reduction.

Turbidity

Because they are visual feeders, primarily on fishes, pinnipeds could have feeding efficiency reduced by turbidity plumes associated with sediment management activities. However, there is very little information on the effect of turbidity on pinniped foraging. Seligsohn (1998) noted that in high-water years when Pacific coast river estuaries were turbid, fewer than 10% of the salmonids had seal scars compared to 33% in years when river water was shallow and clear. However, given the wide range over which pinnipeds forage compared to the limited extent of turbidity plumes associated with beach nourishment, effects of turbidity plumes from sediment management activities are likely to be minor.

Recovery from Disturbance:

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	After cessation of activites				
Burial					X
Sedimentation					X
Turbidity	After cessation of activites				
Habitat Loss					X

Pinnipeds may recover from momentary disturbance within minutes or they may avoid an area for as long as sediment management activities are occurring (up to several months). They would recover from any impacts associated with turbidity plumes when turbidity plumes subsided, usually between hours to months depending on the duration of the sediment management activities.

Critical Impact Thresholds:

No critical impact thresholds relevant to sediment management activities have been established for pinnipeds.

Data Gaps:

There is almost no information on the effects of turbidity on pinniped foraging efficiency.

Restoration:

Because impacts to pinnipeds from sediment management activities would be temporary, restoration would be unnecessary.

Summary:

Pinnipeds appear to be tolerant of noise and activity when they are in the water but sensitive when they are hauled out on land (Richardson et al. 1995). Pinnipeds on shore generally will move into the water in response to disturbance. This response may kill or injure pups on breeding grounds. Sediment management activities would be unlikely to occur near the remote areas that pinnipeds breed. Sediment management activities potentially could occur near mainland or estuarine haul out sites. Depending on the pervasiveness of the disturbance, pinnipeds could reoccupy haul out sites within minutes of the disturbance or might avoid the area during the duration of sediment management activities (potentially months).

Pinnipeds may be killed by vessel strikes. However, collisions have been associated wth fast-moving vessels. The slow speed of dredges makes this type of impact unlikely.

Because pinnipeds are visual foragers, they likely would feed less efficiently within a turbidity plume. However, because pinnipeds forage over a wide area and turbidity plumes from sediment management activities are limited in extent, the impact on pinniped feeding would be expected to be minor.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Relevant Reports	Protective conservatism	Protective conservatism	Relevant reports.
Critical Impact Thresholds	NA	> 120 dB_{rms} (re 1 μPa)	NA	NA	Unknown
Impact Responses	NA	> 120 dB_{rms} (re 1 μPa), mortality	Loss of foraging habitat	Degrade foraging habitat	Impair feeding
Duration of Impacts	NA	Minutes to Months	NA	NA	Hours to Months
Potential for Restoration	NA	Unnecessary	NA	NA	Unnecessary

NA = not applicable.

4.5.3 Cetaceans

Species Common Name	**Whales, Dolphins, and Porpoises**
Species Scientific Name	**Cetacea**

Regulatory Status:

Endangered	Federal Endangered (several whale species)
Threatened	
Other	X
None	Dolphins, porpoises

Photo credit: SAIC

Seven federal endangered species of whales may occur in waters off Calfiornia, including:

- Gray whale ((*Eschrichtius robustus*)
- Blue whale (*Balaenoptera musculus)*
- Fin whale (*Balaenoptera physalus)*
- Sei whale (*Balaenopera borealis)*
- Humpback whale (*Megaptera novaeangliae)*
- Pacific right whale (*Eubalaena glacialis*)
- Sperm whale (*Physeter macrocephalus*)

Distribution:

With the exception of the gray whale, other whale species primarily occur in offshore waters and/or are rare in occurrence. The whale species that regularly occurs along the California coast in nearshore waters is the gray whale. Gray whales begin to enter California waters along their southerly migration in November and December. They begin their northern migration along the California coast from their breeding grounds in Baja California in February, remaining in waters off the California coast until June. Gray whales typically travel in small groups close to shore on their way back to their northern feeding grounds. In most years, a few gray whales remain all summer in the coastal waters along the California coast (Orr and Helm 1989) and some immature whales remain all winter in the kelp beds off the California coast (CDFG 2001).

Gray whale spyhopping

Photo credit: Kathy Keane, Keane Biological Consultants

It is expected that other whales will occasionally occur in nearshore waters near the California coast, but they mainly occur in offshore waters.

The dolphins that regularly occur along the California coast include common dolphins (*Delphinus delphis*), bottlenose dolphins (*Tursiops truncatus*), and Pacific white-sided

dolphins (*Lagenorhynchus obliquidens*). Common dolphins typically range from the equator to southern California, with a preference for water temperatures between 10 and 28 degrees Celsius (Orr and Helm 1989). Common dolphins are the most abundant cetacean in the waters off southern California and are present year-round with peak numbers occurring in January, June, September, and October (Orr and Helm 1989).

Bottlenose dolphins are most common south of Point Conception, occurring very nearshore, as well as in bays, lagoons, and estuaries. Pacific white-sided dolphins occur along the California coast, with the peak abundance in September and October.

The porpoise species that occur along the California coast include harbor porpoises and Dall's porpoises. Harbor porpoises are the smallest cetacean found in California waters, preferring water cooler than 15 degrees Celsius. Local resident populations occur all along the central and northern California coast. This species is less common south of San Francisco Bay and rarely enters southern California waters (Orr and Helm 1989). Dall's porpoises are the largest porpoises and prefer colder waters. This species is common in northern and central coastal waters but does not occur near shore in southern California.

Life Stage and/or Function	California			On Land	Inter-tidal	Nearshore < 30 feet	Offshore > 30 feet	**E**xposed and/or **P**rotected Coast
	South	Central	North					
Adult	X	X	X			X	X	
Juvenile	X	X	X			X	X	
Foraging Habitat	X	X	X			X	X	
Reproductive Habitat	X dolphins	X dolphins	X dolphins					

Functions:

Gray whales obtain most of their food during the summer months in the Arctic (Orr and Helm 1989). Feeding behaviors have been observed throughout the range of the species, indicating opportunistic feeding year-round (Leatherwood and Reeves 1983).

Associated Species	Forage/ Prey	Eaten By
Invertebrates	X	
Fish	X	sharks
Birds		
Vegetation		
Marine Mammals		X
Terrestrial Animals		
Humans		

Dolphins feed primarily on a wide variety of fish and invertebrates. They are also known to exploit human activities for food, e.g. eating netted fish or fish discarded by fishermen (Leatherwood and Reeves 1983; Orr and Helm 1989).

Porpoises feed on a wide variety of fish, crustaceans, and cephalopods. Harbor porpoises prefer schooling, non-spiny fish such as herring, sardines, and mackerel (Leatherwood and Reeves 1983). Dall's porpoises prefer deepwater squid and fish (Orr and Helm 1989).

Predators on cetaceans include one species preying on another and sharks.

Life History Facts:

Gray whales do not mate and give birth to young in the waters off California. Mating in Pacific white-sided dolphins peaks in the fall and births peak the following summer. The birth of common dolphin calves peaks in spring and fall, after a gestation period of 10-11 months. The birth of bottlenose dolphin calves peaks in spring and summer following a gestation period of approximately 12 months.

Harbor porpoises and Dall's porpoises mate throughout the year. The majority of harbor porpoise calves are born between May and July, and the majority of Dall's porpoise calves are born in summer.

The cetaceans are a relatively long-lived group, but the exact life spans are not known. It is estimated that porpoises live less than 15 years (Leatherwood and Reeves 1983).

Reproduction		Growth Season	Migratory Season	Longevity Life Span	Motility
Method	Season				
Live birth	Whales: January-March (Baja California) Dolphins: Spring - Fall Porpoises: May - July	Age at Sexual maturity: Whales: 5-11 years old Dolphins: 5-12 years old Porpoises: 3-4 years	Whales: September-January, southward; February-June, northward. Dolphins: seasonal north-south shifts Porpoises: seasonal inshore-offshore shifts	Long-lived, Porpoises: <15 years	Mobile

Adaptations and/or Behaviors to Disturbance:

Cetaceans swim away from disturbance and/or dive.

Potential Impacts from Sediment Management Activities:

Types of sediment management activities and potential impacts to cetaceans may include:

- Maintenance dredging of embayments – equipment, turbidity.
- Offshore borrow site dredging – equipment, turbidity.
- Nearshore placement – equipment, turbidity.
- Profile placement – equipment, turbidity.
- Beach placement –turbidity.
- Dune placement – not applicable.

Potential direct and indirect impacts to different habitat functions are summarized in the table below and reviewed in greater detail in the following subsections.

Functions Potentially Impacted	Construction Phase					Post Construction Phase
	Potential Impacts					
	Equipment Disturbance			Direct Placement Burial	Indirect Turbidity	Indirect Sediment Transport Sedimentation
	Indirect Lights	Indirect Noise	Direct Damage			
Foraging	X	X	X		X	
Growth						
Habitat						
Reproduction						
Resting	X	X	X			

Equipment

Cetaceans may be disturbed by the noise and lights of equipment such as dredges and support vessels working offshore, and may be killed or injured by collisions with vessels involved in sediment management activities. Marine mammals tend to become adapted to steady noise sources but may be startled by more sudden sounds. Vessels are major contributors to overall background noise in the sea (Richardson et al. 1995). Sound levels and frequency characteristics are roughly related to ship size and speed. The dominant sound source is propeller cavitation.

In general odontocetes tend to be tolerant of vessels. The level of avoidance of baleen whales to vessels appears to be related to the speed and direction of approaching vessels (Richardson et al. 1995). Whales often move away in response to strong or rapidly changing vessel noise, especially when a boat approaches directly. Gray whales have been observed to change course at a distance of 666 to 1000 ft (200-300 m) in order to move around a vessel in their paths. On the other hand some gray whales have not been observed to react until a ship is within 50 to 100 ft (15 to 30 m). Humpback whales have been observed to avoid vessels and change behavior when a boat approached within a half mile.

Available information suggests that noise during dredging operations are within Level B harassment levels for continuous noise, 120 dB_{rms} (re 1 μPa), but may attenuate below harassment levels beyond 500 ft (150 m) from the source (Section 5.3.3.6). Dredge noises appear to be well below thresholds associated with TTS in in dolphins and white whales has been estimated as 195 dB (re $\mu Pa^2 s$) (Finneran et al. 2005).

Dredge noises may be detectable above background as far away as 12 to 15.5 mi (20 to 25 km) from the dredge (Richardson et al. 1995). Beluga whales in Alaska showed less reaction to stationary dredges than to moving barges despite similarities in their sounds (Richardson et al. 1995). The whales approached to within 1,312 ft (400 m) of the dredge. In experiments with the reaction of bowhead whales to dredge sounds, whales within 0.5 mi (0.8 km) of the sound stopped feeding and moved more than 1.2 mi (2 km) away from the noise (Richardson et al. 1995). However, bowheads appeared to behave normally in areas where actual dredging was occurring. These results suggested that the whales may initially avoid the noise, but become adapted to it.

A cetacean could be killed or injured by collision with a dredge, barge, or a support vessel.

Cetaceans have the potential to be hit by vessels associated with offshore sediment management activities, if present. One or more baleen whales are injured or killed by vessel collisions in California waters in a year (Carretta et al. 2004). Laist et al. (2001) reported one record of a whale fatality from collsion with a hopper dredge. Odondocetes rarely are reported as victims of ship strikes. The risk of vessel collision injuries to whales may be lessened at vessel speeds less than 10 kn (Laist et al. 2001). Risk for collision may be higher for fast moving support vessels than slow moving dredges and barges.

Burial/Sedimentation

Burial and/or sedimentation will not directly affect cetaceans. Indirect effects also are unlikely because cetaceans mainly feed on pelagic prey.

Turbidity

Odontocetes use sight as well as echolocation to locate prey (Richardson et al. 1995). Therefore, turbidity caused by sediment management activities could interfere with the foraging behavior of dolphins and porpoises. Because of the wide range of these animals relative to the extent of turbidity from sediment management activities, any impacts of turbidity on foraging are likely to be minor.

Recovery from Disturbance:

Cetaceans would be expected to recover from the disturbance associated with offshore equipment as soon as the equipment leaves the area. It is likely that they would become habituated to the noise and disturbance if the equipment continued working over an extended period. However, the extent to which California cetaceans habituate to dredging disturbance is unknown.

Cetaceans would recover from any impacts of turbidity when the turbidity plume subsided, generally within hours to months depending on the duration of the sediment management project.

Impact	Recovery Rates				
	< 1 year	1-2 years	> 3 years	Unknown	Not Applicable
Equipment	After cessation of activites				
Burial					X
Sedimentation					X
Turbidity	After cessation of activites				
Habitat Loss					X

Critical Impact Thresholds:

NOAA-Fisheries adopted 120 dB as the Level B harassment threshold and 180 dB as the Level A injury levels.

Data Gaps:

There is no information on the reaction of California nearshore cetaceans to dredging noises.

Restoration:

Because impacts of sediment management activities to cetaceans would be limited to temporary disturbance, restoration is not necessary.

Summary:

Because they are wide-ranging, cetaceans generally are not a focus of concern for sediment management activities. Cetaceans could be disturbed by the noise and lights of offshore equipment and associated vessels. Odontocetes are relatively tolerant of vessel noises (Richardson et al. 1995). Baleen whales tend to avoid approaching vessels (Richardson et al. 1995). Limited information is available on the response of cetaceans to dredges. Observations on whales in Alaska suggest that whales initially will avoid dredging noise but may adapt to it (Richardson et al. 1995).

Cetaceans may be injured or killed by a collision with a vessel involved in sediment management activities. Odontocetes rarely are hit by vessels. One or more baleen whales are injured or killed by vessels in California every year (Carretta et al. 2004). Laist et al. (2001) reported one record of a whale fatality from collision with a hopper dredge. However, because minimal increase in vessel traffic is associated with sediment management activities (a couple of support boat trips per day), the risk of injury to a whale from a vessel strike is relatively low.

Turbidity from dredging or sediment discharge could interfere with foraging by odontocetes, which use visual as well as acoustic clues to find prey. However, the foraging range of these animals is large compared to the amont of area that would be affected by a turbidity plume.

The following table summarizes the basis of concern and key aspects of potential impact concerns of sediment management activities on cetaceans.

Issue	Type of Impact				
	Beneficial	Equipment	Burial	Sedimentation	Turbidity
Basis of Concern	NA	Documented	NA	Protective conservatism	Protective conservatism
Critical Impact Thresholds	NA	> 120 dB_{rms} (re 1 µPa)	NA	NA	Unknown
Impact Responses	NA	> 120 dB_{rms} (re 1 µPa), mortality	NA	NA	Impair feeding
Duration of Impacts	NA	Minutes to Months	NA	NA	Hours to Months
Potential for Restoration	NA	Unnecessary	NA	NA	Unnecessary

5.0 REVIEW AND SUMMARIES OF BENEFICIAL AND ADVERSE BIOLOGICAL EFFECTS OF SEDIMENT MANAGEMENT ACTIVITIES

This report section provides overview summaries that address the following question of interest to the CSMW:

- *What are the beneficial and adverse ways habitats and species may be impacted by sediment management activities?*

Potential beneficial and/or adverse impacts from sediment management activities are summarized in this section based on integration of reviews provided for habitats and species in Sections 3 and 4, respectively. More comprehensive, integrated reviews of physical and biological factors related to impact significance are reviewed in this section.

Section 5.1 summarizes potential benefits to biological resources. Section 5.2 provides an overview of adverse impact issues and concerns. Sections 5.3 through 5.5 provide summaries by main type of impact; i.e., equipment, burial and sedimentation, and turbidity. These summaries facilitate review of the scientific basis of available information according to type of impact.

Section Topics:

5.1 Summary of Potential Beneficial Biological Effects
5.2 Overview of Potential Adverse Impact Issues and Concerns
5.3 Review and Summary of Equipment and Disturbance Impacts
5.4 Review and Summary of Burial and Sedimentation Impacts
5.5 Review, Evaluation, and Summary of Water Quality Impacts

The summaries consider the range of sediment management activities from obtaining source materials through sand placement; including dredging/excavation in embayments, offshore borrow site dredging, use of terrestrial derived sand sources, beach placement, dune placement, nearshore placement, and/or profile placement. Direct, indirect, and cumulative impact issues associated with those activities are considered.

Impacts may have adverse, neutral, and/or beneficial effects on habitats and species depending on a number of project specific factors such as project design, size, and sediment characteristics. Project design defines location, footprint of activity, and implementation methods. Project size determines temporal and spatial considerations such as impact duration, area of influence, and magnitude of effect. Since sediment is the resource being managed, all impact issues tie back to sediment characteristics and the specific methods employed during removal, transport, and/or discharge in the coastal environment. Sediment characteristics influence compatibility with native sediments, burial, sedimentation, and turbidity impacts. Each of the above-mentioned factors is described in greater detail in the following summary sections. Sediment contamination is a separate issue with some sediment management projects, but is not addressed further because the emphasis of this report is on activities associated with beach nourishment, which uses “clean” sands.

The focus of this review is on impact issues relevant to California biota; therefore, results of monitoring California sediment management projects are featured in the following sections. However, many of the available monitoring studies are from areas outside California. Several are from the Atlantic and Gulf Coasts of the United States, where shoreline erosion and protection remain critical issues, and a few are from the Pacific Northwest. In addition, other relevant studies from outside the United States are available from areas where substantial shoreline management programs have been established (e.g., Australia, New Zealand, Netherlands, and United Kingdom). While studies conducted elsewhere increase understanding of sediment management impact issues and concerns, there also may be differences unique to geographic location that limits relevance to California (e.g., differences in habitats and/or species, natural disturbance regimes associated with wave and storm climates, and/or sediment transport rates). An attempt was made herein to identify relevant lessons learned from studies conducted elsewhere in an appropriate context for California. For example, beach nourishment monitoring of coral reef habitats in the southeastern United States are not directly applicable to rocky reefs in California; however, turbidity and sedimentation effects on associated biological resources (e.g., invertebrates, fish) may be similar even though the habitats differ.

5.1 Review of Potential Beneficial Biological Effects of Sediment Management Activities

This section addresses the following questions of interest to the CSMW regarding potential biological benefits associated with beach nourishment:

- *What are the positive or beneficial effects of beach nourishment on habitats and/or ecosystems?*
- *What types of species benefit from beach restoration?*
- *How do sediment characteristics affect beneficial response (e.g., nutritive, beach profile structure, habitat value)?*

The NRC (1995) reviewed that while beach nourishment projects generally are not done to protect upland habitats or to restore beaches for biota, those benefits have been cited occasionally. Table 5.1-1 lists reports of benefits associated with beach nourishment. These reports as well as relevant ecological information summarized in Sections 3 and 4 were considered in the summary of potential benefits to California habitats and species listed in Table 5.1-2.

Biological benefits from beach nourishment relate to habitat enhancement and/or protection. Habitats with the potential to benefit the most include sandy beach and coastal dune and/or strand, where sand is the primary habitat constituent. Under conditions of limited sediment supply, sandy beach habitat may become seasonally limited (i.e., eroded beach) and coastal dune and/or strand habitats may be subject to shoreline erosion and retreat (NRC 1995, Greene 2002).

Beach nourishment has been shown to enhance habitat functions for biological resources in areas with erosive beach conditions. Types of species that may benefit include vegetation, sandy beach invertebrates, California grunion, birds, and sea turtles (Crain et al. 1995, NRC 1995, Steinitz et al. 1998, Melvin et al. 1991, Greene 2002, CZR 2003, SAIC 2006).

Table 5.1-1. Reported biological benefits from beach nourishment projects.

Biological Resource Benefit	Location	Reference
Erosion Protection		
Endangered plants	Boca Raton, Florida	Spadoni 1993 (cited in NRC 1995)
Vegetated foredunes	New Jersey	http://gannet.stockton.edu/test /cape_may2.htm
Brown pelican nesting habitat	Bird Key, South Carolina	NRC 1995, Sanders et al. 2005
Enhanced Nesting and/or Spawning Habitat		
Loggerhead turtles	Florida	LeBuff and Haverfield 1990, Witham 1990, Flynn 1992, Spadoni and Cummings 1992 (cited in NRC 1995)
Piping plovers	Maryland, Massachusetts, New Jersey, New York	Melvin et al. 1991, Melvin 2005, Brandreth 2005, Burlas 2005, Fraser and Cohen 2005, Kumer 2005
Snowy plovers	San Diego, California	USFWS 2001, SAIC 2006
California grunion	San Diego, California	SAIC 2006
Enhanced Resting Habitat		
Shorebirds, gulls, terns	North Carolina, San Diego, California	CZR 2003, SAIC 2006
Enhanced Nutritive Value		
Early season development of intertidal invertebrate community	San Diego, California	SAIC 2006
Increased bird foraging opportunity across tide condition	San Diego, California	SAIC 2006

Often physical characteristics of the beach fill (e.g., substrate, slope) are important to realized benefits (Melvin et al. 1991, NRC 1995, Greene 2002). Functions that may be supported include primary habitat for vegetation and/or invertebrates; spawning habitat for grunion; nesting habitat for sea turtles; and foraging, resting, and/or nesting habitat for birds.

Gulls resting on City of Encinitas receiver site after beach nourishment

Photo by: William Haas

Although sea turtles range into California waters, their nearest nesting sites are in Baja California, Mexico (Grupo Toruguero 2006); therefore, potential benefits to sea turtle habitat are not a relevant consideration for California and are not discussed further herein. Greene (2002) indicated that beach nourishment has the potential to enhance and/or adversely impact habitat for horseshoe crabs, but further research of effects is needed. Horseshoe crabs do not occur in California and are not discussed further in this report.

Table 5.1-2. Potential benefits to California habitats and species from beach nourishment.

California Coastal Habitats and Species	Enhance and/or Improve				
	Reduce Erosion	**Primary Habitat**	**Nesting, Spawning, Nursery Habitat**	**Resting Habitat**	**Foraging Habitat**
Habitats					
Coastal Dune and/or Strand	BN (D)	BN (I)	BN (I)	BN (I)	BN (I)
Sandy Beach	BN (D)	BN (D, I)	BN (I)	BN (I)	BN (I)
Sandy Subtidal					
Rocky Intertidal					
Rocky Subtidal					
Kelp Forest and/or Bed					
Surfgrass Bed	BN (I)?				
Eelgrass Meadow					
Shallow Inlet Embayment					
Deepwater Inlet Embayment					
Species					
Abalone					
California Lobster					
Dungeness Crab					
Pismo Clam		BN (I)?			
Sea Urchins					
Sandy Beach Invertebrates		BN (I)	BN (I)		BN (I)
Sandy Subtidal Invertebrates					
Rocky Intertidal Invertebrates					
Rocky Subtidal Invertebrates					
California Grunion			BN (I)		
Pacific Herring					
Salmonids					
Demersal Fish					BN (I)
Pelagic Fish					
Subtidal Reef Fish					
Tidepool Fish					
California Brown Pelican					
California Least Tern			BN (I)	BN (I)	
Western Snowy Plover		BN (I)	BN (I)	BN (I)	BN (I)
Gulls and Terns				BN (I)	BN (I) gulls
Shorebirds		BN (I)	BN (I)	BN (I)	BN (I)
Wading Birds					
Waterfowl					
Cetaceans					
Pinnipeds					
Sea Otters					

Note: Blank entries denote no reports of beneficial effects from sediment management activities.
Project type: BN = Beach Nourishment
Nature of effect: (D) = direct, (I) = indirect.
? = speculative benefits

The following factors appear to influence the potential for biological beneficial effects from beach nourishment:

- Existing conditions, which define baseline conditions and whether habitat functions or values are degraded from erosion.
- Project volume, which influences shoreline protection from erosion, persistence of sandy beach habitat, and duration of post-project benefit.
- Project design width and slope, which influences extent of available beach habitat and wildlife movement patterns.
- Grain size characteristics, which influence compatibility of placed sediments with habitat functions and values.

Project size or volume has been long recognized as a main consideration in maximizing potential recreational and shoreline protection benefits associated with beach nourishment projects (NRC 1995). Generally, cross shore profiles of sand elevation from the backshore to depth of closure (beach profiles) are used to document beach width, sand movement, and duration of shoreline protection and recreational benefits. Available information indicates that biological benefits also relate to physical features of beach habitat related to sediment placement volume and/or fill design. For example, beach width, sand depth, and sand persistence contribute to habitat functional values for beach invertebrates, spawning habitat for California grunion, and foraging and/or resting habitat for birds (CZR 2003, SAIC 2006). Beach slope is an important consideration of fill design at beaches used by sensitive species such as endangered piping plovers and turtles (Melvin et al. 1991, Crain et al. 1995, Brandreth 2005, Melvin 2005).

Compatibility with native sediments generally is preferred to increase project predictability and performance. The NRC (1995) summarized that sand grain size that is only slightly smaller than native sands can result in significantly narrower equilibrated dry beach widths compared to sand the same size as (or larger) than native sand. Thus, sediment compatibility is an important consideration of duration of potential shoreline protection benefits as well as habitat functions related to beach width (e.g., resting habitat for shorebirds).

Substrate characteristics are important to invertebrate recovery; habitat suitability for fish foraging and spawning; and bird foraging, resting, and/or nesting. Available information indicates that substrate characteristics, sand persistence, and swash climate influence invertebrate community development and nutritive values of beaches. Generally, invertebrate species richness decreases with coarser sands and harsh swash climate and increases with finer sands and more benign swash (Defeo and McLachlan 2005). Invertebrate species richness and community development across seasons increase with sand depth and persistence (SAIC 2006). Consequently, more developed and persistent invertebrate communities provide greater potential nutritive values to secondary consumers (surf zone fish, shorebirds and gulls).

During beach nourishment some resources may be attracted to the project area as a result of exposure of prey items and organic matter. Birds (especially gulls) may congregate at the discharge of hydraulically pumped dredge materials, presumably to feed on dead invertebrates and associated organic matter (USACE 1998a; Peterson et al. 2002; AMEC,

2002; Melvin 2005; Green, personal observation). Similarly, localized attraction was reported for some fish (kingfish) during beach nourishment off New Jersey apparently from increased prey availability as a result of resuspension of newly deposited sand (Burlas et al. 2001, Wilber et al. 2003). Attraction effects apparently are short-lived and limited to the construction period.

Gulls attracted to hydraulic discharge during Surfside-Sunset beach nourishment

Photo credit: David Cannon, Everest International Corporation

Other sediment management activities involving dredging to maintain and/or restore embayments may provide benefits to biological resources (Table 5.1-3). Maintenance dredging typically is performed to maintain navigational and entrance channels (see Table 2.1-1). In shallow inlet embayments, maintenance dredging and/or excavation may be required to maintain an open inlet and tidal flushing. Shallow inlet embayments represent important nursery areas for nearshore fish (Section 3.3.9); therefore, this activity maintains functional habitat values for these resources as well as water quality for aquatic resources.

Restoration dredging may be periodically undertaken in shallow and deepwater inlet embayments to remove excess sedimentation to improve hydrodynamics, water quality, and habitat functions for biological resources. Because of the close association between water quality and habitat quality for biological resources, maintenance and/or restoration dredging has the potential to indirectly benefit a number of species that use embayments as foraging, spawning, and/or nursery habitats.

Ecosystem enhancement and/or restoration dredging may indirectly benefit submerged aquatic vegetation (SAV) such as eelgrass, which is susceptible to degradation from sedimentation and/or turbidity (Section 3.3.8). Because eelgrass habitat supports multiple functional uses for a variety of species, indirect benefits from enhancement of this habitat may increase primary, foraging, and/or nursery habitat for numerous species of invertebrates and fish, including Dungeness crab, Pacific herring, and salmonids.

Dredged materials have been beneficially used to create nesting islands for birds in several areas of the United States. Increased and/or more protected nesting areas have indirectly benefited several species, including terns, plovers, gulls, black skimmer, brown pelican, and American oystercatcher (Melvin et al. 1991, Calver 2005, Golder et al. 2005, Guilfoyle et al. 2005, Jenkins and Erwin 2005, Melvin 2005). Dredge material islands have been created in several embayments in California, benefiting endangered least terns, threatened snowy plovers, and other terns, black skimmers, and gulls.

Potential biological benefits from sediment management activities involving beach nourishment and/or dredging are summarized in more detail in Subsection 5.1.1 for habitats and Subsection 5.1.2 for species.

Table 5.1-3. Potential benefits to California habitats and species from dredging activities.

California Coastal Habitats and Representative and/or High Interest Species	Enhance and/or Improve				
	Reduce Sedimentation and/or Improve Tidal Flushing	**Primary Habitat**	**Nesting, Spawning, Nursery Habitat**	**Resting Habitat**	**Foraging Habitat**
Habitats					
Coastal Dune and/or Strand					
Sandy Beach					
Sandy Subtidal					
Rocky Intertidal					
Rocky Subtidal					
Kelp Forest and/or Bed					
Surfgrass Bed					
Eelgrass Meadow	RD (I)	RD (I)	RD (I)		RD (I)
Shallow Inlet Embayment	MD (D), RD (D)	MD (I), RD (I)	MD (I), RD (I)	RD (I)	MD (I), RD (I)
Deepwater Inlet Embayment	MD (D), RD (D)	RD (I)	RD (I)	RD (I)	RD (I)
Species					
Abalone					
California Lobster					
Dungeness Crab			RD (I)		
Pismo Clam					
Sea Urchins					
Sandy Beach Invertebrates					
Sandy Subtidal Invertebrates (embayment)		MD (I), RD (I)			
Rocky Intertidal Inverts					
Rocky Subtidal Inverts					
California Grunion					
Pacific Herring			RD (I)		
Salmonids			RD (I)		RD (I)
Demersal Fish			MD (I), RD (I)		MD (I), RD (I)
Pelagic Fish			MD (I), RD (I)		MD (I), RD (I)
Subtidal Reef Fish					
Tidepool Fish					
California Brown Pelican			RD (I)		
California Least Tern			RD (I)	RD (I)	MD (I), RD (I)
Western Snowy Plover			RD (I)	RD (I)	MD (I), RD (I)
Gulls and Terns			RD (I)	RD (I)	MD (I), RD (I)
Shorebirds			RD (I)	RD (I)	MD (I), RD (I)
Wading Birds				RD (I)	MD (I), RD (I)
Waterfowl				RD (I)	MD (I), RD (I)
Cetaceans					
Pinnipeds					
Sea Otters					

Note: Blank entries denote no reported beneficial effects.
Project type: MD = Maintenance Dredging, RD = restoration dredging,
Nature of effect: (D) = direct, (I) = indirect.

5.1.1 Habitats

Potential biological benefits are summarized below for each of the ten reviewed coastal habitats, which are organized under umbrella headings according to habitat categories; i.e., coastal dune and/or strand, soft substrate, hard substrate, submerged aquatic vegetation, and embayments. The summaries also identify if no reports of biological benefits from sediment management activities were identified from the literature review and/or no benefits would be expected based on relevant reports.

5.1.1.1 Coastal Dune and/or Strand

Dune restoration in California has primarily focused on eradication of non native species and/or revegetation with native species (Section 3.3.1). Dunes with native species are less subject to erosion and support greater biological diversity than degraded habitats with monotypic stands of non-native species. Consequently, restored dunes increase potential shoreline protection and biological benefits. On occasion dune restoration has been implemented in California as part of sediment management projects. For example, the Ventura Port District implemented a dune revegetation program to stabilize South Beach (USACE 1998b). Dune restoration also was conducted at Port Hueneme to reduce sand loss and associated maintenance (DBW and SCC 2002).

Beach nourishment in combination with dune stabilization techniques has been implemented to foster more natural and cost effective shoreline protection along the Atlantic and Gulf Coasts of the United States and internationally (e.g., Australia, Holland, New Zealand, United Kingdom) (NYSDEC 1998, SNH 2000, Maryland DNR 2003, Dahm et al. 2005, Florida DEP 2005, Louisiana DNR 2005, Sciaudone et al. 2005). Beach nourishment may provide an immediate benefit of increased shoreline protection associated with increased beach width and a longer term benefit by providing a sand source to dunes via aeolian transport. Dune stabilization techniques have included revegetation, sand and/or drift fencing, thatching, and/or use of sand retention walls (Brooks and Agate 2001, Dahm et al. 2005).

Beach nourishment also may indirectly benefit sensitive plants and/or wildlife using coastal dune and/or strand habitat. Endangered and/or threatened plant species have been protected from erosion by beach nourishment in Florida (Spadoni 1993 cited in NRC 1995). Vegetated foredunes were protected from erosion by nourishment of degraded beaches in New Jersey (http://gannet.stockton.edu/test/cape_may2.htm). Nesting sites of endangered piping plovers in backshore areas have been indirectly protected from erosion by beach nourishment projects throughout the East Coast of the United States.

5.1.1.2 Soft Substrate

Sandy Beach

Beach nourishment may enhance sandy beach habitat for indigenous biota or wildlife that use the beach for foraging, resting, or nesting (NRC 1995, Melvin et al. 2001, CZR 2003, SAIC 2006). Sand is the limiting factor associated with seasonal development of the beach invertebrate community, use by fish as spawning habitat, and functional use by birds as foraging, resting, and/or nesting habitat. Therefore, beach nourishment benefits to sandy beach habitat apply to erosive beach areas where sand supply is limited. Habitat enhancement would not be expected from sand placement at dissipative beaches, which

have limited sand mobility and a well developed invertebrate community (Hesp and Short 1982, McLachlan 1992, Brown and McLachlan 2002, Defeo and McLachlan 2005).

Biological benefits from beach nourishment may be associated with substrate change, increased beach width, and/or extended habitat suitability for functional uses across seasons. For example, narrow beaches characterized by extensive cobble cover and/or sand wash out with seasonally limited or few biological resources were changed to wider and seasonally persistent sandy beach habitats after the 2001 San Diego Regional Beach Sand Project (SAIC 2006). The invertebrate community developed earlier in the season, potential habitat suitability for grunion extended across more of their spawning season, and bird foraging and resting occurred across more of the tide range at nourished beaches compared to non-reciever sties. Increased beach width was associated with enhanced habitat suitability as resting habitat for birds was reported after a beach nourishment project in North Carolina (CZR 2003).

Cardiff receiver site prenourishment

Cardiff receiver site post-nourishment

2001 San Diego Regional Beach Sand Project

Photos: K. Weldon, City of Encinitas (above) and Karen Green (below)

Other studies also have shown sand persistence to be an important factor to functional habitat quality. Dugan and Hubbard (1996) reported that older (i.e., overwintered) *Emerita* sand crabs had higher abundance on beaches where sand is retained through winter months than on beaches where scour and erosion are substantial. It is possible that a higher abundance of older *Emerita* also may reflect greater sand volume stability in the nearshore. Shallow, sandy subtidal waters may provide refuge for *Emerita* during storms, extremely high tides, and/or winter months (Morris et al. 1980, Dugan et al. 2000b).

An important indirect benefit of increased sand persistence and greater invertebrate community development is an enhanced forage base and potential increase in the nutritive value of beaches for secondary consumers such as fish and birds.

Movement of sediments away from beach nourishment sites also may result in indirect benefits to downcurrent beaches (NRC 1995). For example, indirect habitat benefits were observed at beach sites located approximately 1,000 to 3,000 ft (300 to 900 m) downcurrent of sites that received 101,000 to 132,000 cy of sand from the 2001 San Diego Regional Beach Sand Project (SAIC 2006). The amount of benefit appeared to relate to how erosive conditions were prior to nourishment. Downcurrent beach sites changed from seasonal to persistent sandy beach habitat where pre-project substrate consisted of a mix of cobble and sand; whereas, sand volumes were insufficient to prevent seasonal wash out at sites where pre-project cobble was extensive. Although indirect benefits from sand transport were documented, the spatial extent of downcurrent benefits was not determined with that study.

Beach nourishment has the potential to enhance habitat use by sensitive species. For example, threatened snowy plovers were observed foraging at two beach sites that directly

and indirectly received sand during the 2001 San Diego Regional Beach Sand Project, whereas, the sites had cobble cover prior to nourishment (SAIC 2006). Melvin et al. (2001) reported that beach nourishment has increased available nesting habitat for endangered piping plovers on the East Coast of the United States.

Sandy Subtidal

No reports of beneficial impacts to sandy subtidal habitat from sediment management activities were identified from the literature review. It is unknown to what extent, if any, beach nourishment benefits (discussed above) may extend to shallow, inshore sandy subtidal habitat across the cross-shore beach profile in eroded beach areas. Sediment compatibility and hydrodynamics may be important considerations with respect to the potential for benefits and/or adverse impacts to sandy subtidal habitat. Temporary silt-loading after beach nourishment may result in short-term enhancement; whereas, persistent silt-loading can alter benthic communities (Parr et al. 1978, Rakocinski et al. 1996, 2001). No benefits to sandy subtidal habitat would be expected from sediment management activities involving dredging and/or excavation.

5.1.1.3 Hard Substrate

No reports of beneficial impacts to rocky intertidal or rocky subtidal substrate from sediment management activities were identified with the literature review. No potential benefits would be expected given that sand scour and sedimentation are disturbance factors that adversely affect recruitment of attached invertebrates and plants (Foster and Schiel 1985, Airoldi 2003). Dredging operations typically are not conducted in areas of rocky substrate.

5.1.1.4 Submerged Aquatic Vegetation

Kelp Forest and/or Bed

No reports of beneficial impacts to kelp habitats from sediment management activities were identified from the literature review. No potential benefits would be expected from beach nourishment or dredging given that sedimentation and turbidity are disturbance factors that adversely affect recruitment, persistence, and/or species diversity in kelp beds (Aleem 1973, Devinny and Vose 1978, Foster and Schiel 1985, Konar and Roberts 1986, North 1986, Bence et al. 1989, Murray and Bray 1993, Pondella et al. 1996, DFG 2001).

A giant kelp variety occurs in the Santa Barbara Channel that is adapted for living on sand substrate. While sand is a primary habitat condition for this kelp variety, recruitment is still on hard substrate above the sand (e.g., holdfast, worm tube, etc.). Thus, sand may represent a beneficial or adverse factor to this kelp variety depending on life stage. However, little to no relevant information is available regarding those potential relationships (Section 3.3.6).

Surfgrass Bed

No reports of beneficial impacts to surfgrass from sediment management activities were identified with the literature review. Surfgrass attaches to hard substrate, but is a sand tolerant or sand-enhanced species adapted to periodic sand inundation and partial burial (Gibbs 1902, Littler et al. 1983, Cooper and McRoy 1988, Stewart 1989, http://www.coastal/researchcenter.ucsb.edu/cm/surfgrass.html). Sand erosion during storm conditions can weaken the rhizome anchorage of surfgrass, contributing to interannual

variability in surfgrass distribution (Stewart 1989). There is limited understanding with respect to the beneficial relationship between sand and surfgrass; therefore, potential beneficial impacts to this habitat from beach nourishment are speculative. Substantial sand burial of surfgrass is detrimental (Section 5.4.3.4).

Surfgrass may decrease shoreline erosion because of the sand binding properties of its rhizomatous root system (Gibbs 1902, NOAA 2001b). Although the ecological benefits of surfgrass are well recognized (Section 3.3.7), more attention to the potential shoreline protection benefit of this habitat is warranted, particularly in light of the role seagrasses had in protecting coastal areas during the December 2004 tsunami (see the section below on Other Seagrass Species).

Eelgrass Meadow

No reports of beneficial impacts to eelgrass from beach nourishment were found from the literature review. Eelgrass grows in soft substrate and is tolerant of sand movement and some partial burial, but substantial burial can result in plant loss (Blois et al. 1961, Onuf and Quammen 1983, Harrison 1990). Therefore, no direct benefits to eelgrass habitat from beach nourishment would be expected.

Eelgrass may be adversely affected by substantial sedimentation and turbidity (Section 3.3.8). Dredging to remove excessive sedimentation and improve water clarity has been included in planned and implemented enhancement/restoration projects at several California embayments with potential benefits to eelgrass habitat (e.g., Agua Hedionda Lagoon, Bolinas Lagoon, Morro Bay). Creation of eelgrass habitat also has been included in restoration projects and/or as mitigation for port development in several other embayments (e.g., Anaheim Wetlands, Batiquitos Lagoon, Mission Bay, Newport Bay, Oakland Harbor, San Diego Bay). Enhanced eelgrass distribution and/or quality has the potential to benefit a variety of species that use the habitat as spawning and/or nursery grounds and/or foraging areas (e.g., California halibut, Dungeness crab, Pacific herring, salmonids) (Section 3.3.8).

Other Seagrass Species

The benefits of seagrasses to coastal shoreline protection were recently demonstrated on a world-wide scale associated with the December 2004 tsunami. Rapid assessments of coastal seagrass meadows were undertaken in tsunami impacted areas (http://www.worldseagrass.org/WSA_webissue02.pdf). Results demonstrated substantial shoreline protection benefits and relatively minor impacts to seagrass habitat, as summarized below.

> Thailand – "The seagrass meadows along the Andaman coast of Thailand cover an area of 7,937 hectares. A rapid assessment undertaken by the Department of Marine and Coastal Resources of MONRE covered approximately 70% of the total seagrass area and found 3.5% of the inspected areas impacted through siltation and sand sedimentation and 1.5% of the inspected areas suffered total habitat loss. The seagrass meadows of Talibong Island, Trang Province, which are the largest seagrass areas in Thailand's Andaman coast ....did not suffer any loss, although 10% was impacted by siltation or superficial erosion. It was estimated that it would take three months for seagrass to recover from siltation, but no estimates were provided as to how long it will take to recover from sand sedimentation. The

assessments also revealed that seagrass meadows covering the intertidal zone appeared to have prevented soil erosion of beaches during the tsunami event."

Indonesia – "Besides coral reefs, highly productive seagrass meadows, totaling approximately 600 hectares, are found off the coast of Nias and off Pulau Weh and Banyak Islands. Functionally, they also serve to trap coastal sediments, provide coastal protection from high waters, and support endangered green sea turtle and dugong populations in the area. The National Development Planning Agency (BAPPENAS) initial damage assessment estimated 20% loss of seagrass meadows. .....Wetlands International has also conducted preliminary assessments of the impact on seagrass in a number of Islands. Early results suggest extensive damage to seagrass meadows in Pulo Aceh, with less severe but significant impact in the Simeulue and Weh Islands".

Sri Lanka – "Seagrass meadows constitute the most extensive coastal ecosystem in Sri Lanka. They occur along the open coast as well as within estuaries and lagoons (UNEP-WCMC, 2003). ..... In Sri Lanka, the impact of the tsunami on coral reefs and coastal ecosystems was highly varied, ranging from almost unaffected to extremely damaged. Damage to seagrass meadows however, was minor and where present was mostly due to shifting rubble. Hardly any uprooting was observed. Severe beach erosion was observed both in the east and southwest areas, but impact was patchy".

Seychelles – "The Seychelles has a coral reef area of 1,690 square kilometers with eight seagrass species. Damage to seagrass meadows was low, with only one definite case of damage recorded at Baie Ternaie Marine Park, Mahé Island. In this case, a seagrass meadow adjacent to a drainage channel in the reef was smothered by sediment, probably mobilized from the extensive shallows and reef flat area, and backwash from land."

5.1.1.5 Embayments

Shallow Inlet Embayment

Beach nourishment may represent a beneficial use opportunity for littoral sands dredged and/or excavated from shallow inlet embayments to maintain open inlet functions (Section 3.3.9). In addition, beneficial use of dredged sands often is a component of ecosystem enhancement and/or restoration projects in California (e.g., Batiquitos Lagoon, Bolinas Lagoon, Bolsa Chica Lowlands, San Dieguito Lagoon, San Elijo Lagoon).

Deepwater Inlet Embayment

Sediments dredged from deepwater inlet embayments to maintain entrance and/or navigational channels may be placed on receiver sites located downcurrent of breakwaters and/or jetties to restore beaches that become eroded from structural interruption of littoral transport (e.g., Channel Islands Harbor, Port Hueneme Harbor, Santa Barbara Harbor, USACE 1994a, 1998a). Dredging and beneficial use of suitable sediments for beach nourishment also may be conducted as part of enhancement and/or ecosystem restoration

projects in deepwater inlet embayments (e.g., Morro Bay, Upper Newport Bay, USACE and County of Orange 2000, USACE 2003).

5.1.2 Species

Similar to the habitat summaries, the summaries for species are organized under umbrella categories according to taxonomic association; i.e., invertebrates, fishes, birds, and marine mammals. The summaries focus on California species and also reference when no reports of biological benefits were identified from the literature review and/or no anticipated benefits would be expected based on species distribution and/or behavior considerations.

5.1.2.1 Invertebrates

Beach nourishment may provide primary habitat and/or enhanced habitat quality for sandy beach invertebrates. Beach nourishment changed a cobble beach with few biological resources to sandy beach habitat supporting a variety of invertebrate species after the 2001 San Diego Regional Beach Sand Project (SAIC 2006). In addition, a greater variety of invertebrates developed earlier in the season at beaches that changed from seasonally erosive to persistent sand.

Sandy beach invertebrates represent important forage base for shorebirds, gulls, and surf zone fish (McLachlan et al. 1981, Reilly and Bellis 1983, Baird 1993, Dugan et al. 2000a, 2003, DeLancey 1989, Wilber et al. 2003). Therefore, earlier season development of the invertebrate community increases the quality of the invertebrate forage base for secondary consumers. For example, larger sizes of *Emerita* mole crabs and *Donax* clams may be attained by the end of the season, as a function of the time period available for growth, when populations develop from early season recruitment (Reilly and Bellis 1983).

Pismo clams are long-lived and mainly associated with persistent sand beaches (Section 4.2.4). Therefore, increased sand persistence throughout the beach profile as a result of beach nourishment has the potential to benefit the species. SAIC (2006) reported the occurrence of juvenile Pismo clam at a beach site that changed from cobble to sand after indirect nourishment from the 2001 San Diego Regional Beach Sand Project. However, substantial population establishment in the intertidal was not documented up to four years after the projects. Therefore, potential benefits to Pismo clam from beach nourishment have not been documented and are speculative.

Restoration dredging in embayments to remove excess sedimentation and improve water quality may indirectly benefit a variety of invertebrates and nursery habitats such as eelgrass, which may be used by commercially important species such as Dungeness crab.

5.1.2.2 Fishes

Enhancement of grunion spawning habitat after beach nourishment in San Diego County was documented (SAIC 2006). Enhancement was associated with increased sand persistence and beach width, which provided suitable habitat conditions for spawning across the entire spawning season. Prior to nourishment, habitat suitability was seasonal with unsuitable conditions (cobble, thin sand layer) early in the season and suitable sand depths later in the season after sufficient sand accreted. Sand migration from receiver sites also enhanced habitat suitability of downcoast sites (measured up to 2,500 ft, 750 m away).

Grunion eggs were incidentally documented during collection of invertebrate samples during spring surveys at two of the studied receiver and non receiver sites, confirming early season beneficial effects of direct and indirect beach nourishment. Enhanced habitat suitability for grunion spawning was still evident four years after beach nourishment when the study was concluded; the duration of benefit was not documented (SAIC 2006).

There is indirect evidence that sand persistence may enhance potential forage for surf zone fish. Dominant sandy beach invertebrates such as *Emerita* mole crabs and *Donax* clams are important prey items for demersal-feeding surf zone fish (Reilly and Bellis 1983, Peterson et al. 2000b, DeLancey 1989, Wilber et al. 2003). Dugan and Hubbard (1996) reported that older (overwintered) *Emerita* sand crabs may have higher abundance (survivorship) on beaches where sand is retained through winter months than on beaches where scour and erosion are substantial. In addition, SAIC (2006) found that the invertebrate community developed earlier in the season at beach nourishment and other sites where sand habitat was persistent across seasons than at seasonally erosive beaches. These findings suggest that persistent sandy beach habitat has the potential to benefit secondary consumers in the surf zone, although benefits to surf zone fish have not been demonstrated to-date.

Sediment management activities in embayments may indirectly benefit fish. Embayments provide essential nursery habitat for more than one-half of the fish species on the California continental shelf (439 species) (Horn and Allen 1976); therefore, dredging and/or excavation to maintain open inlet conditions in shallow inlet embayments and/or to remove excess sedimentation to enhance/restore habitat quality may indirectly benefit fish populations that use these areas as spawning, nursery, and/or foraging habitats (e.g., California halibut, Pacific herring, salmonids).

5.1.2.3 Birds

Several studies have documented beneficial effects to birds from beach nourishment. Increasing beach width and/or decreasing cobble cover with sand appears to enhance foraging, resting, and/or nesting habitat functions for shorebirds, gulls, and terns (CRZ 2003, SAIC 2006). Important factors affecting potential benefits may include substrate suitability, project design (e.g., slope), and schedule (Melvin et al. 1991, Melvin 2005).

Cardiff receiver site, after beach nourishment

Photo credit: Karen Green

Beach nourishment appeared to have a positive effect on bird use in northern San Diego County (SAIC 2006). Prior to nourishment, study beaches were erosive with either persistent cobble cover or a seasonal mix of cobble and sand. Few to no birds were observed during spring reconnaissance surveys when beaches were seasonally erosive (MEC 2000a). Following beach nourishment, total bird abundance (shorebirds and gulls) was higher at receiver sites compared to non-receiver sites, presumably related to the increased sand habitat and/or greater beach widths across tide condition (SAIC 2006). Observations of foraging and resting confirmed that beach nourishment resulted in functional habitat value for birds.

Increased beach width also appeared to benefit birds after a beach nourishment project in North Carolina (CZR 2003). The benefit was not consistently reflected in bird abundance,

which was higher or lower at receiver beaches compared to non receiver beaches. Instead there was a change in behavior of shorebirds, gulls, and terns with more time spent resting relative to flying which was beneficial from the perspective of improved energetics.

Beach nourishment may enhance and/or protect habitat of sensitive threatened and/or endangered bird species (NRC 1995, Greene 2002). Federally threatened western snowy plovers were observed foraging at beach sites that changed from cobble to sandy beach habitat after nourishment in northern San Diego County (SAIC 2006). The sites were located adjacent to a lagoon where snowy plovers nest, demonstrating movement between embayment and beach habitats. Beach nourishment was recognized as likely providing a temporary benefit to critical habitat for snowy plover at Mission Beach, San Diego County (USFWS 2001). Endangered piping plover habitats have been improved from beach nourishment in Maryland, Massachusetts, New Jersey, and New York (Melvin et al. 1991, Melvin 2005, Brandreth 2005, Burlas 2005, Fraser and Cohen 2005, Kumer 2005). Beach nourishment protected endangered brown pelican nesting habitat from erosion at Bird Key, South Carolina (NRC 1995, Sanders et al. 2005). Brown pelicans nest at offshore Islands in California; therefore, no benefits to nesting habitat are expected. However, benefits potentially could occur if sand spit resting areas along the mainland are protected and/or enhanced. Brown pelican foraging may benefit after restoration dredging in embayments.

Melvin (2005) reviewed design criteria to enhance beach nourishment for endangered piping plovers, including: compatible substrate (grain size, color), accessible slope (10:1 preferred), minimum elevation (allow for overwash), no or minimal vegetation and/or sand fencing, and protective restrictions (symbolic fencing, dog and vehicle restrictions).

Nesting islands have been created from dredged materials in several lagoons and bays in California, providing benefits to endangered California least tern, threatened snowy plover, and other birds such as Caspian tern, Royal tern, and black skimmer (e.g., Batiquitos Lagoon, Bolsa Chica, San Dieguito Lagoon, upper Newport Bay). In several areas of the United States, habitat loss has made some bird species dependent on dredge-material islands (Guilfoyle et al. 2005).

Management may be necessary to maintain beneficial uses for birds after beach nourishment and/or island creation. Vegetation removal, fencing, and/or predator control are conducted to maintain and protect least tern and snowy plover nesting sites in California and dredge material nesting islands elsewhere in the United States (Jedrey 2005, Jenkins and Erwin 2005). Management needs for piping plovers at Atlantic coast beaches with high human use include restrictions of human access, pets, trash, vehicles, kite flying, ball playing, and mechanical beach cleaning (Cohen et al. 2005, Jannsen 2005).

5.1.2.4 Marine Mammals

No reports of beneficial impacts to marine mammals from sediment management activities were identified with the literature review. No beneficial impacts would be expected from beach nourishment or dredging based on the highly mobile nature of species and/or relatively greater association of marine mammals with pelagic, hard bottom, and/or kelp bed habitats (Sections 4.5.1 through 4.5.3). Pinnipeds may use sand beach habitat for resting; however, primary haul-out areas are associated with rocky outcrops or artificial structures, and rookeries are in remote locations (Section 4.5.2). .

5.2 Review of Adverse Impact Issues and Concerns

The following questions of interest to the CSMW are addressed in this section:

- *What are the known negative effects of beach replenishment on habitats (and/or ecosystems) and species?*
- *Are the documented concerns based on scientific data, uncertainty-based conservatism, or other information?*
- *Are sediment management impacts in general short-term and transient or are they long term?*
- *Is there a natural or bio-resilience that can be quantified?*
- *Are there habitats that lie dormant during particular times of year, yet activities conducted during the dormant periods have the potential to affect marine resources? Do activities conducted during the dormant periods lessen the potential to affect marine resources?*

Section 5.2.1 reviews types of direct, indirect, and cumulative impact concerns. Section 5.2.2 summarizes the scientific bases of concerns to habitats and species from equipment, burial, sedimentation, and turbidity impacts. The general duration of impacts; i.e., whether they are short- or long-term are summarized in Section 5.2.3. In addition that section also reviews factors that influence duration and magnitude of impact including project design, sediment compatibility, schedule and time-of-year seasonal considerations, proximity to sensitive resources, natural resilience, and frequency of disturbance.

5.2.1 Types of Adverse Effects

Sediment management activities may result in adverse direct and indirect impacts during construction and indirect impacts after construction (Navqi and Pullen 1982, Nelson 1993, NRC 1995, Wilber and Clarke 2001, Greene 2002, Germano and Cary 2005). Equipment used during beach nourishment and/or dredging may result in direct habitat damage and direct and/or indirect disturbance, damage, injury, and/or mortality to wildlife. Sand placement may result in direct burial impacts within the receiver site and indirect sedimentation of adjacent habitats during and/or after construction. Physical and/or hydrodynamic conditons may be altered by sediment dredging and/or discharge with potential adverse effects to biota. Dredging and/or beach nourishment may impact water quality (turbidity, oxygen reduction, contaminant release) as a result of sediment suspension and resuspension with potential adverse effects to vegetated habitats, aquatic animals, and fish-feeding birds. Direct and/or indirect impacts have the potential to add and/or interact with other project effects (past, present, or foreseeable future) to yield cumulative impacts.

Types of possible adverse effects from disturbance across different levels of biological organization are listed in Table 5.2-1. Disturbance, which initially affects individuals, may or may not affect higher levels of biological organization (population, community) depending on severity of impact. It also is possible that a negative impact at one level may produce a positive effect at a higher level of organization (Hall 1994). For example, sand placement burial of benthic invertebrates may result in increased sand persistence and beach width that increases habitat suitability for benthic invertebrate recovery, California grunion spawning, and bird foraging and/or resting (CRZ 2003, SAIC 2006).

Table 5.2-1. Potential effects of disturbance across different levels of biological organization.

Level of Organization	Potential Effects
Individual	Increased probability of mortality Displacement and energetic cost of re-establishing Displacement and increased exposure to predation Reduced reproductive output Secondary effect on food availability
Population	Change in density Change in recruitment intensity and/or variability Change in dispersion patterns
Community	Change in species diversity Change in total abundance Change in biomass Change in size structure and productivity Change in patterns of energy flow or nutrient recycling

Modified from: Hall 1994

Generally, impact concerns relate to degree of change from existing conditions and environmental consequence of change. Impacts of particular concern for coastal habitats include those that result in loss and/or degradation of sensitive habitats (reefs, SAV), loss and/or degradation of spawning and/or nursery areas for important fishery species, reduced and/or degraded function of native habitats, and injury and/or disturbance of sensitive wildlife (Naqvi and Pullen 1982, NRC 1985, 1995, Newell et al. 1998, Greene 2002). Direct, indirect, and cumulative impact concerns associated with sediment management projects are summarized in the following subsections.

5.2.1.1 Direct Impact Concerns

Direct effects are "caused by the action and occur at the same time and place" (40 CFR Sec. 1508). The following direct impact concerns have been reported for sediment management activities (Naqvi and Pullen 1982, Mauer et al. 1986, LaSalle et al. 1991, Nelson 1993, NRC 1995, Lindeman and Snyder 1998, Reine et al. 1998, Wilber and Clarke 2001, Greene 2002, Germano and Cary 2005):

- Equipment damage to sensitive habitats and/or injury to species.
- Sand placement burial of sensitive habitats and/or benthic organisms.
- Dredge removal of sensitive habitats and/or benthic organisms.
- Dredge entrainment and mortality of benthic invertebrates and fish.

5.2.1.2 Indirect Impact Concerns

Indirect effects are "caused by the action and are later in time or farther removed in distance, and may include ..... related effects on water and other natural systems, including ecosystems" (40 CFR Sec. 1508).

The area of potential effect associated with indirect impacts includes that affected by noise, lights, turbidity, and sand transport. Indirect consequences of direct impacts may include

forage reduction associated with recovery rates. The following types of indirect adverse impact concerns have been reported for sediment management activities (Hirsch et al. 1978, Stern and Stickle 1978, Naqvi and Pullen 1982, LaSalle et al. 1991, O'Connor 1991, NRC 1995, Clarke and Wilber 2000, Peterson et al. 2000a, Peterson et al. 2002, Wilber and Clarke 2001, Greene 2002, Colby and Hoss 2004, Germano and Cary 2005):

- Reduced invertebrate forage prey to secondary consumers (birds, fish, marine mammals).
- Displacement and/or attraction of mobile wildlife due to noise, lights, increased human activity, equipment, and/or turbidity.
- Sublethal and/or lethal turbidity effects on aquatic plants and animals.
- Sublethal and/or lethal sedimentation effects on aquatic vegetation, hard bottom habitats, and demersal early life stages of fish and invertebrates.
- Delayed recovery and/or altered community due to changed physical conditions.

In some cases an indirect impact may result in a "press disturbance", which is one that continues to affect a biological system for some relatively long period of time after disturbance, as contrasted with a "pulse disturbance", which is a discrete event (Peterson and Bishop 2005).

5.2.1.3 Cumulative Impact Concerns

The CEQ regulations for the implementation of NEPA define cumulative effects as the "impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions ..." (40 CFR 1508.7). The area of potential effect may occur in the project area over time and/or be regional in scope. Cumulative impacts may arise from additive and/or interactive processes in the following ways (CEQ 1997, USDOI/MMS 1999 cited in Greene 2002):

- Time crowding effects – repeated effects from an action in the same area.
- Space crowding effects – high density of different impacts in the same area.
- Additive effects – multiple sources that all add to an overall impact.
- Compounding effects – multiple sources that interact to yield impact greater than additive effects of individual source impacts.
- Nibbling – combination of effects taking place slowly, incrementally or decrementally.
- Time lags – delayed effects.
- Cross boundary effects – occur away from the source.
- Fragmentation – impact results in change of landscape pattern.
- Triggers and thresholds – fundamental change in system behavior or structure.
- Indirect (secondary) effects – project facilitates other projects and their impacts.

Peterson and Bishop (2005) stated that a more rigorous analysis of cumulative impacts is of critical concern for beach nourishment given its expanding scope due to sea level rise and the consequences of multiple escalating stressors in the coastal zone. They emphasized that cumulative impact analysis is "the essence of ecosystem-based management for coastal resources, an overarching recommendation of the U.S. Commission on Ocean Policy."

The following sediment management activities have been identified as potential concerns for cumulative impacts: large-scale sand placement at several sites, repeated disturbance at a location, and/or placement in areas with stresses from multiple other projects (Greene 2002, Posey 2002, Peterson and Bishop 2005). Similarly, cumulative impacts concerns may apply to dredging of borrow sites depending on frequency and/or intensity of disturbance (e.g., Boyd et.al. 2004, Cooper 2005).

Other factors that may be relevant to consider include the potential for: (1) cumulative change in sand elevation with renourishment to exceed burial tolerance thresholds of sensitive hard bottom habitats (if present); (2) substantial alteration of substrate and/or hydrodynamics from beach nourishment or dredging to result in altered fisheries use patterns and fishing activities; and/or (3) beach nourishment to facilitate increased recreational use impacts on wildlife.

Cumulative impacts have been reported with respect to commercial aggregate extraction mining and commercial shellfishing (Section 5.2.3.7). While those examples provide some relevance to sediment management activities, the spatial and temporal scales of disturbance generally exceed those associated with periodic sediment management projects.

5.2.2 Scientific Bases of Concern

Several studies have documented direct impacts to coastal habitats and species from beach nourishment and/or dredging. The scientific basis of concern for direct impacts is supported by studies that have documented mortality and recovery of benthic organisms after burial from beach nourishment and/or removal and recovery after dredging (e.g., Naqvi and Pullen 1982, NRC 1985, NRC 1995, Newell et al. 1998, Greene 2002). Dredge entrainment and mortality of organisms also has been documented (reviewed by LaSalle et al. 1991, Reine and Clarke 1998). Less frequently documented are damages to habitats (e.g., Courtenay et al. 1972, Hoffman 1990, USACE 1998b, Peterson et al. 2000a, Goreau 2001, Sabol et al. 2005) and/or injury to wildlife (USFWS 2000, Laist et al. 2001).

The scientific base of concern for indirect impacts associated with sedimentation, turbidity, and/or wildlife displacement is based on scientific documentation that those impacts occur, and consideration of other relevant ecological, experimental, and/or monitoring studies that document adverse effects. However, the biological consequences of indirect impacts at the scale associated with sediment management activities are less understood because of limited quantitative data, few studies with sufficient sampling designs, and experimental research, and data gaps regarding critical thresholds of significance (e.g., reviewed by NRC 1995, Wilber and Clarke 2001, Greene 2002, Airoldi 2003, Germano and Cary 2005, Peterson and Bishop 2005, Wilber et al. 2005).

The basis of concern for cumulative impacts largely results from uncertainty-based, protective conservatism. A few studies have documented delayed recovery and/or altered species compositions of benthic invertebrate communities after beach nourishment and/or borrow site dredging as a result of changed substrate and/or hydrodynamic conditions (NRC 1995, Newell et al. 1998, Peterson et al. 2002). However, study design limitations and/or lack of information on consequences to higher trophic levels limit understanding of impacts to the ecosystem.

Historically, cumulative impact analysis of sediment management projects has received little attention and/or has been characterized by only cursory analysis leading to a conclusion of no significant impact (Greene 2002, Peterson and Bishop 2005). Guidance documents have been prepared to help standardize and improve the quality of the cumulative analyses and review (CEQ 1997, USEPA 1999, CEQ 2005).

Cumulative impact analysis remains challenging along developed coastlines where multiple impact sources occur. Studies that documented cumulative impacts from commercial dredging activities associated with aggregate extraction and/or fishing included weight of evidence approaches involving temporal and spatial trend analyses of multiple information sources across relatively large geographic regions (Cooper 2005, van Gils et al. 2005). For example, a Geographic Information System (GIS) was used to evaluate spatial extent of dredging interference on fishery use areas and data on registered vessels and catch landings were used to assess temporal trends in fishing effort (Cooper 2005). The comprehensive analytical approach underscores the challenge associated with cumulative impact analyses on a project-by-project basis, and also suggests the need for a more comprehensive and regional approach to monitoring and cumulative analysis. NOAA recommends addressing cumulative impacts of dredging and marine mining operations on essential fish habitat by considering them as part of the permitting process (Hanson et al. 2003).

The scientific bases of concern of adverse impacts to habitats and species from sediment management activities are reviewed further in Subsections 5.2.2.1 and 5.2.2.2, respectively. Available scientific information is reviewed by impact factors (equipment, burial and sedimentation, turbidity) in Sections 5.3 through 5.5.

5.2.2.1 Habitats

Table 5.2-2 summarizes the scientific bases of concern to coastal habitats from sediment management activities based on the summaries for each habitat provided in Section 3. The table distinguishes whether concerns are based on documented projects, relevant reports, protective conservatism, or not applicable.

Documented adverse equipment impacts during beach nourishment include direct damage and loss of sensitive coastal strand habitat from pipeline placement (USACE 1998b), and adverse effects to sandy beach habitat from use of earthmoving equipment (NRC 1995, Peterson et al. 2000a).

Documented adverse equipment impacts during dredging include removal of sandy subtidal habitat at offshore borrow sites and/or soft substrates in embayments (Naqvi and Pullen 1982, NRC 1985, NRC 1995, Greene 2002), loss of eelgrass habitat (Hoffman 1990, Nitsos 1990, Sabol et al. 2005), and damage to hard bottom reef habitats from offshore borrow site dredging (Courtenay et al. 1972).

Other relevant reports provide supporting information for potential equipment impact concerns. For example, damage to kelp bed and/or subtidal reef habitats have been documented from vessels and anchoring associated with pipeline and offshore oil development projects (e.g., Chambers Consultants and Planners 1982, Foster and Schiel 1985, Lissner et al. 1991, MEC 1995). Temporary adverse impacts to sandy subtidal habitat also occur from anchoring (Lissner et al. 1991).

Table 5.2-2 Summary of scientific basis of concern for potential adverse impacts to coastal habitats associated with sediment management activities.

Habitat	Equipment	Burial	Sedimentation	Turbidity
Type of Impact – Beach Nourishment (Beach, Dune, Nearshore, Profile Placement)				
Coastal Dune and/or Strand	Documented	Protective conservatism	NA	Protective conservatism*
Sandy Beach	Documented	Documented	Relevant reports	Relevant reports
Sandy Subtidal	Relevant reports	Documented	Documented	Relevant reports
Rocky Intertidal	Protective conservatism	Protective conservatism	Documented	Relevant reports
Rocky Subtidal	Relevant reports	Protective conservatism	Documented	Relevant reports
Kelp Forest and/or Bed	Relevant reports	Protective conservatism	Relevant reports	Relevant reports
Surfgrass Bed	Relevant reports	Relevant reports	Relevant reports	Protective conservatism
Eelgrass Meadow	Relevant reports	Relevant reports	Relevant reports	Relevant reports
Shallow Inlet Embayment	NA	NA	Documented	NA
Deepwater Inlet Embayment	NA	NA	Documented	NA
Type of Impact – Dredging/Excavation				
Coastal Dune and/or Strand	NA	NA	NA	NA
Sandy Beach	NA	NA	NA	NA
Sandy Subtidal	Documented	NA	Documented	Documented
Rocky Intertidal	NA	NA	NA	NA
Rocky Subtidal	Documented	NA	Documented	Relevant reports
Kelp Forest and/or Bed	Relevant reports	Protective conservatism	Relevant reports	Relevant reports
Surfgrass Bed	NA	NA	NA	NA
Eelgrass Meadow	Documented	Documented	Relevant reports	Documented
Shallow Inlet Embayment	Documented	NA	Documented	Relevant reports
Deepwater Inlet Embayment	Documented	NA	Documented	Documented

NA = not applicable, *Potential concern if habitat used as nesting site for California least tern and beach nourishment conducted in vicinity of dune habitat during nesting season.
Notes: Documented = reported with respect to sediment management activity, Relevant reports = experimental studies and/or reports associated with other activities with similar impacts, Protective conservatism = ecological sensitivity to disturbance reported and/or expected based on consideration of relevant reports.

Lessons learned from other similar activities are relevant to activities associated with beach nourishment that include laying temporary pipelines to shore, anchoring, and/or offshore borrow site dredging in proximity to areas with hard bottom, surfgrass beds, and/or kelp beds. Other relevant reports of equipment impacts to eelgrass include damage and loss from boat propellers (Moore and Orth 1997). Studies of impacts associated with commercial fishing activities involving dredging and/or trawling also provide some relevant information on physical impacts and recovery rates of soft-substrate habitats that further the understanding of effects at different spatial scales.

Several reviews have documented direct burial and recovery impacts to sandy beach habitat from beach nourishment and to sandy subtidal habitat from nearshore placement (e.g., Naqvi and Pullen 1982, NRC 1985, NRC 1995, Greene 2002). Burial associated with open water disposal and/or substrate slumping and mounding after dredging also have been reviewed (Hirsch et al. 1978, Newell et al. 1998). Direct burial impacts have been reported for eelgrass in embayments associated with discharge of dredged materials (Harrison 1990).

Indirect sedimentation associated with deposition of resuspended sediments from dredging has been documented. Available reviews indicate that areas of primary concern include SAV, coral and tropical reefs (considered herein to have some relevance to hard substrate reefs), commercial shellfish beds, and spawning grounds (fish, shellfish) (LaSalle et al. 1991, Newell et al. 1998, Germano and Cary 2005, Wilber et al. 2005).

Temporary indirect sedimentation in the nearshore after beach nourishment has been reported with several projects. Adverse impacts to subtidal invertebrates associated with indirect silt-loading after beach nourishment was documented in one study (Rakocinski et al. 1996). Adverse impact from sedimentation and/or turbidity also has been surmised based on anecdotal observations of lack of seasonal onshore migration of overwinterd invertebrates (Reilly and Bellis 1983). Indirect sedimentation associated with sand movement after beach nourishment has been documented for several intertidal and/or subtidal hard bottom habitats for projects implemented in the southeastern United States (Lindeman and Snyder 1999, Goreau 2001, Coastal Planning and Engineering 2004a,b). Increased volumes of sand trapped in embayments downcurrent of beach nourishment projects was documented for some coastal lagoons after the 2001 San Diego Regional Beach Sand Project (Coastal Frontiers 2004), and is considered a potential concern for deepwater inlet navigational channels downcurrent of beach nourishment sites (NRC 1995).

Several relevant reports of sedimentation impacts on rocky intertidal and rocky subtidal habitats are available from field experiments and ecological studies, including assessment of effects of seasonal sand inundation and landslides (e.g., Daly and Mathieson 1977, Littler et al. 1983, Pondella et al.1996, Airoldi 2003). Reports of sedimentation and/or turbidity impacts to coral reef and/or worm reef habitats after beach nourishment and/or dredging have been documented off the southeastern coast of the United States (e.g., Courtenay et al. 1972, Lindeman and Snyder 1999, Goreau 2001), which provide relevance to concerns for potential impacts to rocky intertidal and/or subtidal habitats in California.

Sedimentation impacts to eelgrass habitat have been documented after storms (e.g., Onuf and Quammen 1983). Effects of sedimentation on other seagrass species increase understanding of potential effects to California seagrasses (eelgrass, surfgrass) (Kirkman 1997, Terrados et al. 1998). Relevant reports of sedimentation effects on kelp forests and beds include ecological studies in the vicinity of landslide areas, point source discharges, and runoff (Bence et al. 1989, Murray and Bray 1993, Konar and Roberts 1996, Pondella et

al. 1996). In addition, several laboratory studies examining effects of sedimentation on a variety of invertebrates, algae, seagrasses, and fish eggs have been reviewed (e.g., Devinny and Volse 1978, Airoldi 2003, Germano and Cary 2005, Wilber et al. 2005).

Monitoring studies during beach nourishment and/or dredging have documented elevated turbidity in a variety of habitats. Reviews have summarized that field investigations of turbidity effects generally are inconclusive with respect to biological effects (LaSalle et al. 1991, Wilber and Clarke 2001). Many of the concerns with respect to turbidity are based on protective conservatism supported by relevant reports of response to high and/or chronic suspended sediment concentrations. Relevant reports include a combination of laboratory experiments, field experiments, and/or ecological studies in areas exposed to chronic sources of sedimentation, runoff, or point source discharges (Foster and Schiel 1985, Bence et al. 1989, Dayton et al. 1989, Murray and Bray 1992, Konar and Roberts 1996, Pondella 1996, Wilber and Clarke 2001, Airoldi 2003, Berry et al. 2003). Results from laboratory studies have been hindered by a lack of standardization in experimental protocol and/or studies have focused on determination of thresholds for acute response, which often required higher concentrations than commonly associated with dredging projects (LaSalle et al. 1991, Wilber and Clarke 2001).

Few adverse effects of turbidity associated with sediment management activities have been demonstrated. Turbidity and/or sedimentation associated with dredge operations reduced eelgrass habitat in a boat harbor in Massachusetts (Sabol et al. 2005) and reduced habitat of another species of seagrass in a shallow water embayment in Texas (Onuf 1994). A relevant example of turbidity impacts to hard bottom areas includes a study by Courtney et al. (1972), which documented damage to coral reefs from turbidity and/or sedimentation associated with re-handling of dredged sands between an offshore borrow site and beach nourishment site. Reilly and Bellis (1983) surmised that turbidity during beach nourishment had an adverse effect on invertebrate recruitment to the beach based observations of differences in timing of recruitment compared to a reference beach, reduced size structure of *Emerita* mole crab populations the first year after beach nourishment, and apparently missed recruitment of *Donax* clams.

5.2.3.2 Species

Table 5.2-3 summarizes the scientific bases of concern to coastal species from sediment management activities based on the summaries provided in Section 4. The table does not distinguish between beach nourishment and dredging as was done in the above habitat section because of the similar nature of impact response of species to these sediment management activities. Similar to the habitat summary, Table 5.2-3 distinguishes the scientific basis of the concern according to the following categories: documented effects, relevant reports, protective conservatism, and not applicable.

Several types of equipment impacts to species have been documented with sediment management activities. For example, subtidal invertebrates (including Dungeness crab), demersal fish, pelagic fish (herring, anchovy), and juvenile salmon may be impacted by dredge entrainment (LaSalle et al. 1991, Reine and Clarke 1998). Peterson et al. (2000) documented adverse impacts to sandy beach invertebrates from bulldozer activity.

Table 5.2-3. Summary of scientific basis of concern for potential adverse impacts to species associated with sediment management activities.

Species	Equipment	Burial	Sedimentation	Turbidity
Abalone	Protective conservatism	Protective conservatism	Relevant Reports	Protective conservatism
California Spiny Lobster	Protective conservatism	Protective conservatism	Relevant Reports	Relevant Reports
Dungeness Crab	Documented	Protective conservatism	Relevant Reports	Relevant Reports
Sandy Beach Invertebrates	Documented	Documented	Relevant reports	Relevant Reports
Sandy Subtidal Invertebrates	Documented	Documented	Documented	Relevant Reports
Rocky Intertidal Invertebrates	Protective conservatism	Documented	Documented	Relevant Reports
Rocky Subtidal Invertebrates	Documented	Protective conservatism	Documented	Relevant Reports
California Grunion	Relevant Reports	Protective conservatism	Protective conservatism	Relevant Reports
Pacific Herring	Documented	NA	Relevant Reports	Relevant Reports
Salmonids	Documented	NA	Relevant reports	Relevant Reports
Bottom Dwelling Fish	Documented	Protective conservatism	Relevant reports	Documented
Water Column Fish	Documented	Protective conservatism	Relevant reports	Documented
Subtidal Reef Fish	Relevant reports	Protective conservatism	Documented	Relevant Reports
Tidepool Fish	Protective conservatism	Protective conservatism	Protective conservatism	Relevant Reports
California Brown Pelican	Documented	NA	NA	Protective Conservatism
California Least Tern	Relevant reports	NA	NA	Relevant Reports
Western Snowy Plover	Documented	Protective conservatism	Protective conservatism	NA
Gulls and Terns	Relevant Reports	NA	Protective conservatism	Protective conservatism
Shorebirds	Documented	Documented	Protective conservatism	NA
Wading Birds, Waterfowl	Relevant Reports	Protective conservatism	Protective conservatism	Protective conservatism
Sea Otters	Documented	Protective conservatism	Protective conservatism.	Protective conservatism
Pinnipeds	Relevant Reports	Protective conservatism	Protective conservatism	Relevant reports.
Cetaceans	Documented	NA	Protective conservatism	Protective conservatism

NA = not applicable; Notes: Documented = reported with respect to sediment management activity, Relevant reports = experimental studies and/or reports associated with other activities with similar impacts, Protective conservatism = ecological sensitivity to disturbance reported and/or expected based on consideration of relevant reports.

Relevant reports have documented mortality of hard substrate invertebrates and burial and disruption of soft substrate benthos from anchoring impacts (reviewed in Lissner et al. 1991, MEC 1995). Impacts from beach grooming and/or other vehicle use have been reported for invertebrates (Stephenson 1999, Dugan et al. 2003) and California grunion (Martin 2002). Relevant reports also indicate fish may temporarily scatter in response to vessel movement (Chambers Group 1988). Most reviews suggest that fish temporarily move from areas due to noise, vibration, and/or turbidity (Naqvi and Pullen 1982, NRC 1995, Greene 2002).

Temporary displacement of sensitive bird species during sediment management activities has been reported for California brown pelican and western snowy plover (Varanus 1999, Worden and Smith 2004, Chambers Group 2005). Other relevant reports of displacement reaction to human disturbance have been reported for California least tern, gulls, shorebirds, terns, wading birds, and waterfowl (Korschgen et al. 1985, Lafferty 1990, Obst and Johnson 1990, Zeiner et al. 2000, Burger 1991, Strong 2005).

Sea otters and whales have been observed to move from areas of dredging activities and/or vessels (Bodkin and Rathbun 1988, Richardson et al. 1995). Pinnipeds exhibit sensitivity to human activities while on land (Richardson et al. 1995, Carretta et al. 2004). Relevant reports have documented vessel collisions with marine mammals, most have resulted from fast moving vessels, although there is one documented collision with a hopper dredge (Laist et al. 2001).

Several studies have documented direct burial/removal impacts to beach and subtidal soft-bottom invertebrates from beach nourishment and/or dredging by monitoring recovery rates after impact (e.g., Oliver et al 1977, Kaplan et al. 1975, McCauley et al. 1977, Parr et al. 1978, Navqi and Pullen 1982, Soloman et al. 1982, NRC 1985, NRC 1995, Van Dolah et al. 1994, Kenny and Rees 1996, Newell et al. 1998, Burlas et al. 2001, Greene 2002, Dalfsen and Essink 2001, Jutte et al. 2002, Versar 2004).

Burial effects of concern to fish and birds may include direct burial of early life stages from sediment placement and/or indirect forage reduction associated with burial and recovery of invertebrate populations. Few studies have examined secondary effects of reduced invertebrate forage base on fish and birds after beach nourishment. Invertebrate recovery rates after beach nourishment generally are less than one year unless there is interference with recruitment and/or changed substrate (Section 4.2.6, Table 4.2-1). No significant impacts to fish foraging, abundance, number of species, and/or species composition have been documented after beach nourishment (Naqvi and Pullen 1982, NRC 1995, Burlas et al. 2001, Greene 2002, USACE 2002b, Versar 2004). Therefore, the basis of concern with respect to invertebrate prey reduction on fish is considered protective conservatism.

Reduced shorebird foraging at nourished beaches may be expected during the invertebrate recovery period (NRC 1995, Greene 2002). No apparent adverse effects to forage base or shorebird foraging (including snowy plovers) were detected during a study of nourished and unnourished beach sites two to four years after the 2001 San Diego Regional Beach Sand Project, which used sands compatible with local beaches (SAIC 2006). However, Peterson et al. (2002) documented reduced foraging by shorebirds during the 2001-2002 beach nourishment at Boque Banks, North Carolina, which the author's attributed to an increase in shell hash and fine content of sands and lower abundance of favored prey items (*Emerita, Donax*). The duration of that effect was not reported. These studies suggest that reduced shorebird foraging habitat is a temporary effect of beach nourishment unless there is alteration of beach substrate that reduces prey availability.

No studies of duration of forage reduction effects on demersal fish or birds associated with dredging in embayments were identified with the literature review. Maintenance dredging potentially could result in localized reduction in area and/or quality of forage habitat for fish and waterfowl. Generally, invertebrate recovery rates are less than 1 year in frequently disturbed navigational channels (see Section 4.2.7). Longer benthic recovery rates may be associated with one-time and/or infrequent dredging of embayment habitats associated with enhancement and/or restoration projects, which have the potential to affect benthic foraging sites for shorebirds, wading birds, and/or waterfowl depending on project design. Potential impacts to demersal fish and bird foraging after enhancement and/or restoration dredging would be expected to relate to size of affected area, invertebrate recovery rates, and proximity to alternate forage locations. Because of the project-specific nature of impacts, the basis of concern associated with benthic forage reduction as a result of embayment dredging is considered protective conservatism for fish and birds.

No studies of effects of beach nourishment burial on benthic forage prey of sea otters, pinnipeds, and/or porpoises were identified with the literature review; therefore, the basis of concern for marine mammals is considered protective conservatism.

Indirect sedimentation effects associated with sand transport after beach nourishment have been documented for hard substrate intertidal and subtidal reefs with reported and/or surmised effects to invertebrates and fish along the southeastern coast of the United States (e.g., Courtenay et al. 1980, Lindeman and Snyder 1998, Goreau 2001, Coastal Planning & Engineering 2004a,b). Partial burial lof rock groins may have had a temporary effect on fish distribution after beach nourishment off New Jersey (Wilber et al. 1983). Relevant reports indicate that several species of invertebrates associated with hard bottom habitats (e.g., abalone, lobsters, other mollusks) avoid recruitment and/or move from areas with substantial siltation and/or sand inundation (Littler et al. 1983, Herrnkind et al. 1988, DFG 2001, review by Wilber et al. 2005).

Indirect sedimentation impacts to subtidal invertebrates associated with increased silt-loading associated with beach nourishment has been documented (Rakocinski et al. 1996). Indirect sedimentation of sandy beach habitat from beach nourishment involving use of compatible sands may result in beneficial effects to invertebrates (Section 5.1.2.1); however, relevant reports indicate adverse impacts may occur from introduction of substrates with substantial silt/clay, very coarse sand, and/or shell content (Peterson et al. 2002, Cummings et al. 2003, Thrush et al. 2003).

Turbidity has been associated with temporary avoidance displacement of water column fish during in-bay disposal in San Francisco Bay (O'Connor 1991). Temporary displacement of fish and mobile invertebrates from coral patch reefs in response to elevated turbidity were reported in areas of offshore borrow site dredging in Florida (Courtenay et al. 1972, Courtenay et al. 1980 cited in Naqvi and Pullen 1982).

Laboratory studies of fish and invertebrates document a range of responses from no effects to reduced foraging, egg hatching, anoxia, and/or mortality (reviewed by LaSalle et al. 1991, Wilber and Clarke 2001, Berry et al. 2003). However, reviews indicate that most laboratory effects data have only limited relevance to dredging projects due to testing at concentrations outside those commonly observed during dredging. In addition, few marine species have been tested. Other relevant reports indicate degraded rocky intertidal and subtidal invertebrate communities in areas of chronic turbidity from landslide activity and to a lesser extent creek runoff (Pondella et al. 1996, CRM 1997).

Limited information is available with respect to turbidity impacts on birds and/or marine mammals; however, because many are visual foragers, the scientific basis of concern primarily is protective conservatism. Relevant reports indicate that turbidity may interfere with foraging by California least terns (Collins et al. 1979) and pinnipeds (Seligsohn 1998).

5.2.3 Short-Term, Long-Term, and Significant Impact Issues

Sediment management activities have the potential to result in environmental impacts across a range of temporal and spatial scales. Generally short-term impacts do not extend much beyond the construction period, and may include temporary avoidance, attraction, and/or disturbance interference during construction. Impacts to habitats also have been considered short-term if habitat loss does not occur and reovery is not prolonged. Therefore, impacts extending beyond the construction period have been considered as short- and/or long-term..

Generally, disturbance that occurs over a short timeframe has been defined as a “pulse” disturbance; whereas, disturbance that continues to affect a biological system for some relatively long period of time after the action is referred to as a “press disturbance (Bishop and Peterson 2005). Equipment, burial, and turbidity impacts generally have been considered as pulse disturbances; whereas, altered physical characteristics (substrate, hydrodynamics) and/or sand transport sedimentation may result in press disturbances.

Although impact duration is an important element in classifying an impact as short- or long-term, there is no standard definition of these terms for beach nourishment and/or dredging projects, which involve both pulse and press disturbance factors. For example, long-term impacts have been defined as exceeding one year (e.g., CRM 1997, CRM 2000, MEC 2000a), 5 years (e.g., Chambers Group 1992), or 10 years (e.g., USACE 1994a, USACE 2000b). Examples of short-term and long-term impacts based on environmental thresholds of significance, which have been applied to representative California beach nourishment projects are given in Table 5.2-4 (see Section 6.1). Significant impacts generally have been defined with respect to long term changes in native species populations, habitat community structure and/or functions, substantial degradation of a native habitat, and/or substantial adverse impact to sensitive species.

Several reviews have concluded that environmental impacts from sediment management activities are varied, ranging from short- to long-term, but many concerns remain unresolved due to a variety of limitations. Several reviewers have noted limitations with respect to design and/or duration of monitoring studies, integration between field measured conditions and laboratory experiments, little attention given to trophic linkage effects, and/or technical challenges associated with translating individual impacts to population-level consequences (Navqi and Pullen 1982, NRC 1985, NRC 1995, Newell et al. 1998, Reine et al. 1998, Greene 2002, Clarke et al. 2005). Peterson and Bishop (2005) reviewed 46 beach nourishment monitoring studies and reported that the majority of them had flaws in sampling designs, statistical analyses, interpretations, and conclusions. They additionally stated that many of the studies terminated before recovery was demonstrated, lacked adequate before impact and/or reference data, and most lacked sufficient analysis to understand how changes have caused biological response. The above-stated limitations indicate that scientific knowledge regarding adverse biological effects is incomplete, especially regarding indirect and cumulative impacts.

Table 5.2-4. Examples of short- and long-term impacts associated with sediment management activities.

Impact	Short Term	Long Term
Noise, lighting, equipment and/or increased activity disturbance	Avoidance displacement, attraction, foraging interference	Displacement with mortality, starvation resulting in impaired reproduction, starvation, substantial interference of wildlife movement
Equipment damage	Minor damage and recovery	Sensitive habitat and/or species loss
Dredge entrainment	Incidental loss	Substantial loss to breeding and/or spawned population
Sediment removal, Sediment placement	Recovery of pre-disturbance native habitat and community within approximately 1 year	Prolonged change in community structure and/or reduced habitat functions, sensitive habitat loss, destruction of important spawning or nursery grounds, substantial loss of native population
Turbidity	Avoidance displacement, attraction, foraging interference, reduced photosynthesis	Sensitive habitat degradation or loss, mortality of sensitive species, substantial interference of wildlife movement and/or foraging
Sedimentation	Avoidance, attraction, foraging interference, reduced photosynthesis	Prolonged change in community structure and/or reduced habitat functions, sensitive habitat loss, destruction of important spawning or nursery grounds, substantial loss of native population

During this review it was noted that many biological monitoring reports provide minimal description of project features and environmental conditions during monitoring. That data gap limits evaluations of differences in biological response that may be related to project design and/or implementation (e.g., construction methods, operational controls. In addition, differences in impact duration and/or recovery rates that may be influenced by hydrodynamics (e.g., wave climate, circulation) and/or oceanographic conditions (e.g., ENSO, PDO) are poorly understood.

The nature and magnitude of impacts relates to several project specific factors (NRC 1995, Greene 2002), which are further reviewed in the following subsections:

- Project design, which defines the project elements, size/volume, methods, equipment, and operational factors that relate to the physical characteristics of the impact.
- Project duration and work schedule, which define project duration and impact exposure periods.
- Sediment characteristics, which relate to construction turbidity impacts, and compatibility of placed sediments to functions supported by the habitat.
- Location and proximity to sensitive resources, which relate to existing biological conditions and potential vulnerability and/or risk for impact.
- Project timing and seasonal considerations, which relate to existing biological conditions and potential vulnerability and/or risk for impact.
- Natural recovery and resilience of habitats and species, which relate to recovery rates.

- Frequency of disturbance, which relates to intensity of disturbance and potential cumulative impacts.

5.2.3.1 Project Design

Three aspects of project design have the potential to influence impacts to biological resources, including: project elements, project size (or volume), and design features.

Project Elements

Two project elements associated with beach nourishment, include:

- Obtaining source sediments.
- Delivery of sands to the nourishment site.

Section 2.2 provides an overview of obtaining, delivery, and placement of sands for beach nourishment. Several methods may be used for obtaining sands, including dredging in embayments and/or offshore, excavation to maintain inlets of shallow embayments, use of equipment to transfer accumulated sand to a sand starved area (e.g., bypassing, backpassing), and/or coordination to use sand from a terrestrial source (e.g., catchment basins, coastal development).

Method of sediment delivery will depend on sand placement location (e.g., dune, beach, nearshore, profile) and may be by self-contained hopper dredge, dump scow or barge, hydraulic pipeline discharge (beach, swash zone, nearshore), and/or trucks.

Methods used to implement a project will define potential impact factors associated with equipment, operations, and activities related impact factos (LaSalle et al. 1991, NRC 1995, Greene 2002). For example, direct and indirect impacts to biological resources may occur from equipment use (displacement, disturbance, entrainment, mortality), dredge or excavation removal of sediment, sand placement burial, sand transport sedimentation, and/or turbidity depending on placement location and existing biological conditions at the time of placement. Potential impacts are reviewed further by impact factor in Sections 5.3 (equipment), 5.4 (burial, sedimentation), and 5.5 (turbidity).

Project Size

Spatial and temporal scales of impact relate to project size. The area of potential effect associated with sediment management projects has two spatial scales, including the smaller, direct impact construction footprint and larger, adjacent area subject to indirect impacts (e.g., turbidity, sedimentation, noise). As expected, the areas of direct and indirect impact increase with project size. Larger projects generally require longer schedules to complete than smaller projects; however, duration of construction may be influenced by equipment and methods. Generally, impact concerns increase with duration and magnitude of impact (Wilber et al. 2005).

Biological monitoring studies have been conducted for beach nourishment projects ranging in size from thousands to several million cy of sediment. Due to the small area of potential effect and duration of disturbance, the primary concern with small projects is the potential to impact sensitive resources. Sensitive resource protection also is a primary concern with large projects;

however, additional concerns arise because of incomplete knowledge of indirect and cumulative impacts (e.g., NRC 1995, Greene 2002).

The most comprehensive monitoring of a large project was for the nearly 8.1 million cy Asbury Park to Manasquan Inlet Beach Erosion Control Project, New Jersey, which included water quality, sediment grain size, benthic recovery at beach placement, nearshore, and offshore borrow site locations, ichthyoplankton composition in the surf zone and nearshore, and fish composition and food habits in the surfzone and offshore borrow site areas (Burlas et al. 2001, Wilber et al. 2003). That study reported temporary and localized reduction in turbidity, benthic recovery rates of months for sandy beach and 1 to 2.5 years for offshore borrow sites, and localized fish response to dredging and sand placement. The study did not monitor bird foraging; however, the reported rapid recovery rates for sandy beach invertebrates suggests that impacts would have been temporary. The study has received some criticisms with respect to methods used to evaluate effects (Greene 2002, Peterson and Bishop 2005). Nevertheless, the nourished beach sites and borrow areas appeared to develop representative communities within relatively short recovery periods and no large-scale effects were detected.

The primary concern with respect to project size is exceeding critical impact thresholds. Because information on which to base critical thresholds is limited (Sections 3 and 4), the ability to appropriately match project size to sensitive environmental constraints is challenging. In addition, natural environmental variability makes the task complex since the threshold at which an impact may be detected from natural variability may be higher than desired to prevent impact. Therefore, the primary concern with increasing project size is an increase in uncertainty and/or risk of impact.

Sediment management projects may span a wide range of project sizes (Table 5.2-5). Most of the reviewed montoring studies indicated recovery and/or substantial recovery over the surveyed period. A few moderate to large project reported damage to reefs from siltation during borrow site dredging and/or burial after beach nourishment (Courtenay et al. 1972, Marsh and Turbeville 1981Coastal Planning and Engineering 2004b, Lindeman and Snyder 1999). Some moderate to large beach nourishment projects resulted in delayed benthic invertebrate infauna recovery, which was attributed to changed substrate and/or turbidity and project timing rather than to project size (Reilly and Bellis 1983, Peterson et al. 2000a, Versar 2004). A moderate dredging project resulted in eelgrass loss in an area of restricted circulation (Sabol et al. 2005). One report of an altered benthic infauna community in the nearshore was attributed to sedimentation from a very large beach nourishment project (Rakocinski et al. 1996); however, a lack of similar result for other very large projects suggests some other factor besides project size may have been influential; e.g., hydrodynamics (see Section 4.2.7).

Several reports of benthic infauna recovery rates were not included on Table 5.2-5 because the reviewed reference (sometimes a secondary source) lacked information on project size (refer to Sections 4.2.6 and 4.2.7, Tables 4.2-1 and 4.2-2). Most reports of delayed recovery or altered benthic communities were attributed to a change in substrate and/or hydrodynamics rather than project size. In a few cases, delayed recovery rates were associated with sites that had experienced high intensity commercial aggregate extraction (see Section 4.2.7, Table 4.2-2), which were not included on Table 5.2-5 because of the different intensity of the activity from that associated with sediment management (Kenny and Rees 1996, Hitchcock et al. 2002, Boyd et al. 2004, Newell et al. 2004).

The mix of projects with and without reported adverse effects across moderate to very large project sizes suggests that impacts likely relate to project specific and/or environmental

conditions. Therefore, impact thresholds for one area may not be applicable in another environmental setting. Insufficient monitoring information is available to support evaluations with the aim towards optimizing project design to minimize environmental concerns.

Table 5.2-5. Reported adverse effects by project size for representative sediment management projects.

Project Size	Volume	Beach Nourishment	Dredging
Very Small	1,000 to 25,000		McCauley et al. 1977
Small	25,000 to 100,000	Chambers Group 2004	VanDolah et al. 1984
Moderate	100,000 to 500,000	AMEC 2005, Culter and Mahadeven 1982, Coastal Planning and Engineering 2004b**, Lindeman and Snyder 1999**, Marsh and Turbeville 1981*, Peterson et al. 2000a*, SAIC 2006, Saloman and Naughton 1984	Culter and Mahadeven 1982 Courtenay et al. 1972**, Johnson and Nelson 1985, Marsh and Turbeville 1981*, Saloman et al. 1982, Sabol et al. 2005*
Moderately Large	500,000 to 1,000,000	Coastal Planning and Engineering 2004a,c Gorzelany and Nelson 1987, Parr et al. 1978	
Large	1,000,000 to 5,000,000	Coastal Planning and Engineering 2004a** Jutte et al. 1999, Reilly and Bellis 1983*	Jutte et al. 2002
Very Large	> 5,000,000	Burlas et al. 2001, Rakocinski et al. 1996*, Versar 2004*	Burlas et al. 2001

*Adverse impact to recovery of benthic infaunal invertebrates reported, ** adverse impact to hard bottom habitat reported

Project Design Features

The following project design features may modify the physical characteristics in the project area and influence spatial and temporal aspects of potential impacts:

- Beach-fill volume per unit area.
- Dredge/excavation depths.
- Beach slopes.
- Placement methods.

Dredging in embayments generally is associated with maintenance of navigational channels, port and harbor development, and/or ecosystem restoration within prescribed project limits that define the spatial scale of impact. In contrast, dredging of offshore borrow sites to obtain source sands for beach nourishment have involved different methods with the potential to yield similar sand volumes (e.g., project size), but at different spatial scales of impact. For example, anchor hopper dredges remove sediment from a sequence of specific points, resulting in deep,

depressions and/or pits (>15 to 66 ft, > 5 to 20 m in depth). Altered hydrodynamics and reduced water quality (e.g., anoxia) is an impact concern with deep excavations (NRC 1995, Greene 2002). Trailer suction hopper dredges remove the upper sediment surface (8 to 22 in, 20 to 55 cm) over a broader area, although overlaps may result in furrows to 6 ft (2 m), (Newell et al. 1998, Greene 2002). Spatial scales of borrow areas have ranged from a few to over 380 acres (> 150 hectares).

Beach fill volume per unit area may influence impacts related to burial and/or sedimentation overburden depths. Burial depth and sediment bulk density both contribute to what has been termed as overburden stress (Hinckley et al. in press cited in Wilber et al. 2005). Duration of burial and/or sedimentation also is of importance. Depths that exceed natural burrowing rates of invertebrates and/or cover plant leaves beyond the period tolerated with stored energy reserves may result in mortality (e.g., Mauer et al. 1986, Harrison 1990). Thin deposits of sediment may interfere with recruitment of marine vegetation and/or smother demersal eggs of fish and/or invertebrates (LaSalle 1991, Wilber and Clarke 2001, Airoldi 2003, Berry 2003, Germano and Cary 2005, Wilber et al. 2005).

Often sand is placed on the beach at slopes steeper than equilibrium to allow easier documentation of fill placement volume and to provide a temporarily wider beach during the equilibrium phase (NRC 1995). The steeper slope (scarp) gradually diminishes as waves rework and transport sediment seaward and the beach approaches an equilibrium profile. Steep scarps have the potential to adversely affect movement of some wildlife species, if present in the area of beach nourishment activities.

Relatively gentle beach slopes (e.g., ≤10:1 horizontal:vertical) are recommended to minimize impacts to movement of endangered piping plovers (Brandreth 2005, Melvin 2005). NMFS (2002) recommended that restored bank slopes along the Columbia River have a minimum steepness of 10 to 15% to prevent fish stranding.

5.2.3.2 Sediment Characteristics and Compatibility

Sediment characteristics are relevant to nearly every aspect of sediment management activities, from determination of sand source compatibilities (e.g., dredging, uplands) for beach nourishment to environmental considerations of longevity of shoreline protection benefits. In between those planning and performance issues, sediment characteristics also influence dredging and discharge methods, transport and fate of plumes and sediments, and a variety of biological resource impact considerations.

Substrate characteristics at dredge and discharge sites will be modified by those sediment management activities. Depth and extent of dredging may influence hydrodynamic conditions, which may lead to changed substrate type and composition, texture, and organic loading (Greene 2002). Removal of sediments also has the potential to uncover substrate that differs from surface sediments. Several studies of marine mining borrow sites have shown post-project decreases in mean grain size and sometimes increases in silt/clays (NRC 1995). In a few cases, anoxic sediments developed in deep, sand extraction sites due to organic deposition in areas with limited circulation (Naqvi and Pullen 1982, NRC 1995, Greene 2002, Brynes et al. 2004b).

Available reviews indicate that meeting sediment compatibility guidelines for beach nourishment does not necessarily mean there won't be a change to sediment characteristics. The NRC

(1995) reviewed that use of beach-compatible materials may result in changes in physical characteristics compared to non-nourished beaches with respect to grain size and shape, surface texture, shear resistance, moisture content, and sand compaction. Depending on the nature of deviations in substrate characteristics, some changes may be benign while others may affect biological resource uses. Pilkey and Coburn (2005) characterized several beach nourishment projects on the East Coast as ecologically "bad" beaches as a result of use of sediment with substantial mud, shell hash, or limestone cobbles, or replacement of quartz sand with carbonate sand.

USACE and USEPA (2004) guidelines for acceptability of dredge material for beneficial use (e.g., beach nourishment) specify that materials should closely match the sediment composition of the eroding beach and be low in fine sediments, organic material, and pollutants. Generally, sediments with a silt/clay content within 10 percentage points of the finest beach sample or sediments with less than 20 % silt/clay have been permitted for beach nourishment in California (Higgins et al. 2004). The recent Regional General Permit (RGP) for beach nourishment in southern California requires percent fines (silt/clay) to be within 10 percent of the receiver beach (e.g., if beach has 5 % fines, discharge cannot exceed 15 % fines) and not exceed 25 %.

Several opportunistic beach nourishment programs have been developed in California at the local level, including the cities of San Clemente and Carlsbad (Moffatt & Nichol 2000a, 2000b). A joint opportunistic beach fill program effort also has been planned along the south-central coast (Santa Barbara and Ventura counties) (Moffatt & Nichol 2001, 2005a). Sediment compatibility criteria for these programs are generally similar, as follows:

- Chemistry (i.e., free of harmful contaminants).
- Color (must reasonably match color of existing beach after natural color changes occur).
- Particle shape (must not be substantially angular or jagged shaped).
- Debris content (must be free of litter, trash, or significant quantities of organics).
- Compactibility/moldability (material must not form a hardpan crust after repeated wetting and drying).

Criteria associated with sediment gradation have varied somewhat among the opportunistic beach fill programs (Moffatt & Nichol 2000a, 200b, 2001, 2005a). For example, sediments are considered compatible for beach nourishment with percent fine contents up to 15 to 25% (Carlsbad), 25% (San Clemente), and 25 to 35% (Santa Barbara, Ventura). For the Carlsbad and San Clemente opportunistic programs, the sediment gradation requirement also specifies that the coarse grain fraction not include particles larger than cobble-sized and not constitute greater than 10% of the beach fill volume (Moffatt & Nichol 2000a, 2000b). Proposed maximum annual beach fill volumes for these opportunistic programs have ranged from 45,000 to 250,000 cy per beach site.

SANDAG and the CSMW sponsored and managed preparation of the Sand Compatibility and Opportunistic Use Program (SCOUP) for statewide implementation in California with a pilot project within the San Diego region (Moffatt & Nichol 2006a). Sediment compatibility requirements consider grain size distribution across the entire beach profile (i.e., to depth of closure), silt/clay content, particle shape, and a process associated with use of both optimum and less-than-optimum sands. Optimum sand was defined as having a fine content within 10% of the existing dry beach sediments; e.g., fill material potentially ranging up to 15% fines. Less-

than-optimum material was defined as having a fine content within 10% of the existing nearshore sediments, e.g., fill material containing between 15 and 45% fines.

Application of the SCOUP program may vary geographically depending on existing grain size characteristics and environmental constraints, including proximity and/or seasonal occurrence of sensitive biological resources. For example, implementation of a pilot SCOUP program in Oceanside, San Diego County specifies a maximum of 45% fines with a cap of 150,000 cy during fall-winter and 50,000 cy during spring-summer (Moffatt & Nichol 2006a). Application of the SCOUP program in the cities of Encinitas, Solana Beach, Coronado, and Imperial Beach specifies a maximum fine content of up to 25% depending on beach and with different annual volume allowances depending on fine content (e.g., up to 150,000 cy with 0 to 10% fines, and up to 25,000 cy with 11 to 25% fines) based on consideration of sensitive resource constraints (Moffatt & Nichol 2006b).

Sediment compatibility requirements in California may differ from those used elsewhere based on regional considerations. For example, North Carolina compatibility criteria are based on comparison with prenourishment conditions, where post-nourishment average percent content of sediments cannot exceed the prenourishment average by 5% for fines (< 0.0625 mm), 4% for coarse grains (> 4.76 mm), and 40% for carbonate content; in addition, material removed from navigational channels is considered suitable if the fine content does not exceed 10% and dredge depths do not exceed dimensions of previously dredged channels (NCDENR 2005). In Adelaide, Australia, preferred sand characteristics are specified as 50 % of the sand coarser than 0.2 mm, less than 5% silt/clay, rounded sand grains, and off-white or pale in color (DEH 2005).

Several references emphasize the importance of sediment compatibility of source materials for beach nourishment with native sediments to minimize adverse biological impacts and to provide substrate suitable to support functional uses of biota for foraging, spawning, and/or nesting (Parr et al. 1978, Naqvi and Pullen 1982, NRC 1995, Greene 2002). Rice and Peterson (2005) stated that material significantly coarser than native beach sediments can lead to impacts to fauna that may last indefinitely, and material significantly finer than native beach sediments can adversely affect invertebrates and fish. Slow invertebrate recovery rates and/or altered communities may occur from placement of substrate with lenses of clay or clay balls, high shell content, and/or very coarse sediment (Pullen and Naqvi 1983, Reilly and Bellis 1983, McLachlan 1996, Peterson et al. 2000). Silt/clay deposition on sandy substrates may result in a greater impact to invertebrates than if overburden was of similar sediments (Maurer et al. 1986, Turk and Risk 1981, Cummings et al. 2003). Laboratory studies using angular particles were detrimental to fish and yolk-sac larvae at lower concentrations than finer, natural sediments (Rogers 1969, Boehlert 1984 cited in LaSalle et al. 1991).

Biological impacts and/or reduced habitat functions for invertebrates and bird foraging have been reported when sediments had a relatively high percentage of silt/clay and/or shell material (Reilly and Bellis 1978, Peterson et al. 2002). In non-tidal areas used for sensitive bird nesting, sand or a combination of sand, gravel, or shells has been recommended as suitable substrate for piping plovers (Melvin et al. 1991).

Shell and higher content of fines after 2001-2002 nourishment at Boque Banks, North Carolina

Used with permission: Peterson et al. 2002

Limited information is available with respect to differences in recovery rates of sandy beach invertebrates according to differences in percent contents of silt/clay, coarse materials, and/or shell content. A data deficiency identified with many monitoring studies of beach nourishment has been limited description of substrate characteristics. Peterson and Bishop (2005) reported that only 56% of 16 studies of impacts to macroinvertebrates included information on mean grain size and grain size distribution. Therefore, limited scientific data are available to support establlishement of impact thresholds associated with deviations from existing substrate characteristics and/or to optimize project design based on environmental constraints.

Dredging of offshore borrow sites may alter substrate characteristics by uncovering coarser underlying materials and/or from accumulation of fines due to reduced circulation in bathymetric depressions (Naqvi and Pullen 1982, NRC 1995, Greene 2002). Relatively slower benthic infauna recovery rates and/or altered species composition have been associated with changed substrates in offshore borrow sites (Newell et al. 1998, Boyd et al. 2004). In marine aggregate extraction areas in Europe subjected to high intensity dredging activities, substrates generally exhibit a greater variety in substrate composition (and benthic assemblages) than surrounding undredged areas (Boyd et al. 2004). Newell et al. (1998) point out that recovery of biological communites is not controlled solely by particle distribution, but likely is affected by an array of environmental variables including particle mobility and complex associations of chemical and biological factors that affect processes of compaction and stability of sediments.

Boyd et al. (2004) consider minimizing substrate alteration a precautionary and scientifically sound management position after cessation of offshore dredging. The rationale is based on a substantial body of literature demonstrating that the dynamic equilibrium in any given locality results from a number of interacting environmental influences, which find partial expression with grain size characteristics (e.g., Cabioch 1968, Rees et al. 1999 cited in Boyd et al. 2004). Following cessation of commercial aggregate mining in the United Kingdom, license conditions may require the seabed to be left in a comparable state to that prevailing before dredging (e.g., similar sediment type and eveness profile) to facilitate benthic recolonization and ensure minimal interference with commercial fishing practices (Boyd et al. 2004).

5.2.3.3 Project Duration and Work Schedule

Duration of impact exposure is an important consideration with respect to biological effects. Implementation of sediment management projects may range on the order of days to over a year depending on project sediment volume (e.g., Rakocinski et al. 1998, SANDAG and USDN 2000, Burlas et al. 2001, Moffatt & Nichol 2003). However, exposure of individual biological resources to construction disturbance may vary across temporal scales ranging from hours to months depending on work schedule, movement of equipment, and/or mobility of biota.

Work activities may vary among mobilization, construction operations, and demobilization phases. Work schedules may vary between standard versus 24-hour work days and between five- to seven-day work weeks. Generally, local permit requirements and variance restrictions factor into work schedule decisions (e.g., SANDAG and USDN 2000). Standard work schedules limit impact exposure to daytime and include overnight and weekend periods of respite from equipment related impacts as well as periods during which turbidity may dilute and dissipate by tides and currents in aquatic habitats. During 24-7 work schedules, impact exposure durations at any particular location may vary with movement of construction activities and/or type of equipment being used.

With dredging projects, the location of disturbance changes as the dredge moves along the project footprint. For example, Advance rates for cutterhead hydraulic pipeline dredges may range from 20 to 50 ft/hr (6 to 18 m/hour) depending on pipeline size and sediment type, and mechanical dredges may advance near the upper end of that range (Clarke and Wilber 2000). Hopper dredges move between the dredge and discharge locations, with a span of time associated with vessel transit between the locations (USACE 2004). Clarke and Wilber (2000) estimated that exposure durations of sessile organisms at a stationary point along a dredged channel may vary on the order of one to several days depending on equipment and hydrodynamic conditions near the dredge site. However, exposure durations may be longer in areas with restricted circulation (e.g., Sabol et al. 2005).

At a beach replenishment site, disturbance also moves along the length of the site as it is constructed. Hydraulic pumping of sands to the beach may be nearly continuous with use of a cutterhead dredge. Therefore, with that method, exposure duration mainly relates to work schedule and whether the discharge location is fixed or moved along the beach. In contrast, hydraulic pumping from a hopper dredge or dump scow is discontinuous with intervals associated with vessel movement to obtain and deliver sand loads.

Use of trucks to deliver sands generally involves discontinuous sand placement activities tied to tidal cycle; e.g., sands placed during low tide. Delivery of sands by trucks is a slower placement method than hydraulic pumping of sands for the same project volume. For example, beach placement of approximately 100,000 cy of sand took approximately one week with hydraulic pumping during the 2001 San Diego Regional Beach Sand Project (AMEC 2005), whereas several weeks to months could be required to to place a similar amount by truck (14 cy capacity) depending on number of trucks and hourly trips per day (Moffatt & Nichol Engineers 2006a).

5.2.3.4 Location and Proximity to Sensitive Resources

Biological existing conditions within the area of potential effect are primary considerations with respect to potential impact occurrence and/or significance. Sensitive habitat boundaries may vary across years, and sensitive species occurrence may vary seasonally with migration. Consequently, impact evaluations should be based on recent data with respect to proximity to sensitive resources.

Habitat diversity and supported functions decrease along a gradient of increasing disturbance (Pearson and Rosenberg 1978, Newell et al. 1998). Therefore, potential risks of impacting sensitive resources often are greater in areas with greater environmental stability. Spatial proximity concerns may vary across different temporal scales. For example, the spatial extent of some perennial sensitive habitats (e.g., dunes and/or coastal strand, submerged aquatic vegetation) may vary among years in response to natural environmental conditions (e.g., severe waves and/or storms, ENSO, PDO). Intertidal and subtidal reefs may display boundary changes with respect to seasonal and/or longer term changes in sand level relative to reef elevations (Sections 3.3.4 and 3.3.5). Sedentary species may exhibit microhabitat (e.g., living on higher relief rocks), depth distribution (e.g., living near or beyond the depth of the littoral zone), and/or behavior patterns that reduce exposure to shifting sands (Morris et al. 1980, Littler et al. 1983).

Several sensitive and/or important fishery species display seasonal migratory and/or transient occurrence (e.g., California grunion, California least tern, Dungeness crab, Pacific herring,

salmonids, cetaceans). Project timing based on seasonal considerations is discussed further below.

Project location also is an important consideration with respect to project size and potential turbidity and sedimentation concerns. Greene (2002) referenced personal communication (Van Dolah 2002) that a potential concern of beach nourishment in areas that do not have naturally high turbidity, or beaches that are not typically subjected to storm-related turbidity, may experience greater impacts from project-related turbidity, especially if a higher silt/clay content is present in the beach fill. This statement is revelant to project planning considerations in areas with sensitive habitats such as intertidal and nearshore reefs and vegetated habitats. Monitoring reports evaluated for this document that were from areas subject to chronic turbidity and sedimentation (e.g., landslides, point-source discharges) and to lesser extent, creek runoff indicate reduced species diversity than at nearby less unaffected areas (Bence et al. 1989, Schroeter et al. 1993, Konar and Roberts 1996, Pondella et al. 1996, CRM 1997) (see Sections 3.3.4-3.3.6). Based on this evaluation, location of beach nourishment sites in proximity to stream inlets, but downcurrent (to minimize potential shoaling issues), to serve as feeder sites may lessen turbidity and sedimentation impacts at higher quality habitats, if present farther downcurrent of inlets. Project size and sediment characteristics are important considerations with respect to the relevance of this site-selection consideration, with potential greater relevance as project size and/or silt/clay content deviation from native beach increase. Better understanding of proximity of sensitive habitats to stream inlets and temporal trends in suspended sediment loads discharged from streams would enable a more careful assessment of this potential environmental planning strategy for regional sediment management.

5.2.3.5 Project Timing and Seasonal Considerations

Most coastal habitats have a seasonal difference in resource development and supported habitat functions. For example, sandy beaches have seasonal invertebrate resource development and seasonal use by California grunion and migratory shorebirds (Morris et al. 1980, Dugan and Hubbard 1996, Dugan et al. 2000a, 2004, Gregory 2001, Lafferty 2001b, Hubbard and Dugan 2003). At erosive beaches, the above functional uses may occur over a shorter time frame than the potential seasonal use periods of the species due to the time lag associated with accreting sufficient sand after winter erosion (Hubbard and Dugan 2003, SAIC 2006). In contrast, beaches with sufficient sand across seasons have the potential to support functional uses as they vary across season. Some notable exceptions may include beaches with high human use disturbance (e.g., high recreational use, dogs, beach grooming), which have been shown to have lower functional use by shorebirds than less disturbed beaches (Lafferty 2001b, Dugan et al. 2003).

California sandy beaches display seasonality, with recruitment and development of invertebrate populations during spring-summer, use as spawning and/or nesting habitat by California grunion and western snowy plover in spring-summer, and seasonal peaks in bird use of beaches between summer-winter associated with spring and fall migration and over-wintering patterns (Morris et al. 1980, Dugan and Hubbard 1996, Dugan et al. 2000a, 2004, Gregory 2001, Lafferty 2001b, Hubbard and Dugan 2003). Therefore, potential impacts to biological resources from beach nourishment activities will differ according to season and whether the beach is used by sensitive species. Generally, spring through summer represents the peak period of biological resource use of sandy beach habitat in California.

No coastal habitat is fully dormant, although some vegetated habitats exhibit substantial seasonal change in appearance and development. Giant kelp forests and eelgrass meadows have a seasonal cycle of growth and die back (Foster and Schiel 1985, MEC 2000b). Bull kelp beds are highly annual with recruitment in winter-spring, rapid growth over the summer, and die back in late-summer to fall (Abbott and Hollenberg 1976, Denney et al. 1997). Some understory kelps (e.g., feather boa kelp, bladder chain kelp) also exhibit considerable seasonal variability in canopy development (Black 1974, Rais 2003). Habitats with annual cycles of growth and die back may have less vulnerability to adverse impacts depending on when a project is scheduled and the nature of the activity. For example, sediment management activities in the vicinity of eelgrass may have less potential for impact during its seasonal low than productive period as long as the activity is non-destructive (i.e., does not disrupt roots and/or seed bank).

Although coastal habitats are used year round for foraging and resting, reproduction and/or recruitment generally peak from mid to late spring through summer in California (Morris et al. 1980, Love 1996, CDFG 2001). Several reviews and studies have recommended conducting sediment management activities during seasonal low recruitment and productivity periods to minimize biological impacts (Peterson et al. 2000a, Greene 2002). Enviornmental windows have been routinely used to schedule construction activities in coastal habitats to avoid potential interference with sensitive resources; however, concerns have been identified that windows may be overly conservative and/or based on limited scientific data or subjective opinion (Reine et al. 1998, see Section 6).

5.2.3.6 Natural Recovery and Resilience

Coastal species exhibit different sensitivities, tolerances, and/or responses to disturbance based on a variety of behavior, morphology, and/or life history characteristics (Sections 3 and 4), which in turn contribute to resistance to and/or resilience from disturbance. Resistance is the capacity to withstand the effects of disturbance; whereas, resilience refers to the capacity to recover from disturbance (Garcia et al. 2003). At the community level, resistance is measured by the degree of modification of the species composition or a species assemblage after a disturbance, and recovery rate is used to measure resilience (*ibid*.). At the ecosystem level, resilience is the capacity to tolerate a temporary but substantial disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes (Walker et al. 2002). The temporary shock or period of stress is important because any continuously applied perturbation will eventually lead to a changed state (Lélé 2000).

Marcot and Vander Heyden (2001) defined community resistance and resilience in a functional sense related, respectively, to the capacity to resist change or return to the same starting point of diversity of community functions, richness (habitat structure), and redundancy (i.e., the number of species performing the same ecological function in a community).

Reviews clarify that the concept of “recovery” is complex since the composition of biological communities may vary over time even in areas that remain undisturbed (Connell and Sousa 1983, Newell et al. 1998). Connell and Sousa (1983) defined persistence to indicate that a population or species recolonizing an area within the time span required for one turnover of all individual of that species in the place. Newell et al. (1998) suggest that a practical approach to defining recovery is recognition of the establishment of a self-sustaining community in which at least 80% of the species diversity and biomass has been restored. Consideration of biomass ensures that recovery considers secondary production to higher trophic levels. In addition, biomass provides a good integrator between organism size distribution and abundance, given

that biomass typically is lower early in the recolonization process when small, opportunistic species dominate, but increases as populations re-establish (e.g., juvenile through adults) and/or there is succession towards larger, slower growing species.

Recovery after disturbance from sediment management activities may vary due to the following factors (Pullen and Naqvi 1983, NRC 1995, Newell et al. 1998, Greene 2002):

- Existing community structure and life histories of associated species.
- Environmental conditions.
- Nature and degree of change from existing conditions.
- Magnitude of disturbance.

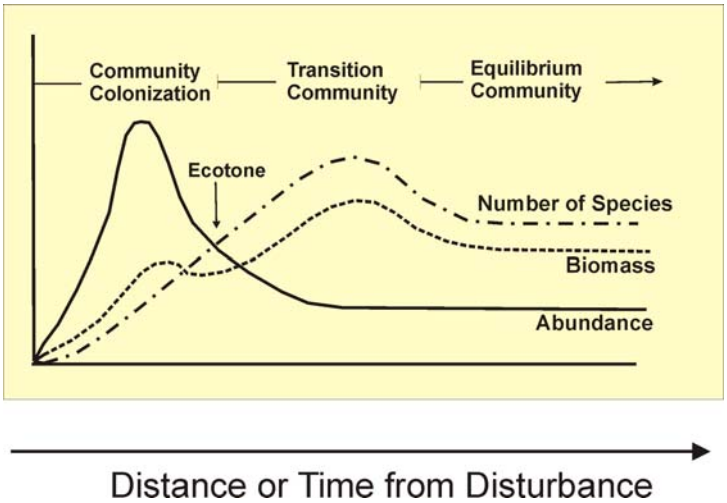
Generally, communities experiencing substantial environmental variability and/or frequent disturbance are less diverse and dominated by *r*-strategists (opportunistic species with high reproductive output and short life spans) and migrating opportunists; whereas, communities characterized by low environmental variability are more diverse and dominated by *k*-strategists (equilibrium species with slow growth rates, long life span, delayed and/or few reproductions per year) (Pearson and Rosenberg 1978, Naqvi and Pullen 1982, Wilber and Stern 1992, NRC 1995, Newell et al. 1998).

Resilience increases along a gradient of environmental variability, with communities characterized by a high degree of natural disturbance exhibiting greater resilience and shorter recovery rates than environmentally stable communities (Newell et al. 1998, Lélé 2000). Thus, communities in areas of low environmental variability that support greater diversity and functional redundancy contribute to resistance to change and permit the neglect of resilience; whereas, communities adapted to substantial environmental variability give primacy to resilience (Lélé 2000). After major disturbance, less resilient communities may display functional attenuation with fewer or less functional redundancies, shift to a new functionally stable state, or loss of imperiled functions (*ibid.*).

Generally, species diversity increases and natural bio-resilience decreases along gradients from intertidal to subtidal depths and from exposed to protected coasts. Diversity also varies among different beach morphodynamic states that differ in wave energy, slopes, and sand mobility, with intertidal diversity in the following order: dissipative > intermediate > reflective (Hesp and Short 1982, Wright and Short 1984, McArdle and McLachlan 1992). However, intermediate morphodynamic beaches display the greatest degree of sand mobility associated with highly changeable wave conditions. Barros et al. (2002) found subtidal diversity in the surf zone to be lower for intermediate than reflective or dissipative morphodynamic beaches. This is relevant to Califonria beaches, many of which are of the intermediate bar-trough mrophodynammic type (Dugan et al. 2000a).

Impact considerations often differ substantially between locations characterized by frequent disturbance versus greater environmental stability. For example, navigation channels subject to periodic maintenance dredging often are characterized by low diversity invertebrate assemblages of opportunistic species with short life spans (McCauley et al. 1977). Intermediate morphodynamic beaches with substantial seasonal sand mobility and movement also have less developed invertebrate assemblages, skewed towards short-lived species, than more stable dissipative beaches (McArdle and McLachlan 1992, Brown and McLachlan 2002). Locations that naturally experience substantial sedimentation and/or turbidity from landslide activity also have less developed aquatic communities (e.g., Pondella et al. 1996). Recovery rates after

disturbance generally decrease with increasing environmental disturbance (Newell et al. 1998). Consequently, recovery time considerations often relate to whether the impact occurs to a community characterized by frequent or infrequent disturbance (Figure 5.2-1).



Modified from Pearson and Rosenberg 1978 and Newell et al. 1998

Figure 5.2-1. Conceptual diagram of recovery process after disturbance.

Recovery rates of the benthic invertebrate community may vary depending on size and mobility of fauna. Small meiofauna may take years to recover after dredging (Navqi and Pullen 1982, Vanaverbeke et al. 2003). Meiofauna distribution and abundance are influenced by sediment characteristics (particularly silts that fill interstitial spaces), organic content, and depth of the anoxic layer (Oakden 1996). These characteristics may account for their sensitivity to changed hydrodynamics and substrate characteristics.

Most studies of benthic infauna community recovery have focused on macroinvertebrate infauna (generally defined as animals ≥ 1 mm in size) living in the upper 2 ft (60 cm) of sediment. Recovery rates of infauna communities from sediment burial (beach nourishment) and/or removal (dredging, excavation) may occur within the same year for highly energetic (e.g., sandy beach), shallow nearshore, and frequently disturbed (e.g., dredged navigational channels) habitats (e.g., McCauley et al. 1977, Oliver et al. 1977, Parr et al. 1978, Van Dolah 1984, Gorzelany and Nelson 1987, Burlas et al. 2001, Greene 2002, Versar 2004).

However, invertebrate recovery may take two or more years for less energetic nearshore, offshore, and/or more environmentally stable embayment areas dominated by equilibrium species (Oliver and Slattery 1973, 1977; de Groot 1986; Kenny and Rees 1996, Newell et al. 1998, Burlas et al. 2001; Van Dalfsen and Essink 2001, Jutte et al. 2002, Boyd et al. 2004). Generally, nearshore benthic infaunal communities in sandy areas recover from dredging impacts within 2 to 3 years, but as substrate becomes coarser may reach 5 to 10 years (Newell et al. 1998, Boyd et al. 2004). In areas subject to high intensity offshore dredging, invertebrate communities may remain in a perturbed state for many years (Boyd et al. 2004).

Dynamic relationships between sediments and their hydrodynamic environment influence differences in benthic community structure and recovery rates. Recovery rates appear to be slower in deep pits produced by anchored hopper dredges than shallow furrows from trailer suction hopper dredges (Naqvi and Pullen 1982, Jutte et al. 2002, Brynes et al. 2004b, Newell et al. 2004). Recovery of shallow furrows may be facilitated by the slumping of undredeged areas between the furrows (Jutte et al. 2002). Shallow dredge depths that focused on bathymetric peaks (associated with ridge swale topography) may have influenced rapid recovery (< 3 years) at borrow sites associated with the Asbury Park to Manasquan Inlet Beach Erosion Control Project, New Jersey (Burlas et al. 2001).

Hydrodynamics also appear to influence benthic invertebrate community recovery rates from indirect sedimentation. Silt-clay loading of the nearshore dissipated within the first storm season and had little influence on the benthic invertebrate community after a 760,000 cy beach nourishment project off the Imperial Beach, San Diego County (Parr et al. 1978). Nearshore invertebrate recovery also was relatively rapid after beach nourishment projects ranging from 5.6 to 8.1 million cy off the Altantic coast of New Jersey (Burlas et al. 2001) and North Carolina (Versar 2004). Storm activity also was considered influential to the dispersion of silts deposited in the nearshore off New Jersey (Burlas et al. 2001). In contrast, silt-clay loading was persistent and the invertebrate community remained altered over a two year monitoring period associated with the 5.5 million cy beach placement portion of a 9.1 million cy profile (beach and nearshore) nourishment project off Perdido Key, Florida in the Gulf of Mexico (Rakocinski et al. 1996, 2001).

Change in substrate characteristics may substantially affect benthic invertebrate community recovery rates. Recovery may take longer and/or not at all when there is substantial difference in sediments between native beach and beach nourishment source materials and/or existing and post-dredging conditions; i.e., representing a substantially changed environmental condition (Sections 4.2.6, 4.2.7, 5.2.3.3). Relatively slower benthic infauna recovery rates and/or altered species composition also have been associated with changed substrates in offshore borrow sites and at marine aggregate extraction sites (Sections 4.2.7, 5.2.3.3).

Mobile invertebrate epifauna and fish may move from and return to dredge affected areas, and some species may be attracted to dredged areas early in the recolonization phase, presumably to an increased food source associated with the disturbance regime (Courtenay et al. 1972, 1980, Naqvi and Pullen 1982, Van Dolah et al. 1994). Few studies have examined longer-term response of mobile, epifauna and demersal fish in areas of offshore dredging. No substantial changes in fish species composition, abundance patterns, or diets of three demersal fish species were reported one to two years after relatively shallow, dredging of bathymetric peaks (Burlas et al. 2001). Van Dolah et al. (1994) reported similar numbers of fish and crustacean species within one year following borrow site dredging for the Folly Beach, South Carolina beach nourishment project, with changes in species composition attributed to normal seasonal and yearly variability rather than the effects of dredging (cited in Greene 2002). The short study duration limits understanding of long-term recovery at that borrow site.

Localized depressions of the abundance of some demersal fish species have occasionally been reported. Some of the changes may reflect differences in food resources and/or substrate change (Courtenay et al. 1980, Boyd et al. 2004, Cooper 2005; see Sections 4.2.7 and 4.3.4). Recovery of the benthic forage base relates to nature and extent of disturbance. Reduced diversity, density, and biomass of epifaunal invertebrates and a shift towards dominance by

mobile, scavengers and predators was observed years after cessation of high intensity marine aggregate extraction areas off the United Kingdom (Boyd et al. 2004).

Generally, hard substrate and vegetated communities are more diverse and less resilient to disturbance than soft substrate communities. Recovery of hard bottom and/or SAV habitats may be relatively fast or slow depending on extent of impact and life history characteristics of species. For example, recovery of hard bottom habitats may be relatively rapid when impact is localized, occurs to low relief ephemeral substrate naturally exposed to sand scour, and/or dominant organisms are short-lived, opportunists; however, recovery may take years if impact is extensive and/or dominant organisms are long-lived species (e.g., Lissner et al. 1991, Sections 3.3.4, 3.3.5). Recovery in coral reef areas may take 8 to 10 years (reviewed in Newell et al. 1998).

Recovery of kelp beds may be relatively rapid if a local supply of spores is present and, in the case of the soft-substrate variety, holdfasts are not removed (Section 3.3.6). Eelgrass and surfgrass generally exhibit slow recovery, unless there is minimal disturbance and rhizomes are not removed (Sections 3.3.7 and 3.3.8). Increased mobilization of sands in transport may represent an abrasive effect inhibiting the growth and survirorship of epifauna such as hydroids and bryozoans (Boyd et al. 2004). Sedimentation also inhibits recruitment of hard substrate vegetation (algae, kelp, surfgrass) (DeVinny and Vose 1978, Foster and Schiel 1985, Stewart 1989, Airoldi 2003).

Recovery rates will vary with magnitude of disturbance, which may vary across spatial and temporal scales. Generally, recovery rates are relatively rapid when the extent of disturbance is small, but slow as spatial and/or temporal disturbance scales increase. Important spatial factors include area and depth of disturbance. Important temporal factors include duration and frequency of disturbance. Recovery rates also may be affected by biological (e.g., life history characteristics of species) and environmental conditions (stablility, morphodynamics, substrate characteristics).

Table 5.2-6 provides a conceptualized summary of factors considered influential to faster or slower recovery of coastal habitats to impacts associated with sediment management activities, based on the above considerations of magnitude of disturbance, environmental conditions, potential for change from existing conditions, life histories of associated species, and seasonal use considerations of sensitive resources.

5.2.3.7 Frequency of Disturbance

Frequency of sediment management activities generally considers safety issues such as shoreline protection needs and/or entrance and navigational channel shoaling rates. The amount of time between recurring sediment managaement activities also is an important environmental consideration related to ecosystem recovery.

Habitat recovery after disturbance relates to natural resilience but may exceed natural rates if additional impact occurs during the recovery period. For example, benthic invertebrate community recovery was delayed when beach nourishment included two placement periods because insufficient sand volume was initially placed by the contractor (Versar 2004). Recovery rates in marine aggregate extraction areas have been demonstrated to be slower in areas subject to higher versus lower intensitiy of dredging (Boyd et al. 2004). Thus, frequency of sediment management activities is an environmental resource protection concern.

Table 5.2-6. Conceptual summary of influential factors with respect to recovery rates of coastal habitats.

Habitat	Faster Recovery	Slower Recovery
Coastal dune and/or strand	Rhizomes remain intact Vegetation persists	Loss of rhizomes Loss of vegetation
Sandy beach	Reflective, Intermediate beach types Similar source sediment Shallow deposition Dune placement Fall-winter*	Dissipative beach type Dissimilar sediment Deep overburden Beach or swash placement Spring-summer
Sandy subtidal	Intermediate beach type Similar source sediment Shallow deposition Shallow furrow Dune, beach placement Winter	Dissipative, Reflective beach types Dissimilar sediment Deep overburden Deep excavation Nearshore placement Spring-fall
Rocky intertidal	Ephemeral reef Dominated by opportunists Partial burial	Persistent reef Dominated by equilibrium species Burial
Rocky subtidal	Ephemeral reef Dominated by opportunists Partial burial	Persistent reef Dominated by equilibrium species Burial
Kelp forest and/or bed	Holdfast remains intact	Loss of holdfast Burial of recruitment substrate
Surfgrass bed	Rhizomes remain intact	Loss of rhizomes Burial of leaves
Eelgrass meadow	Rhizomes remain intact Winter	Loss of rhizomes Burial of leaves Spring-summer
Embayment	Open inlet Winter-early spring**	Inlet closure Spring-summer

*Potential to substantially affect overwintering shorebirds should be considered, **Potential to affect migration of Pacific herring and/or salmonids should be considered

Several beaches have been repetitively used during maintenance dredging projects as beneficial reuse sites (refer to Table 2.1-1). However, limited monitoring data are available from areas with recurring sediment management activities. This data gap limits the scientific information available for understanding potential cumulative impacts associated with beach nourishment (Lindeman and Snyder 1998, Greene 2002, Peterson and Bishop 2005).

In addition, limited information is available with respect to recovery rates of offshore benthic communities after repetitive dredging operations. Boyd et al. (2004 reviewed limitations with respect to management of marine aggregate extraction practices in the United Kingdom that appear equally relevant to considerations associated with location and use of offshore borrow sites in the United States. The primary limitation is that few multi-year monitoring studies are available from different geographic areas and environmental conditions. This data gap limits the abilitly to identify appropriate thresholds of dredging frequency and management strategies to minimize ecosystem impacts.

Most available information on cumulative impacts in the coastal zone relate to chronic impacts and/or high intensity impacts related to commercial activities (e.g., fishing, marine aggregate mining in Europe). Although temporal scales of those disturbances exceed those of sediment management activities, they provide relevant examples of what effects may occur with substantial disturbance. For example, chronic turbidity impacts associated with landslides and/or point source discharges may result in less diverse hard bottom communities and vegetated habitats (Murray and Bray 1993, Bence et al. 1996, Pondella et al. 1996, DFG 2001).

In another example, cumulative impacts to shorebirds were linked to commercial fishing using mechanical dredging in the Dutch Wadden Sea (van Gils et al. 2005). Over several years, sediments became coarser after dredging events, indirectly leading to reduced settlement success, feeding performance, and reduced quality (flesh-to-shell ratio) of edible cockles *(Cerastoderma edule)*. The reduction of cockles was linked to decreases in local survival and decline in the European wintering population of red knot (*Calidris canutus islandica*).

Cumulative impacts from commercial aggregate mining to commercial and/or recreational fisheries for brown crab (*Cancer pagurua*) and smoothhound shark (*Mustelus mustelus*) are reported concerns off Great Britain. Cooper (2005) reported that commercial crab fishermen generally avoid licensed commercial aggregate mining areas due to the potential for gear damage and perceived changes in the seabed (changes in sediment composition, changes in topography). This avoidance of certain areas has increased fishing pressure on brown crab at alternative fishing grounds. In that case, relationship between dredging and fishing was considered indirect and over-fishing was likely an important factor to declines in stock. In the case of smoothhound sharks, catch was reduced at an area where dredging activities removed part of a known foraging area; therefore, direct impact could not be ruled out.

5.3 Equipment and Disturbance Impacts

Equipment used during sediment management activities includes some combination of dredges, vessels, sand delivery pipelines, earthmoving equipment, and/or trucks. The following question of interest to the CSMW is addressed in this section.

- *How are sensitive habitats and species affected by equipment and/or other types of disturbances?*

Equipment use during beach nourishment activities has the potential to result in the following types of impacts depending on placement method (e.g., dune, beach, nearshore, profile) and existing environmental conditions in the area of potential effect (Navqi and Pullen 1982, Nelson 1993, NRC 1995, Peterson et al. 2000a, Greene 2002):

- Equipment damage to habitats and/or species.
- Increased human activity and/or equipment disturbance of wildlife.
- Noise (above and/or underwater) displacement and/or disturbance of wildlife.
- Light displacement disturbance and/or attraction of wildlife.

Many of the above impact concerns also apply to sediment management activities involving dredging and/or excavation. Other potential equipment impacts associated with these activities include (Navqi and Pullen 1982, Nelson 1993, NRC 1985, 1995, Reine et al. 1998, Newell et al. 1998, Greene 2002):

- Dredge or excavation removal of sediment and associated organisms.
- Dredge entrainment of invertebrates and/or fish.
- Changes in water depths, hydrodynamics, and/or water quality.
- Change in substrate characteristics of benthic habitat.

Equipment use is limited to the construction period; therefore, resulting disturbances will span days to months depending on project volume, method, and schedule. However, equipment disturbance impacts over a course of a work day may range from continuous, continuous during daylight hours, or discontinuous. Generally, the potential for adverse biological effects increases with duration of exposure to disturbance.

Another important consideration is the extent to which existing conditions may be adversely influenced by other vessels, vehicles (beach grooming, lifeguard), noise sources, lighting sources (e.g., piers, adjacent development, other vessels), and/or high public use. Other sources of disturbance may adversely affect habitat quality, biological resource occurrence, and/or lessen habitat sensitivity to potential impacts. Therefore, other sources of disturbance are important considerations of environmental impact assessments.

This section is organized in four subsections. The different types of equipment used in sediment management projects are briefly introduced in Section 5.3.1. Different types of equipment impacts are summarized in Section 5.3.2. Summaries of equipment related impacts follow for habitats (Section 5.3.3) and species (Section 5.3.4).

5.3.1 Types of Equipment Used During Sediment Management

Several types of equipment may be used during beach nourishment and/or dredging associated with sediment management projects (also see Section 2.5).

5.3.1.1 Beach Nourishment

The type of equipment used will depend on placement location and method of delivery of sand source (e.g., dredging, terrestrial).

Beach, dune, or profile (intertidal) placement may include use of the following equipment:

- Trucks, bulldozers, front loaders, fork lifts, graders, cranes.
- Sand delivery pipelines, pumps.
- Generators, lights.

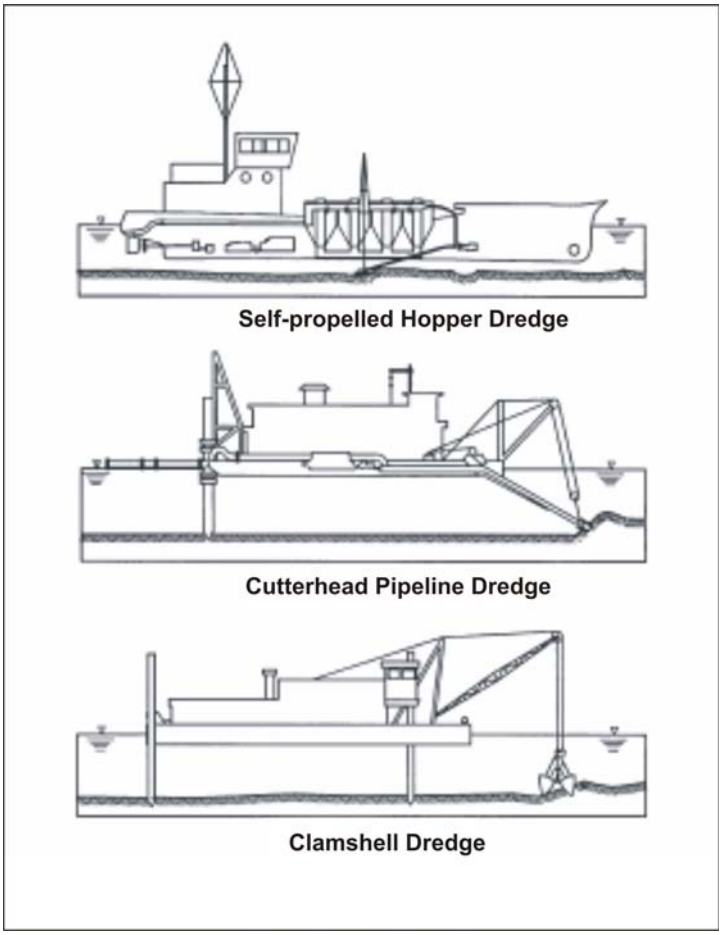
Nearshore or profile (subtidal) placement may include use of the follwing equipment:

- Dredges, pipelines, dump scows, and/or support vessels.

5.3.1.2 Dredging

There are three types of commonly used dredges (Figure 5.3-1), which have different advantages of use related to environmental conditions (LaSalle et al. 1991, USACE and EPA 2004):

- Cutterhead dredges are hydraulic dredges that are unpropelled, but use pivoting spuds at the stern of the dredge to step the dredge forward during operation, which is nearly continuous. The rotating head of the dredge dislodges sediment, which is withdrawn along with entrained water into the intake pipe, and the resulting low-density slurry is conveyed by pipeline to the discharge location. Cutterhead dredges perform best in calm waters and are extensively used for embayment and harbor maintenance projects, although they also have been used for offshore borrow site dredging off the southeastern United States (e.g., Courtney et al. 1972).
- Hopper dredges are self-propelled vessels that hydraulically remove and store sediment in hopper bins. Hopper dredges may be operated withile the vessel is underway (trailing suction hopper dredge) or anchored (stationary hopper dredge). Hopper dredges transit between the dredge and discharge location, where sediment is either emptied through the bottom of the ship's hull (e.g., nearshore or offshore placement) or by pumping the material to the discharge stie through a pipeline. Hopper dredges are used in rough waters and/or in areas of heavy ship traffic. Hopper dredges may anchor and tie-up to a monobuoy while pumping materials to beach receiver sites (e.g., USACE 1995a, SANDAG and USDN 2000).
- Mechanical dredges are operated from a crane or derrick mounted on a barge or operated from shore in ports and harbors (USACE and EPA 2004). They typically leave an irregular, cratered bottom (LaSalle et al. 1991). Dump scows may be used to transport the dredged materials to the discharge area.



Source: USEPA and USACE 1992 (updated 2004)

5.3-1. Illustration of different dredge types.

5.3.2 Summary of Different Types of Equipment Impacts

Equipment use may result in a variety of impact considerations, including:

- Vehicle damage and/or disturbance of habitat and/or wildlife.
- Dredge sediment removal impacts to habitat and/or wildlife.
- Dredge entrainment impacts to early life stages of organisms.
- Vessel anchoring, propeller, and/or collision impacts to habitat and/or wildlife.
- Pipeline placement/removal damage and/or disturbance to habitat and wildlife.
- Noise disturbance and/or displacement of wildlife.
- Light attraction and/or disturbance of wildlife.

The following subsections provide overview summaries of the above impact considerations. Equipment related impacts to habitats and species are summarized in Sections 5.3.4 and 5.3.5, respectively.

5.3.2.1 Vehicles

This section addresses two types of sediment management activities that involve vehicle use: beach nourishment and beach scraping.

Beach Nourishment

Vehicles may be used to bring, place, and/or redistribute sands within the beach receiver site. Projects involving hydraulic pumping of sands to the beach generally use earthmoving equipment to redistribute the sand within the fill site (e.g., SANDAG and USDN 2000). In those cases, vehicle impacts are largely masked by the more substantial impact associated with sand placement.

Goleta Beach Demonstration, 2003
Photo by: Moffatt & Nichol

Cranes, forklifts, and other support vehicles may be used during pipeline placement and/or removal. A helicopter is used to move pipeline at Morro Bay, Calfiornia (USACE 2001). The area of potential effect may include the sand placement site, site access route, and pipeline route.

Sand back-passing may use trucks and/or front-end loaders to move sand from one side to another of an obstruction (e.g., breakwater). The area of potential effect includes the area where the sand is removed and the placement location. This sediment management activitiy uses beach scraping (discussed below) to move sand.

For small projects, trucks and/or front-end loaders may be used to place sand piles in the swash zone for tides to redistribute (e.g., Sherman et al. 1998). With swash zone placement, multiple vehicle trips are made from the beach access route to low intertidal zone to deposit single load sand piles. The area of potential effect includes the entire zone in which the vehicles move and where sand is placed.

Swash placement from inlet excavation of San Elio Lagoon, 2004
Photo by: William Haas

The following habitats have the potential to be affected by vehicles during beach nourishment depending on site conditions:

- Coastal dune and/or strand.
- Sandy beach.

Stephenson (1999) reviewed several studies of vehicle impacts on beach backshore with the following findings:

- Vehicle use on the backshore may compact beach sand at depth, but loosens the surface and renders it more susceptible to aeolian and/or swash activity. Shearing and compaction effects have been reported to depths of approximately 8 in (20 cm) (Anders and Leatherman 1981, Niedoroda 1979).
- Vehicle use retards or inhibits development of drift line vegetation and/or seaward advance of coastal strand vegetation (Gilbertson 1977, Anders and Leatherman 1987).

Several relevant studies emphasize the vulnerability of dune plants to damage and/or destabilization and erosion of habitat from vehicles and/or trampling (Brodhead and Godfrey 1977, Hosier and Eaton 1980, Rickard et al. 1994, Stephenson 1999). Pipeline placement to convey maintenance dredge materials to South Beach in Ventura resulted in damage to dune vegetation, which was mitigated with a revegetation program (USACE 1998b).

Fewer studies have examined vehicle impacts to intertidal biota. Relevant reports indicate that vehicle impacts to sandy beach habitat vary across tide elevation, with relatively minor impact in the low and middle intertidal to common invertebrates such as *Emerita* mole crabs and *Donax* clams (reviewed in Stephenson 1999). Experimental studies suggest that intertidal animals are relatively safe from damage by a 4-wheel drive vehicle, even at relatively high traffic intensities when animals were buried and sand was reasonably compact (van der Merwe and van der Merwe 1991). In contrast, supralittoral crustaceans (e.g., talitrid amphipods, isopods, ghost crabs) appear to be highly sensitive to impacts from vehicles (Wolcott and Wolcott 1984, van der Merwe and van der Merwe 1991). Relevant studies of beach grooming practices indicate substantial impact to talitrid amphipods, isopods, and other wrack-associated invertebrates (Brown and McLachlan 2002, Dugan et al. 2003).

Existing conditions are an important consideration with respect to potential for vehicle impacts to invertebrates. Under erosive conditions, little sand and biological resources may occur at upper tidal elevations to to support supralittoral crustaceans (SANDAG and USDN 2000, Greene 2002, SAIC 2006). At seasonally erosive beaches, little sand and resources may extend throughout the intertidal zone during winter-early spring (MEC 2000a, SAIC 2006).

California grunion spawning is vulnerable to vehicle impacts. Martin (2002) demonstrated that beach grooming is detrimental to California grunion eggs, if present.

Vehicle use and increased human activities may disturb birds foraging and/or resting on the beach. Monitoring studies during beach nourishment indicate birds move from the path of moving trucks and heavy equipment (Worden et al. 2002, Worden and Smith 2004). Birds tend to move a distance away rather than leave the beach. For example, snowy plovers have been observed foraging adjacent, but outside immediate areas where dredging and/or discharge activities were occurring (Chambers Group 2001, 2005).

Pinnipeds also may be disturbed by vehicles and activities associated with beach nourishment, if present. Seals and sea lions are sensitive to disturbance while on land and if disturbed typically retreat to the water (Richardson et al. 1995).

Beach Scraping/Berm Construction

Beach scraping or bulldozing are terms applied to use of earth moving equipment to pick up and move or push sand from one location to another. It may be used in back-passing, as noted above. Beach scraping/bulldozing is sometimes used to protect coastal strucutres from wave runup damage during the storm season (Greene 2002). In that case, earth moving equipment is used to push and/or move sand to form a berm. Generally, beach scraping for shoreline protection is performed in the fall prior to the onset of winter storms and the berm is knocked down after the storm season.

Greene (2002) reviewed that beach bulldozing has the potential to alter sedimentology, compaction, sorting, and the nature of sands (Wells and McNinch 1991, Lindquist and Manning 2001).

Available information suggests that beach scraping effects are temporary. Greene (2002) referenced several studies that reported rapid recovery after that activity (Lankford and Baca 1987, Lankford et al. 1988, CSA 1991, Levinsen and Van Dolah 1996). Recovery was within 60 days for one the referenced studies. Lindquist and Manning (2001) did not report any negative impacts from bulldozing on an amphipod (*Amphiporeia virginiana*), polychaete (*Scoloepis squamata*), or *Donax* clams. Reductions in *Emerita* mole crab abundance were temporary, but longer lasting (6 to 8 months) reductions in ghost crab populations were reported.

Peterson et al. (2000a) also reported more pronounced effects on ghost crabs from bulldozing. In that study, the abundance of dominant species (ghost crabs, *Emerita* mole crabs, *Donax* clams) were compared at bulldozed and untreated segments of a beach in North Carolina approximately three months after bulldozing operations (beach scraping occurred in April, observations were made in July-August). Beach profiles indicated no remaining evidence of bulldozing three months later. A significant reduction in ghost crab burrows was observed on bulldozed berm faces compared to native dune faces, which was attributed to differences in substrate characteristics (i.e., berm faces had less vegetation and looser, sediments of coarser particles with more shell fragments that were incapable of supporting burrows). The number of ghost crab burrows on the lower beach was either similar or lower on bulldozed compared to untreated beach segments. No significant difference in denstiy was detected for large *Emerita* mole crabs; however, significantly fewer small mole crabs were observed at bulldozed compared to untreated beach segments. The density of *Donax* clams was significantly higher at bulldozed beach segments. The authors stated that these differences in effect between large and small sand crabs and higher abundance of clams were not clear.

One potential contributing factor, although speculative, ist hat the higher density of *Donax* clams contributed to the lower density of small *Emerita* mole crabs observed by Peterson et al. (2000a). Other studies have demonstrated density-dependent competitive interactions between *Emerita* and small clams (reviewed in Dugan et al. 2004). For example, reduced numbers of small sand crabs perhaps was related to larval recruitment and establishment being adversely affected by a high density of *Donax* clams. Because the density of large *Emerita* did not differ between bulldozed and untreated beach segments, bulldozing did not appear to affect onshore migration of overwintered adults.

An experimental study also suggests rapid recovery occurs after disturbance of the upper surface of sand. Shoeman et al. (2000) removed the upper 1 ft (0.3 m) of sand from 200 m^2

quadats from the mid-intertidal zone of a beach in South Africa and found recovery to be rapid (at most one semi-lunar cycle) for invertebrate species richness, abundance, and abundance and biomass of numerically dominant *D*onax clams. On the days immediately following disturbance there was no visible evidence of disturbance due to tidal reworking and infilling of sand.

Beach scraping may be limited to the upper sediment layer to promote rapid infilling. For example, Peterson et al. (2000a) stated that the North Carolina Coastal Resources Commission allows only 1 ft (30 cm) of sediment to be removed from the lower beach in a bulldozing project, an amount that is usually rapidly replaced by natural sediment transport (cited Wells and McNinch 1991).

The above studies suggest that seasonal beach scraping effects may be temporary for most sandy beach invertebrates. On East Coast beaches, longer lasting effects may occur to ghost crabs, if present. Ghost crabs do not occur on California beaches.

Seasonal timing and localized area of effect are considered important factors to fast recovery rates after beach scraping. Scraping conducted prior to onset of the storm season coincides with a period of low invertebrate productivity.

Bulldozing to create a storm protection berm also may involve movement of sand from the backshore above the high tide line. That practice does not result in disturbance of marine life.

Based on the above considerations, location (above high tide line), season (fall-winter), and depth restriction (no more than upper 1 ft, 0.3 m removed) may avoid or minimize effects of of beach scraping.

Inlet Excavation

Excavation refers to the use of earth moving equipment under low tide conditions to remove shoaled littoral sediments from the entrance of shallow inlet embayments (e.g., lagoons, sloughs). Equipment may include use of bulldozers, excavator, front loaders, and/or trucks.

Inlet excavation, San Elijo Lagoon
Photo: B. Hass May 2005

Material is typically placed in a series of 3 to 4 ft (1 to 1.2 m) piles in the swash zone with piles being reworked over a tidal cycle (D. Gibson, 2006 personal communication). Generally, excavation involves removal of relatively small volumes (e.g., 5,000 to 20,000 cy) over a week to two-week period (*ibid*).

The direct biological effect of inlet excavation is removal of soft bottom habitat and benthic invertebrates. Equipment may result in short-term displacement of mobile invertebrates, fish, and/or birds in the vicinity. Recovery rates of benthic invertebrates are expected to be rapid because inlet areas naturally experience frequent disturbance associated with shoaling and scour during storm runoff.

5.3.2.2 Dredging

Dredging refers to the use of dredge equipment to mechanically and/or hydraulically remove subtidal sediment. Different types of dredging projects provide a potential beneficial reuse opportunity of suitable sands for beach nourishment projects in California (Section 2.1, Table 2.1-1).

A primary source of sands placed on California beaches is from maintenance of navigational channels in bays and harbors that accumulate littoral sediments. Dredging to maintain inlets and/or hydraulic functions of shallow inlet lagoons and estuaries represent another source. Dredging of nearshore sand deposits (also termed offshore borrow sites) has been conducted. Offshore borrow sites have been the most common source of beach fill material on the East Coast of the United States and in the United Kingdom (NRC 1995, Newell et al. 1998, Hitchcock and Bell 2004).

Dredging may result in the following physical changes from the removal of sediment depending on nature of project and existing conditions (Navqi and Pullen 1982, NRC 1995, Newell et al. 1998, Greene 2002, Hanson et al. 2003, Byrnes et al. 2004):

- Increase water depth.
- Alter local hydrodynamics and water quality.
- Change substrate type.
- Change in local wave energy and/or littoral transport dynamics that accelerate beach erosion.

The first three of the above-listed factors may result either from dredging in embayments and/or offshore borrow sites depending the nature of the project. The last factor may occur if borrow sites are located in the littoral zone.

Dredge depths during maintenance of navigational channels may vary along a channel according to sedimentation patterns, generally dredging is conducted to maintenance depths, plus overdraft; e.g., Crescent City and Moss Landing navigational channels are maintained to -15 ft (4.6 m) MLLW (USACE 1998c, USACE 2002c), entrance and navigational channels, including sand trap in Santa Barbara Harbor are maintained to -15 to -35 ft (-4.6 to -10.7 m) MLLW (USACEa), Oceanside Harbor channels are maintained to -25 ft (-7.6 m) MLLW (USACE 2000b), and maintenance depths range from -20 to -30 ft (-6 to -9 m) MLLW in Ventura Harbor (USACE 1998b). Dredge areas may range deeper during major navigational improvement projects to accommodate larger vessels and/or cover broad areas of embayments (e.g., hundreds of acres, hectares) during major port development projects (Jones 1981, USACE and LAHD 1992). Impact concerns with new dredging projects are increasing water depths beyond light compensation depths of SAV and changes in water quality, such as dissolved oxygen concentration. Maintenance dredging has the potential to result in a continuing state of benthic community instability associated with recovery periods being longer than dredging intervals (e.g., McCauley et al. 1978, NRC 1985). The NRC (1985) reviewed that such effects appeared to be negligible in most cases, owing to the small areas affected.

The persistence of dredged pits and/or furrows is related to excavation depth, nature of the substrate, and environmental variability, with more rapid infill rates generally associated with

shallower coastal areas than deeper waters (Newell et al. 1998, Hitchcock and Bell 2004). For example, infill rates ranging from > 2 to more than 15 years have been reported for dredged borrow pits with gravelly substrates, nearshore areas that experience infrequent disturbance, embayments (tidal watersheds) with low current velocities, and tidal flats (reviewed in Newell et al. 1998, Brynes et al. 2004b, Hitchock and Bell 2004). In contrast, rapid infill rates of borrow pits of less than 1 to 2 years have been reported in high velocity channels in the Dutch Wadden Sea (van der Veer et al. 1985 cited in Newell et al. 1998).

Similarly, infill rates may vary across temporal scales ranging from < 1 to several years for relatively shallow dredge furrows, although the persistence range usually is reported as 1 to 4 years (Newell et al. 1998). For example, dredge furrows were not visible after a few tidal cycles in sandy substrate in the highly energetic Bristol Channel and in areas of the Dutch sector of the North Sea where winter storms obliterated tracks within a few months (Newell et al. 1998). Kenney and Rees (1996) used underwater cameras and side-scan sonar to provide an overview of the seabed before and after dredging, and documented that dredge furrows were no longer visible with underwater cameras after 1 year, and were barely visible with side-scan sonar 2 years after dredging off Norfolk, United Kingdom. In contrast, dredge furrows in sands were still visible with side-scan sonar after 2 to 4 years in areas experiencing less natural environmental disturbance offshore the United Kingdom (east of the Isle of Wight) and off the coast of France (reviewed by Newell et al. 1998).

Sediment characteristics in dredged areas may change due to exposure of new substrate, changed depths affecting hydrodynamics of water movement, and/or the excavated site traps fine sediments (Jones 1981, Naqvi and Pullen 1982, NRC 1985, NRC 1995, Newell et al. 1998, Greene 2002, Byrnes et al. 2004, Boyd et al. 2004). Substrate may have a finer grain size distribution in dredge pits than surrounding sediments. For example, the substrate in a 15-ft (49 m) borrow pit offshore Surfside-Sunset Beaches, Orange County was of muddy consistency compared to surrounding sandy substrate (N. Davis, personal communication cited in Chamber Group 1992). In deep bathymetric depressions, a reduction in water quality (e.g., anoxia) may result from deposition of fine particulates and organics (NRC 1995, Newell et al. 1998). Little substrate change may occur in areas where slumping of adjacent undredged areas contributes to infill rates and/or dredging occurs in areas where sediments are frequently reworked (VanDolah et al. 1984, NRC 1995, Newell et al. 1998, Greene 2002, Byrnes et al. 2004b).

Comparison of Potential Impacts According to Offshore Dredging Method

Factor	Deep isolated pits	Shallow extensive furrows
Size of impact area	Lesser	Greater
Alteration of topography	Lesser	Greater
Potential modification of wave and currents	Lesser	Greater
Entrapment of bed load	Greater	Lesser
Development of anoxia	Greater	Lesser
Exposure of underlying substrate different from adjacent areas	Greater	Lesser
Chances of faunal recovery	Lesser	Greater
Interference with fishing	Greater	Lesser

Sources: Compiled based on review of Newell et al. 1998, Hitchcock and Bell 2004

The direct biological effect of dredging and/or excavation is removal of soft bottom habitat and benthic invertebrates (NRC 1985). Dredging has the potential to disturb, remove, and/or degrade the quality of spawning grounds of important fisheries species (fish, shellfish) and/or SAV (NRC 1995, Greene 2002). Dredge equipment may result in displacement of mobile invertebrates and fish (Courtenay et al. 1972). The following biological concerns are associated with estuarine and/or marine dredging and excavation (Navqi and Pullen 1982, NRC 1995, Newell et al. 1998, Greene 2002, Hanson et al. 2003, Boyd et al. 2004, Cooper 2005):

- Direct removal/burial of organisms.
- Delayed recovery and/or altered benthic community with trophic effects to secondary consumers as a result of changed physical characteristics.
- Altered water quality in excavation pit resulting in anoxia.
- Damage to SAV habitats.
- Increased water depth resulting in a decrease in primary productivity.
- Damage to spawning grounds and/or commercial fisheries.

Generally, complete mortality is assumed for dredged removed organisms, although some survival may occur when mechanical dredges are used (La Salle et al. 1991; N. Davis, Chambers Group, 2005 personal communication). Examination of core samples from dredged sediments pumped to a beach verified no live organisms (Parr et al. 1978). Benthic recovery rates generally depend on degree and duration of change in physical and chemical characteristics, natural environmental variability, biological existing conditions, and magnitude of disturbance. Recovery rates also differ with dredging method; e.g., slower recovery rates generally are associated with deep pits than relatively shallow furrows (NRC 1995, Newell et al. 2004).

Dredging in embayments may result in removal of eelgrass, which may take several years to recover (Hoffman 1990, Nitsos 1990, Moore and Orth 1997, Orth et al. 2006). Dredging also may create depths with insufficient light to support eelgrass (Fonseca et al. 1992).

Reviews suggest that impacts from borrow site dredging may be lessened by incorporating the following features in borrow site project design (Thompson 1973, Hurme and Pullen 1988, Posey 2002, Hanson et al. 2003, Boyd et al. 2004, Byrnes et al. 2004, Diaz et al. 2004):

- Avoid mining in waters containing essential fish habitat. (Note: all subtidal waters in California are considered EFH).
- Apply sensible landscape designs (e.g., shapes that maximize recolonization, space areas widely apart, avoid borrow activities in sand-limited areas.
- Conduct shallow dredging over a larger area rather than creation of deep pits covering a limited area.
- Mining several small sites or relatively small portions of several ridges or shoals may facilitate recolonzation.
- Control the level of dredging intensity by leaving untouched areas within larger disturbed zone to act as refugia between dredged furrows.

- Dredge shifting sands rather than more stable bottoms.
- Use modeling and pre-borrow assessments to avoid areas where fine sediment may be trapped in the borrow site.
- Retain similar surface sediment type.
- Maintain buffer from hard bottom areas.
- Minimize duration of operation.
- Conduct project at times when most rapid recovery will occur.

Other recommendations have focused on minimizing potential direct and indirect impacts to sensitive resources (e.g., reefs, SAV, clam beds, spawning grounds) (Naqvi and Pullen 1982, Hurme and Pullen 1988, Chambers Group 1992, NRC 1995):

- Use prescribed dredge limits and/or accurate positioning systems to avoid sensitive habitat areas.
- Identify and establish exclusion zones to protect commercial fisheries.
- Restrict anchoring and mooring cables to areas with sandy substrates.
- Use equipment and techniques that minimize turbidity to sensitive habitats if nearby.
- Avoid peak spawning seasons.

5.3.2.3 Dredge Entrainment

Entrainment is defined as the direct uptake of aquatic organisms in the suction field generated by hydraulic dredges (Reine and Clarke 1998). This generally occurs when pumps are on when the cutterhead or dragarm (hopper dredge) are above the sediment surface. Entrainment also may occur with bucket dredges when the bucket is not filled with sediment.

Entrainment rates have been determined mainly for hopper dredges, although some values also have been identified for cutterhead and clamshell dredges. Fish and shellfish have been the primary resources of concern along the west coast, and sea turtles are an additional concern along the southeastern coast of the United States (LaSalle et al. 1991, Reine and Clarke 1998).

Entrainment rates have been determined for several species using different dredge types. Entrainment rates may vary considerably between different areas within the same water body, at the same location at different times of year, and between different water bodies. This is because entrainment rates relate to factors such as organism occurrence, abundance, size, and operational characteristics of the dredge.

Studies examining dredge entrainment effects report that overall entrainment rates are low, but mortality rates may range from 56 to 100 percent depending on species and their size (LaSalle et al. 1991). Dredge entrainment is of particular concern in areas that serve as nursery areas for managed species (e.g., Dungeness crab) on a seasonal basis.

Mortality rates of entrained organism may range from <10 to 100% depending on species and life stage (LaSalle et al. 1991, Reine and Clarke 1998). The following ranges of

entrainment rates (number of organisms per cubic yard of dredge material) were reported in reviews by LaSalle et al. (1991) and Reine and Clarke (1998):

- Dungeness crab – 0.04 to 0.592 (adults, hopper dredge), 0.32 to 10.78 (juveniles, hopper dredge), 0.0017 to 0.243 (pipeline), 0.012 (cutterhead.
- *Crangon* shrimp – 0.001 to 3.404 (pipeline), 0.079 to 0.280 (hopper, adjusted to samples in excess of 10 cy).
- *Callianassa* shrimp – 0.727 (equipment not specified by LaSalle et al. 1991).
- Oyster larvae– 0.005 to 0.03.
- Anchovy and Herring – 0.001 to 0.018 (hopper).
- Flatfish – 0.001 to 0.076 (hopper), 0.001 to 0.003 (pipeline).
- Sculpin, Cabezon, Lingcod, Kelp Greenling – 0.001-0.092 (hopper), 0.001 to 0.037 (pipeline).
- Surfperch – 0.001 (hopper).
- Chum salmon – 0.008 (pipeline).
- Pipefish – 0.006 to 0.008 (hopper).
- Skate - <0.001 to 0.003 (hopper).

Different models have been used to estimate entrainment losses on local populations. The Empirical Transport Model (ETM) was used to estimate the effects of dredge entrainment on larval fish populations in the Delaware River; the study concluded that entrainment would be minimal based on <1% of the total larval population for selected species being affected (Burton et al. 1992 cited in Reine et al. 1998).

Entrainment loss to Dungeness crab during a typical dredge protect in Grays Harbor, Washington was estimated as 1.2 to 6.5% (Armstrong et a. 1982 cited in Reine and Clarke 1998). A modified Dredge Impact Model using field measured entrainment rates was used to predict crab entrainment, adult equivalent loss, and loss to the Dungeness crab fishery associated with maintenance dredging in the Columbia River; worst-case projections were approximately 1% of the annual crab landings referenced to the prior 10 years of landings (Williams 2004).

Reine et al. (1998) concluded that available evidence suggests that entrainment is not a significant problem for many species of fish and shellfish. However, the authors also noted that data limitations and difficulties associated with determining population-level consequences continue to represent technical challenges. Areas of greatest risk to entrainment effects were considered narrow constricted river channels and/or channels occupied by protected species. LaSalle et al. (1991) summarized that although entrainment rates area low, the potential for entrainment may be significant during certain periods of the yeeear depending on site conditions. The potential risk for entrainment was considered greaeter in restricted bodies of water such as narrow channels where mobile animals may not be able to avid the dredge or whereh passive organism may be concentrated.

Measures used to reduce entrainment impacts in embayments have included use of environmental windows to protect nursery habitats and/or spawning grounds and operational controls to protect migrating juvenile salmon .

5.3.2.4 Vessel Anchoring and Transit

Sediment management activities may involve the use of self-propelled hopper dredges, support vessels, and/or dump scows that transit between dredge (offshore borrow site, embayment) and beach nourishment locations (beach, nearshore, profile placement). A nearshore monobuoy anchorage, consisting of a specially designed floating buoy anchored to the bottom, may be used to unload sediment slurries via pipeline to the beach (e.g., SANDAG and USDN 2000).

Potential vessel related impacts may include anchoring effects on habitats and organisms, propeller damage to organisms, collisions with marine mammals, and/or disturbance associated with vessel movement and/or noise (Section 5.3.2.7). Vessel activities are of concern in areas with sensitive resources and/or commercial fishing (SANDAG and USDN 2000, Cooper 2005). California coastal habitats and/or resources where dredge vessel operation and/or anchoring impacts are of particular concern include:

- Sensitive reefs.
- Kelp forest and/or beds.
- Surfgrass beds.
- Eelgrass meadows.
- Soft-substrate spawning grounds of fishery species (e.g., Dungeness crab, Pismo clam beds).
- Marine santuaries and other protected areas.

Anchoring restrictions have been established in some protected areas. For example, avoidance of anchoring eelgrass beds was recommended as a EFH conservation measure for the Morro Bay Harbor maintenance dredge program (USACE 2001). A regulation was established for the Gulf of Farallones Marine Sanctuary that restricts anchoring in Tomales Bay to protect seagrass beds (i.e., eelgrass) (Federal Register 2006).

Potential impacts associated with vessel anchoring and movements are further summarized below.

Anchoring

No reports of damage to reefs from dredges, barges, or other equipment involved in beach nourishment projects in California were identified with the literature review. Pre-construction surveys have been used to finalize anchorages, pipeline alignments, and vessel routes associated with beach nourishment projects in California (e.g., AMEC 2002).

Damage to reefs during borrow site dredging has been reported off the southeastern coast of the United States. Coral reefs were damaged from dredge equipment, anchor, and/or cable dragging across reefs or when cutting heads of the dredge dug into reef surfaces (Courtney et al. 1972; Spadoni 1978 cited in Naqvi and Pullen 1982, Goreau 2001). Other

relevant reports of anchoring effects include damage to reefs during offshore oil exploration and development (Lissner et al. 1991, MEC 1995).

Anchoring also is a concern for SAV habitats. Relevant reports include entanglement of kelp by anchor cables from a dredge barge and reduction of kelp canopy from vessel transit associated with pipeline construction (Chambers Consultants and Planners 1982). Equipment such as mooring and mooring chains resulted in reductions in eelgrass (Moore and Orth 1997). In some areas of the state (e.g., marine sanctuaries), anchoring is restricted to protect seagrass beds (i.e., eelgrass) (Federal Register 2006).

Anchoring effects in soft substrate may include disruption and burial of benthic organisms from mounding and scarring of the bottom and in hard substrate areas may include abrasion, breakage, crushing, dislodgement, and/or overturning of rock substrate and associated sedentary benthic organisms (Lissner et al. 1991). Anchoring operations also may disturb and displace mobile organisms in the vicinity. Dredge equipment may result in displacement of mobile invertebrates and fish (Courtenay et al. 1972).

Anchoring effects generally are localized within the area encompassed by the anchoring system, unless there are multiple attempts at anchoring or anchor and/or chain dragging occurs (Lissner et al. 1991). Anchor slippage may be more common in low-relief hard substrate areas because the anchor cannot dig into or “hang-up” on the bottom as readily as on soft substrate or high-relief areas (*ibid.*). Use of long lengths of heavy chain in hard bottom areas can result in substantial damage from the sweep and scour of the chain as the vessel rotates around the anchor point with changes in wind direction and water current.

Potential damage to hard bottom areas increases with increasing vessel size and weight of anchors and chain. For example, damage to coral reefs on Tortugas Bank, Florida was linked to vessels in excess of 164 ft (50 m), which are now prohibited from anchoring within the marine sanctuary (Federal Register 1998). Vessels of that size may have anchor gear (anchor and chain) weighing from 8 to 10 tons in comparison to 2,000 pounds for a 180 ft (55 m) coast guard cutter and 80 pounds for a 110 ft (34 m) coast guard patrol boat (*ibid.*). Several incidences of large vessel anchor damages have been reported on the Flower Garden Banks in the Gulf of Mexico (e.g., Texas A&M University 1981 cited in Lissner et al. 1991, http://sanctuaries.noaa.gov/_about/ecosystems/coralimpacts.html). A 2/3-acre (0.27 ha) area of coral reef was damaged by anchor chains from a large vessel offshore the Island of Guana (http://www.irf.org/guanareefdamage.html).

Generally, anchor damage is likely to be less substantial and more transient on a sandy seafloor compared to rocky and/or SAV habitats based on consideration of recovery rates. Soft-substrate community recovery to small-scale disturbance in temperate shallow waters generally is relatively rapid (e.g., weeks) (Boesch et al. 1987, also see Section 4.2.7), although frequent disturbance can delay recovery and/or alter community development (McCauley et al. 1977, Sebens 1986, Newell et al. 1998). Recovery time from disturbance generally increases with increasing depth from littoral to offshore habitats. Anchor scars and spud holes from drilling rigs on the Santa Barbara shelf persist for many years (Chambers Group 1992).

Recovery rates of a disturbed patch within hard bottom habitat will depend on life history attributes of surrounding species. For example, recovery from small-scale disturbance may occur rapidly (e.g., weeks or months) if dominant organisms include short-lived opportunists and/or colonial species with vegetative growth (Lissner et al. 1991). Generally, recovery

rates are slower if dominant species include long-lived, solitary forms. Recovery rates of kelp range on the order of months to years depending on severity of impact and variety of kelp (Section 3.3.6). Recovery of eelgrass and surfgrass can take years when rhizomes are removed (Section 3.3.7 and 3.3.8).

Anchoring effects may be avoided by vessel restrictions and/or pre-construction surveys to obtain site specific information to finalize vessel routes and anchorages to avoid sensitive habitats (see Section 6).

Vessel Traffic and Propellers

Damage and/or removal of vegetation by propellers may occur if vessels transit SAV habitats. Heavy vessel traffic may result in reduction in adult giant kelp density and an increase in juvenile kelp and understory red algae (North 1957 cited in Foster and Schiel 1985). Reduction in kelp canopy from vessel traffic was documented during a pipeline construction project near Coal Oil Point, Santa Barbara County (Chambers Consultants and Planners 1982). Up to 50 acres (20 hectares) of kelp canopy loss was documented from two vessels repeatedly crossing a kelp bed near Ellwood Pier (McPeak 1984 cited in Chambers Group 1992). Use of propellers is prohibited in shallow, eelgrass beds during maintenance dredging projects in Morro Bay, San Luis Obispo County (USACE 2001). Moore and Orth (1997) estimated recovery of eelgrass beds from 3-ft (1-m) wide boat propeller cuts at 3 to 5 years in Chincoteague Bay, Virginia. Propeller damage also has been reported as a cause of substantial damage to seagrass beds in Florida with recovery estimated at several years, if at all (NOAA 2001b).

Vessel collisions with marine mammals occasionally occur in California waters (Laist et al. 2001, Carretta et al. 2004). Laist et al. (2001) reviewed that all sizes and types of vessels can hit whales, but the most lethal or severe injuries are caused by ships 262 ft (80 m) or longer and/or by vessels traveling 14 kn or faster. Similarly, vessel strikes of sea otters and pinnipeds have been associated with fast-moving vessels (Caretta et al. 2004, Harvey 2004). Injuries may result from propellers or blunt trauma. The ability of a whale to avoid collision relates in part to vessel speed and swimming speed of the animal. Gray whales reportedly have a top speed of 8.6 kn when “frightened” (Tomilin 1957 cited in Laist et al. 2001). Generally, no effects have been reported from collisions with vessels traveling between 4 and 6 kn and only minor injury occurs at speeds up to 10 kn (Laist et al. 2001). Vessels used for sediment management activities typically are slow moving during dredging operations. Only one record of a whale fatality from collision with a hopper dredge was reported out of 58 collisions reviewed by Laist et al. (2001).

Vessel traffic (dredge, barge, and/or support boats) and anchoring has the potential to foul fishing gear, if present in the vicinity of sediment management activities. Trap fishing is the only commercial fishing activity permitted in nearshore waters with the potential for interference from dredge/vessel activities associated with beach nourishment (MEC 2000a). Important trap fishing species include California spiny lobster, Dungeness crab, rock crabs, and sheephead. During the 2001 San Diego Regional Beach Sand Project, a cooperative protocol was developed with commercial fishermen to reduce the potential for trap loss and interference (SANDAG and USDN 2000). Recommendations included selecting vessel and pipeline routes away from kelp and hard bottom areas, providing mariner notices of dredge vessel activity areas, having a third party observer document any fishing gear in mariner noticed areas, and contractor liability to compensate for any fishing gear damaged or destroyed if these activities extended outside mariner noticed areas (MEC 2000a).

5.3.2.5 Pipeline Placement/Removal

Pipelines may be used to convey sediments from dredging to discharge loations. Pipelines have been used in Calfiornia to convey sediments to beach receiver sites from offshore borrow sites, harbors, and/or lagoons during maintenance and/or restoration projects. Pipelines may be placed from the nearshore through the surfzone onto the beach, from an embayment to adjacent beach, and/or along the backshore (e.g., USACE 1998b, SANDAG and USDN 2000, USACE 2001).

Pipeline placement and/or removal have the potential to damage sensitive habitats (e.g. coastal dune and/or strand, SAV, reefs), crush sedentary organisms and/or life stages, and/or interfere with wildlife movement, if present. Similar to other localized equipment impacts, the significance of biological effects would depend on occurrence of sensitive habitats and/or species and extent of disturbance from placement and removal activities.

Few studies have documented pipeline placement and/or removal impacts during sediment management projects. One example occurred during the 1986-1987 Ventura Harbor dredge maintenance project, which included hydraulic pipeline discharge of sands to South Beach. Because of erosive beach conditions, the contractor was required to lay the pipeline in a dune re-vegetation area, resulting in minor damage that subsequently recovered (USACE 1998b). Pipeline placement near foredunes also is a concern for sediment management projects at Morro Bay (USACE 2001). Several protective measures have been used to minimize impacts when coastal dune and/or strand vegetation is present. Restriction of pipeline placement to avoid traversing of sand dunes was implemented during placement of maintenance dredged materials near Ventura Harbor (USACE 1998b). At Morro Bay, protective measures have included restriction of pipeline alignment and transportation corridors outside vegetated areas, whenever possible, and restriction against use of all-terrain vehicles by contractors (USACE 2001).

Maintenance dredging at Morro Bay involves use of pipelines to convey dredge materials to a beach placement site. During prior dredging operations, the use of aggregate materials (e.g., sand, gravel, concrete, etc.) to cushion pipelines was found to be detrimental to eelgrass; therefore, such use of aggregates was prohibited for the 2001 to 2007 maintenance dredging program (USACE 2001). Pre- and post-project eelgrass surveys for the area of pipeline placement, with mitigation of loss according to the Southern California Eelgrass Mitigation Policy were specified as an EFH conservation measure for 2001 to 2007 maintenance projects at Morro Bay).

Relevant studies of oil and gas operations indicate that pipeline placement in areas of hard bottom may result in crushing of sedentary organisms (Lissner et al. 1991). Similar effects would be expected in shallow, nearshore areas if sediment delivery pipelines were laid in areas with sensitive vegetated reefs, including surfgrass. Surfgrass is slow to recover when the rhizome mat is removed (Bull et al. 2004). In contrast, little potential for adverse impact may be expected in areas with cobble substrate and/or low relief with few biological resources. Pipeline placement would be expected to result in only temporary displacement of mobile fish and invertebrates capable of swimming over the pipe. Recovery rates of SAV and hard bottom areas from pipeline disturbance may be similar to that discussed above for anchoring impacts; i.e., associated with extent of damage and life history characteristics of species. Pre-construction surveys to finalize pipeline routes to avoid sensitive nearshore

reefs have been recommended and/or implemented prior to several sediment management projects in California (Chambers 1992, 2000b, AMEC 2002, Moffatt & Nichol 2005c).

Pipeline placement on subtidal, soft substrate habitat results in burial and disruption of associated organisms (Lissner et al. 1991). Pipeline placement and removal in sandy beach habitat would be expected to have temporary impact. Experimental studies of the removal of the upper 1 ft (0.3 m) of sand from the mid-intertidal zone resulted in a relatively rapid redistribution of sediment and temporary (two-week) reduction in abundance and biomass of dominant species (*Donax* clams) (Schoeman et al. 2000). Although no recovery rates with respect to pipeline placement and removal during sediment management activities were found with the literature review, recovery would be expected to be rapid for both shallow subtidal and sandy beach habitats given the localized nature of the impact and energetic receiving environment (e.g., beach, shallow subtidal) (Sections 4.2.6 and 4.2.7).

A primary concern of pipeline placement and/or removal at California beaches is the potential to impact threatened western snowy plover and/or endangered California least tern, if present. This is mainly a concern in areas with nesting activities. Pipeline placement and/or removal activities have the potential to damage eggs of threatened western snowy plover (Miller et al. 1999). Many tern nesting sites on California beaches are fenced; however, some nesting has been observed to occur outside the fenced area on some beaches (e.g., McGrath State Beach, Ventura) (USACE 1998b). A seasonal restriction on sand placement and scheduling of pipeline removal outside the nesting season has been specified for several California sediment management projects to protect snowy plover and/or California least tern nesting sites (e.g., USACE 1998a, 1998b, 2001). Similarly, seasonal restrictions on sand placement and scheduling pipeline removal outside the nesting season have been recommended to protect endangered piping plovers during beach nourishment activities on the East Coast of the United States (Melvin 2005).

Pipeline placement and/or removal outside the nesting season may result in temporary displacement of wildlife. Short-term displacement of threatened western snowy plovers was observed during pipeline installation and removal associated with sand placement on McGrath State Beach, Ventura, but was not considered significant (Worden and Smith 2004). Snowy plovers were observed to roost adjacent to the sand delivery pipeline at East Beach, Santa Barbara (USACE 1998a). Restriction of pipeline placement within relatively narrow corridors (e.g., 50 ft, 15 m) and minimizing positional changes of the pipeline have been used to minimize disturbance of snowy plovers during beach and/or surf-zone discharge activities (USACE 1994a, 1998a, USACE 1998b, USACE 2001).

During beach nourishment of a North Carolina beach, Reilly and Bellis (1983) initially thought pipeline placement along the backshore may have interfered with the nocturnal movement of ghost crabs between backshore burrows and tidal foraging areas; however, surveys instead found that ghost crabs were able to move over the pipeline because windblown sand functioned as natural bridges. Similar species of ghost crabs do not occur on California beaches, but small, talitrid amphipods similarly make nocturnal excursions from burrows near the foreshore-backshore boundary down the beach during low tides to feed on stranded vegetation (Thompson et al. 1993). Pipeline placement at or seaward of the foreshore-backshore boundary would have the potential to damage and/or interfere with movement of talitrid amphipods, if present. Presence of talitrid amphipods may relate to sand persistence. Talitrid amphipods were not observed under erosive conditions before

the 2001 San Diego Regional Beach Sand Project, but established on several San Diego beaches after beach nourishment (MEC 2000a, SAIC 2006).

5.3.2.6 Noise

Federal and state standards and local ordinances are used to control noise to limit human population exposure to damaging (physically and/or psychologically) and intrusive noise levels. Underwater noise thresholds have been developed for marine mammals. Limited threshold guidance has been developed to protect fish and coastal marine birds. Noise-related disturbance occasionally has been cited as justification for environmental windows for federal navigation projects (Reine et al. 1998, Dickerson et al. 2001). The following review of available information indicates that noise associated with sediment management activites is below levels that cause injury, but has the potential to disturb wildlife.

The type of sediment management activity will define the types of equipment and noise levels during construction. Depending on method of beach nourishment, equipment may be limited to trucks or may involve use of earth moving equipment and diesel engines to operate hydraulic pumps associated with pipeline delivery of source sediments. Dredges, barges, and/or other support vessels may be used to obtain source sands from offshore borrow sites and/or beneficial reuse sediments from embayments during maintenance or restoration projects.

Useful Online Noise References

- http://www.acousticecology.org/sciencereports.html
- http://www.nrdc.org/wildlife/marine/sound/contents.asp
- http://www.dosits.org/teacher/animalsound.htm
- http://www.nmfs.noaa.gov/pr/acoustics/bibliography.htm
- http://www.nmfs.noaa.gov/pr/acoustics/reports.htm

Noise Measurements

Sound is a pressure wave that is transmitted in air or water. Sound pressure level (SPL) is a logarithmic measure of the root mean square (rms) pressure (force/area) of a particular noise relative to a reference noise source, usually measured in decibels. The standard reference sound pressure at 1 meter is 20 micropascals (re 20 μPa) in air and 1 micropascal (re 1 μPa) in water (http://en.wikipedia.org/wiki/ Sound_pressure_level). Because decibels are measured on a logarithmic scale, a sound level of 70 dB is twice as loud as a sound of 60 dB (WSDOT 2006).

Values on land generally are reported according to the A-weighted decibel scale, which corrects sound pressure level in air to relative frequency of the human ear; that is, a de-emphasis on low and high frequency sounds inaudible to humans. Values underwater are not weighted and are reported as dB (re 1 μPa).

Sound levels differ between air and water due to pressure and physical differences between air and water as propagation media (Buck 1995, Popper 2003, WSDOT 2006). For the same source pressure at 3 ft (1 m), the underwater sound pressure level will be higher by 61.6 dB, due to the difference in reference levels (20 μPa vs 1 μPa = 26.0 dB difference), and the difference in acoustic impedance between air and water (3600 times = 35.6 dB difference) (http://en.wikipedia.org/wiki/Decibel). Conversion factors of 61 dB (Burk 1995, Popper 2003) or 62 dB (WSDOT 2006, http://www.pmel.noaa.gov/vents/acoustics/tutorial/8-

conversion.html) have been referenced for converting noise levels between air and water. For example, a sound level of 140 dB (re 20 μPa at 1m) in air would be 202 dB (re 1 μPa at 1 m) in water. Some references do not adjust for acoustic impedance, and only report a 26 dB difference in noise between air and water based on pressure difference (Jasny et al. 2005).

Sound levels will decrease with increasing distance from the source. Noise attenuation is affected by sound absorbing elements within the path of the sound (e.g., vegetation, suspended matter in water). On land, sound decreases by 3 (line source – e.g., traffic) to 6 (point source – e.g., single moving vehicle, stationary equipment) dBA for each doubling of distance (WSDOT 2006). Absorptive ground results in an additional noise reduction of 1.5 dB per doubling of distance (e.g., 4.5 to 7.5 dBA). Water is considered a reflective rather than absorptive surface (WSDOT 2006). Based on these considerations, a standard attenuation rate of 6 dBA per doubling of distance generally would apply to airborne noise from vessels and equipment used during sediment management projects.

In water, sound transmission loss is somewhere between 3 and 6 dB per doubling of distance, with approximately 4.5 dB per doubling of distance in nearshore waters (Vagle 2003 cited in WSDOT 2006). Suspended solids concentrations may have a pronounced sound-scattering effect. A suspended solid concentration of 20 mg/L was shown to cause attenuation of 3 dB over a path length of 328 ft (100 m) at 100 kHz (Richards et al. 1996 cited in Dickerson et al. 2001).

Noise Levels Associated with Sediment Management Compared to Other Activities

Noise levels of construction equipment may range from 68 to 115 dBA at 50 feet (15 m) (Table 5.3-1). A distance of 50 ft (15 m) is the standard reference distance for construction sound levels at the source (WSDOT 2006). Noise levels of earth moving and handling equipment (e.g., backhoes, bulldozers, compressors, cranes, front loaders, generators, graders, pumps, trucks) may range from 68 dBA to 97 dBA at 50 ft (15 m) using insulated cabs (Table 5.3-1). Average noise levels during beach nourishment have been estimated as 85 to 90 dBA (SANDAG and USDN 2000). Reported noise levels of dredges range from 76 to 88 dBA at 50 ft (15 m). Noise levels may range higher with marine construction projects involving use of pile drivers; e.g., up to 110 to 115 dBA at 50 ft (15 m).

In comparison, ambient noise levels at several beaches in San Diego, Los Angeles, and Santa Barbara, California ranged between 52 to 69 dBA (Chambers Group 1992, USACE 1999b, SANDAG and USDN 2000). Ambient noise levels may vary with human use, proximity to automobile traffic, proximity to surf, and aircraft overflights.

The intensity, periodicity, and spectra of emitted sounds differ greatly among dredge types (Clarke et al. 2003). Bucket dredges produce a repetitive sequence of sounds generated by winches, bucket impact with the substrate, bucket closing, and bucket emptying (Dickerson et al. 2001). Hopper dredge sounds also consist of a suite of sounds, including the relatively continuous engine and propeller noise similar to that of large commercial vessels, sounds at the dredge site of dragheads moving in contact with the substrate, and additional sounds at the discharge site of sediment release. In contrast, cutterhead dredges generate relatively continuous sounds as the cutterhead rotates while embedded in the substrate.

Underwater sound pressure levels produced by dredging operations are in relatively low frequency ranges, primarily 20 to 1,000 Hertz (Hz) for cutterhead bucket dredge (Dickerson et al. 2001) and 31.5 to 2kHz for hopper dredge (AES 2006).

Components of underwater sounds produced by each type are influenced by several factors, including substrate type, geomorphology of the waterway, site-specific hydrodynamic conditions, equipment maintenance status, and skill of the dredge plant operator (Dickerson et al. 2001, Clarke et al. 2003).

Table 5.3-1. Noise levels associated with operation of different types of construction and marine equipment.

Dredges and Construction Equipment	**Airborne Noise dBA at 50 ft (15 m)**	**Dredges and Other Marine Equipment**	**Underwater Noise dB** (re 1 μPa)
Clamshell dredge[2]	76	Large clamshell bucket dredge (sands) [3a]	99 to 124 (RMS) at 500 ft (150 m)
Bucket dredge[7]	75-88	Small clamshell bucket dredge (soft sediments) [3a]	107 (RMS) distance not reported
Hopper dredge, dredging[1]	82	Bucket dredge[3b]	150 to 162 distance not reported
Hopper dredge, discharging[1]	79	Barge loading[3a]	108.6 (RMS) at 500 ft (150 m)
Backhoe (average)*	72-90	Barge discharge[3a]	96 to 108.7 (RMS) at 1,035 ft (316 m)
Backhoe**	84-93	Trailing suction hopper dredge[4]	183 to 195 normalized at 3 ft (1 m)
Bulldozer **	85 -103	Trailing suction hopper dredge[4]	162 to 175 normalized at 33 ft (10 m)
Compressor (average)*	73-88	Trailing suction hopper dredge[4]	142 to 155 normalized at 328 ft (100 m)
Crane (average)*	74-89	**Other Marine Equipment**	
Crane **	90 - 102	Vessel Traffic (ambient)*	130 (peak)
Excavator (average)*	81-97	Ferry Terminal*	131-136 (peak)
Front loader (average)*	72-90	Cable laying[5]	160 at 800 ft (244 m)
Front-end loader**	86-94	Sonar devices*	150 to 215 distance not reported
Generator (average)*	71-82	Pile driving[6]	177 to 220 (peak) at 33 ft (10 m)
Grader (average)*	79-93		
Heavy trucks (average)*	82-96		
Pile driver (peak)*	81-115		
Pumps (average)*	68-80		
Roller (average)*	72-75		

Sources:
Construction equipment: WSDOT 2006*, http://www.cdc.gov/elcosh/docs/d0500/d000573/d000573.html**
Dredges (dBA) = Chambers Group 1992[1], Helix cited in Chambers Group 2000[2], Boeing 2005[7]
Dredges and other marine equipment (dB re 1 μPa) = Dickerson et al. 2001[3a], Miles et al. 1986 and 1987 cited in Dickerson et al. 2001[3b], Bassett Acoustics 2005[4], City of Pittsburg 2005[5], Hastings and Popper 2005[6]
Note: Underwater noise values may be referenced as peak, RMS, or either of these reference levels may not be reported.

Underwater sound pressure levels reported during dredging operations range from 99 to 195 dB (re re 1 μPa) depending on equipment and distance from the source (Table 5.3-1). Underwater noise levels often are not referenced to a standard distance in the literature; therefore, distances associated with underwater noise measurements vary in Table 5.3-1. Also reports vary as to whether values are reported as peak sound pressures ($_{peak}$) or the root mean square pressure level ($_{RMS}$). Values are reported in Table 5.3-1 according to the source reference. A general rule of thumb to convert dB_{RMS} levels to dB_{peak} noise levels is to add 20 dB, and to convert from dB_{peak} to dB_{RMS}, subtract 10 dB (WSDOT 2006).

Underwater sound pressure levels of 99 to 124 dB_{RMS} (re 1 μPa-m) were measured at approximately 500 ft (150 m) of the source during clamshell bucket dredging in Cook Inlet, Alaska (Table 5.3-1). This represents 111 to 148 dB_{RMS} (re 1 μPa-m) at 33 ft (10 m) based on loss of 3 to 6 dB per doubling distance. Noise levels were 11.6 dB_{RMS} (re 1 μPa-m) louder when dredging sands than soft sediments at a distance of 1,821 ft (555 m) (Dickerson et al. 2001). Values of 150 to 162 dB (re 1 μPa-m) with the most intense sounds in the 1/3 octave at 250 Hz were reported during bucket dredging in the Beaufort Sea (Miles et al. 1986, 1987 cited in Dickerson et al. 2001).

Underwater noise levels during dredge operations using a trailing suction hopper dredge in the Port of Melbourne, Australia ranged from 183 to 195 dB (re 1 μPa) when normalized to a distance of 3 ft (1 m), 162 to 175 (re 1 μPa) when normalized to a distance of 33 ft (10 m), and 142 to 155 dB (re 1 μPa) when normalized to 328 ft (100 m) (Bassett Acoustics 2005). AES (2006) reported similar noise levels of 188 to 190 dB (re 1 μPa) at 3 ft (1 m) for hopper dredge operations in different areas of Port Melbourne and Port Phillip Bay, Australia. AES (2006) concluded that underwater noise levels beyond 328 ft (100 m) were below thresholds where “very long” exposure to continuous noise might result in a Temporary Threshold Shift (TTS) in marine mammals and disturbance impacts to fish would be in close range of approximately 164 ft (50 m) of the dredge.

In summary, underwater noise levels during dredging may range between 111 and 175 dB (re 1 μPa) at 33 ft (10 m) depending on dredge type. Underwater noise levels during barge loading and/or discharge may range between 96 and 108.7 dB (re 1 μPa) at distances ranging from 500 to 1,035 ft (150 to 316 m) (Table 5.3-1), which represents 111 to 139 dB (re 1 μPa) at 33 ft (10 m) based on loss of 3 to 6 dB per doubling distance.

Cable laying activities and pile driving generally produce louder underwater noise levels at comparable distances. For example, underwater noise associated with laying cable would be expected to be > 170 dB at 33 ft (10 m) based on a reported value of 160 dB at a distance of 800 ft (244 m) (City of Pittsburg 2005). Pile driving produces noise levels of 177 to 220 dB (re 1 μPa) at 33 ft (10 m) depending on material and size of piles (Hastings and Popper 2005). In contrast, commercial sonar devices produce relatively loud (150 to 215 dB re 1 μPa) noise levels at high frequencies (15 to 200 kHz) (Stocker 2002 cited in WSDOT 2006).

Ambient underwater noise levels vary depending on a number of factors including wind, waves, bathymetry, precipitation, and other noise sources (e.g., vessel traffic). Ambient levels of 74 to 100 dB_{peak} (re 1 μPa) were reported off the coast of central California (Heathershaw et al. 2001 cited in WSDOT 2006). Average levels of 88 dB (re 1 μPa) in the 100 to 200 Hz frequency range have been reported off southern California; values were not referenced as $_{peak}$ or $_{RMS}$ (Andrew et al. 2002). Ambient noise levels in Cook Inlet, Alaska averaged 60 dB (re 1 μPa-m) at frequencies < 100 Hz and averaged around the mid-50 dB

(re 1 μPa-m) level at frequencies ranging from 100 Hz to 1 kHz; peak ambient noise occurred at 73.2 dB (re 1 μPa-m) (Dickerson et al. 2001).

Ambient levels in port embayments may range higher; for example, values between 80 and 90 dB (re 1 μPa) were measured at Everett Home Port, 130 dB_{peak} (re 1 μPa) occur in Puget Sound, 115 to 135 dB_{RMS} (re 1 μPa) occur in Hood Canal, 145 dB_{peak} (re 1 μPa) was measured at the Mukilteo ferry terminal, and 131 to 136 dB_{peak} (re 1 μPa) were measured in the vicinity of the Friday Harbor ferry terminal (WSDOT 2006).

Noise impact assessments consider project-related noise levels relative to noise thresholds and/or deviation from ambient conditions. Generally, noise levels above 70 dBA produce the following human responses: 80 to 90 dBA (annoying), 100 dBA (very loud), 110 to 120 dBA (extremely loud), 130 to 140 dBA (painfully loud), and 180 dBA (irreversible hearing loss) (WSDOT 2006). Duration of noise also influences hearing effect. For example, exposure to 90 dBA over a short duration is considered very annoying; however, hearing damage to the human ear may occur after 8 hours of continuous exposure.

Effects of Noise on Wildlife

Available information indicates that sounds produced during sediment management activities are within the auditory range of wildlife. Generally, values are below levels known to result in injury and/or mortality, but may disturb fish, birds, and marine mammals. Disturbance may include temporary hearing loss (temporary threshold shift – TTS), interference with hearing (masking), and/or change in behavior or movement (Dickerson et al. 2001, Finneran et al. 2005, Popper et al. 2006). Reviews identify that more data are needed to understand noise effects on wildlife, particularly indirect and cumulative impacts (Richardson et al. 1995, Popper 2003, Hastings and Popper 2005, Popper et al. 2006). Several online sources of information provide background on the state of current knowledge of acoustic effects on wildlife.

Invertebrates

Limited information is available on sound and/or vibration perception and response of invertebrates. Popper et al. (2001) reviewed that several decapod crustaceans produce sounds, and many are able to detect substrate vibration at sensitivities sufficient to detect proximity of mates, competitors, or predators (e.g., semi-terrestrial crabs produce and use sounds for communication and snapping shrimps and spiny lobster produce sounds). Patches of sand crabs have been observed to move from approach by humans, suggesting sensitivity to vibration (K. Green, personal observation). Some species of *Donax* clams are sensitive to vibration (Morris et al. 1980).

Hastings and Popper (2005) noted a study demonstrating that increased noise (30 dB above ambient) exposure for a three-month period decreased growth and reproductive rates of sand shrimp (*Crangon crangon*), and changes in physiology continued for up to a month following cessation of the additional noise (cited Legardère 1982, Legardère and Régnault 1980).

Squid exhibit startle response at 174 dB (firing of ink sacks, avoidance behavior) from instantaneous impact noise, disturbance response (increased swimming speed) at 156 dB (re 1 μPa) for a ramped noise, and an estimated annoyance sensitivity of perhaps 144 dB (re 1 μPa) (Stocker 2001).

Fish

Relevant studies demonstrate noise may influence the behavior of fish, which use sound for social interaction, detection of prey and/or predators, and as cue for larval settlement (Suzuki et al. 1980, Wilson et al. 2003, Hastings and Popper 2005, Montgomery et al. 2006). Fish may be grouped into two types, hearing specialists and hearing generalists (reviewed in Popper 2004). Hearing specialists have special adaptations that enhance their hearing bandwidth and sensitivity. Pacific Coast fishes that are known hearing specialists are the sardine and related species (e.g., herrings, shads, menhaden, anchovies) (Hastings and Popper 2005). Hearing specialists may detect signals up to 3,000 to 4,000 Hz, with thresholds that are 20 dB or more lower than the generalists (*ibid.*). Pacific and Atlantic herring produce broadband pulses of 1.7 to 22 kHz, most above 2 kHz; the repetitive nature of the sounds suggest social mediation (e.g., contact calls) facilitating detection and school formation (Wilson et al. 2003).

The majority of native fishes on the Pacific Coast are hearing generalists (Popper 2003, Hastings and Popper 2005). The following references (cited in Hastings and Popper 2005) provide representative sound detection ranges for different types of hearing generalists.

- Salmonids - Atlantic salmon (*Salmo salar*) can detect sounds to frequencies somewhat above 600 Hz (Hawkins and Johnstone 1978), while more recent data show that *Salmo* are also able to detect sounds to well below 20 Hz (Knudsen et al. 1992, 1994).
- Pelagic schooling fish (e.g., mackerel) - the Japanese horse mackerel (*Trachurus japonicus*) may detect sounds from 70 to 3,000 Hz (Chung et al. 1995).
- Bottom-dwelling demersal fish (e.g., flatfish) – limited data suggest poor hearing sensitivity. Plaice (*Pleuronectes platessa*) is able to detect sounds at frequencies up to 200 Hz (Chapman and Sand 1974), marbled sole (*Pleuronectes yokohamae*) can detect sounds to 1,000 Hz with lowest thresholds at around 300 Hz (Zang et al. 1998).
- Sharks and rays - probably do not detect sounds at frequencies above 800 to 1,000 Hz (e.g., Banner 1967, Nelson 1967, Myrberg 2001, Casper et al. 2003).

Impact thresholds for fish mainly have been developed to manage pile driving activities. Thresholds of 180 dB_{PEAK} and 150 dB_{RMS}, which were originally recommended for protecting salmon have been generally adopted (WSDOT 2006). For example, a sound pressure level of 180 dB_{peak} (re 1 μPa) is used to define the threshold for fish injury (http://mapping.orr.noaa.gov/website/portal/pies/piledriving.html,).

A similar critical trigger point and threshold of 155 dB (re 1 μPa) at 328 ft (100 m) is specified in the Environmental Management Plan (EMP) for Melbourne, Australia (Bassett Acoustics 2005). This represenets a noise level of 176 dB (re 1 μPa) at 33 ft (10 m) based on a 6 dB loss per doubling distance, which was the loss rate reported for noise levels normalized to different distances.

Popper et al. (2006) reviewed that the scientific basis for the 180 dB threshold is obscure, and instead recommended use of a combined interim single strike criterion for pile driving that considers both peak sound pressure and sound exposure level (SEL) with

measurements made at a standard distance (33 ft, 10 m) from the source to determine whether signals exceed the following criteria:

- 208 dB dB_{peak} (re 1 μPa) at 33 ft (10 m) from the source and an SEL level of 187 dB (re 1 μPa-s).

WSDOT (2006) stated that the above recommended threshold has not yet been adopted by the USFWS.

Continuous, long-term exposure to levels > 180 dB (re 1 μPa) has been shown to cause damage to the hair cells of the ears of some fishes under some circumstances (Popper 2003, Hastings and Popper 2005). Hastings and Popper (2005) reviewed that injury from pile driving varied with fish size and noted the lowest threshold for injury was > 193 dB (re 1 μPa-s) for the smallest fish (0.01 g).

Sound exposure levels of 180 dB (re 1 μPa-s) may result in temporary hearing loss (temporary threshold shift – TSS), levels as high as 160 dB (re 1 μPa) may cause fish to change their behaviors, and sound levels as low as 60 to 80 dB (re 1 μPa) may mask sounds normally used by fishes (Hammer et al. 2005, Popper et al. 2005). Hammer et al. (2005) referenced that changes in noise levels may affect feeding and reproductive activities of reef fishes that depend on sound for these activities (Stobutzki and Bellwood 1998, Tolimieri et al. 2000) and may affect larval settlement of reef fishes (Myrberg and Fuiman 2002, Montgomery et al. 2006).

Suzuki et al. (1980) indicated that large and/or high speed vessels can frighten fish schools or cause them to change their migration routes. Pacific and Atlantic herring exhibit “startle” or “start” response to noise stimuli (LFR 2004).

Reef fish have been observed to briefly scatter as boats go over a reef (Ebeling, personal communication cited in Chambers Group 1992 and USACE 1994a). Hastings and Popper (2005) reviewed a study (Wardle et al. 2001) where a video system was used to examine the behaviors of fish and invertebrates on a coral reef in response to emissions from seismic air guns (210 dB re 1 μPa to 195 dB re 1 μPa) at 52 to 358 ft (16 to 109 m) from the source, repectively. They found no damage, permanent changes in the behavior of the fish or invertebrates, and no animals appeared to leave the reef.

WSDOT (2006) reviewed that most audiograms of fishes indicate a low threshold (high sensitivity) to sounds within 100 Hz to 2 kHz range. Thus, most fishes would be expected to detect the low frequency sounds (e.g., 20 to 2 kHz) associated with dredging operations. Based on noise values in Table 5.3-1, fish would not be expected to be injured at noise levels associated with dredging or discharge, but have the potential to be disturbed and/or displaced at close distances. Noise levels would be expected to be less than salmonid disturbance levels at distances of approximately 328 ft (100 m) for hopper dredges and at distances closer than that for clamshell or cutterhead dredges. Dredging would not be expected to interfere with high frequency sound detection by hearing specialists.

Duration of disturbance may vary depending on project type, size, and locaton. For example, Hammer et al. (2005) stated that effects of dredging noise on fish populations should be minimal due to the short duration of most projects. Exposure duration also would vary among different dredge types based on discontinuous or continuous operating characteristics (Section 5.3.1). The mobile nature of water-column and demersal fish also would tend to decrease noise exposure duration. However, fish exhibiting high site fidelity

(e.g., reef fish, fish in SAV nursery areas) have the potential to experience relatively longer duration noise exposure from dredging operations depending on proximity to the source and project duration. This would be more of an issue for fixed location rather than mobile dredging operations.

It has been hypothesized that dredging-induced noise could block or delay the migration of fishes through navigable waterways (Dickerson et al. 2001). However, no data are available with respect to sound thresholds that elicit behaviors such as swimming away from feeding or reproductive areas, changing migration routes, etc. (Hastings and Popper 2005).

Birds

There are few data on hearing in shorebirds and seabirds. Studies with other species indicate that birds are sensitive to low frequency sounds in air; however, there is no evidence that seabirds use underwater sound (USDN 2001).

Birds may display startle responses to loud bursts of sound, but may become habituated to continuous or recurring sound. For example, dredge start-up and/or illumination after lengthy periods of inactivity resulted in a temporary (few minutes) shift in position and/or flushing of roosting California brown pelicans within 270 ft (80 m) of dredging in Marina del Rey Harbor, Los Angeles County (Varanus 1999). In contrast, little reaction was observed for pelicans within 328 ft (100 m) of heavy equipment operation and rip-rap installation at Mugu Lagoon, Ventura County (Jaques et al. 1996). Snowy plovers were observed foraging adjacent, but outside immediate areas where dredging and/or discharge activities were occurring (Chambers Group 2001, 2005). Noise activities during beach nourishment appeared to have minor influence on shorebirds (sandpipers, godwits, curlews) at receiver sites during the 2001 San Diego Regional Beach Sand Project (AMEC 2002).

Elevated noise levels have the potential to interfere with breeding activities of sensitive bird species. There are no specific noise standards set by the USFWS for endangered California least tern or threatened western snowy plovery nesting sites (L. Hays, USFWS, personal communication cited in SANDAG and USDN 2000). A noise level of 60 dBA or exceeding the existing ambient level if already above 60 dBA is used as a significance threshold in San Diego County, California for breeding sites of sensitive terrestrial bird species and western snowy plover (City of San Diego 2007). For example, noise exceedances relative to ambient levels were used to determine impact significance for sensitive coastal bird species associated with the 2001 San Diego Regional Beach Sand Project because noise levels from waves exceeded 60 dBA (e.g., SANDAG and USDN 2000).

Impact guidance thresholds were developed for murrelets (diving seabird) as part of the USFWS biological opinion for the Olympic National Forest program of activities, as follows (WSDOT 2006):

- Terrestrial sound-only injury threshold (defined as adult flushed from nest and young missing a feeding) – 92 dB.
- Terrestrial sound-only disturbance threshold (defined as avoidance, defending itself, moving wings or body, or postponing a feeding) – 70 dB for disturbance.
- Undewater sound-only disturbance threshold (defined as interference with foraging) – 153 $dB_{rms.}$

Marine Mammals

Considerable research has been conducted on human-induced sound effects on marine mammals. Noises have caused strandings and mortality or injury, temporary hearing loss, interference sound masking, and behavior changes. Some studies suggest that marine mammals tend to become adapted to steady noise sources, but may be startled by sudden sounds (Richardson et al. 1995).

Currently, NMFS is evaluating revision of the following underwater noise exposure criteria for marine mammals (Federal Register 2005):

- Level A harassment (potential to injure) - a received sound pressure level at or above 180 dB_{rms} (re 1 μPa).
- Level B (potential to disturb) harassment - 160 dB_{rms} (re 1 μPa) for impulse noise and 120 dB_{rms} (re 1 μPa) for continuous noise.

Based on the above criteria and the noise values in Table 5.3-1, marine mammals have the potential to be disturbed by noises associated with dredges and/or support vessels. Available information suggests that noises during dredging operations are below Level A harassment levels at distances beyond 3 ft (1 m) from the source. Dredges produce noise levels within Level B harassment levels near the source, but may attenuate below harassment levels at distances beyond 500 ft (150 m) from the source for bucket dredges, barge loading, and discharge operations based on application of loss rates of 3 to 6 dB per doubling distance to values in Table 5.3-1. Distances > 3,281 (> 1,000 m) may be required before noise levels of trailing suction dredges are below harassment levels based on available reports (Table 5.3-1).

Acoustic signaling is important to communication, food finding, navigation, and predator detection in cetaceans (Chambers Group 1992). Vessels are major contributors to overall background noise in the sea, with sound levels and frequency characteristics roughly related to ship size and speed (Richardson et al. 1995). Although numerous reports demonstrate the sensitivity of whales to sound, there also are records when whales seem oblivious to vessel sound. Laist et al. (2001) reviewed that whales may be less responsive to sound when sleeping, actively feeding, and/or have difficulty in locating approaching vessels due to underwater sound reflections, confusion from the sound of multiple vessels, hull blockage of engine and propeller noise in front of vessels, and a phenomenon known as the Lloyd mirror effect which reduces sound levels at the surface where resting or feeding whales may occur.

Richardson et al. (1995) reviewed that whales may be able to detect dredge noises above background noise levels as far away as 12 to 15.5 mi (20 to 25 km). Whale response may differ depending on whether the noise is stationary or associated with a moving vessel. Beluga whales showed less reaction to stationary dredges than to moving barges despite similarities in their sounds; the whales approached to within 1,312 ft (400 m) of the dredge. Bowhead whales within 0.5 mi (0.8 km) of dredging stopped feeding and moved more than 1.2 mi (2 km) away; however, bowheads also appeared to behave normally where dredging was occurring.

Finneran et al. (2005) reviewed that sound pressure levels necessary to induce measurable amounts (6 dB or more) of TTS in bottlenose dolphins and beluga whales were between 192 and 201 dB_{rms} (re 1 μPa) at frequencies of 3, 10, and 20 kHz, and suggested that a SEL of 195 dB (re $\mu Pa^2 s$) is a reasonable threshold for onset of TTS in dolphins and white whales

exposed to mid-frequency tones. Studies show that onset of TTS may occur at lower sound pressures when exposure duration is longer. For example, TTS in bottlenose dolphins has been measured at sound pressure levels of 160 dB_{rms} (re 1 μPa) and 30 to 50 minute exposures (Nachtigall et al. 2003, 2004 cited in Finneran et al. 2005).

Pinnipeds appear to have greater tolerance to noise levels than cetaceans. Kastelein et al. (2006) demonstrated that captive seals avoid zones where the sound pressure levels were louder than 107 dB_{rms} (re 1 μPa), but noted that it is possible that in the wild, seals may tolerate higher levels, in order to get food, escape predators, or stay with a pup. Finneran et al. (2003) found no measurable TTS at sound pressure levels up to 178 to 183 dB (re 1 μPa) for California sea lions. Kastak et al. (2005) measured TSS in California sea lion, harbor seal, and northern elephant seal at sound pressure levels of over periods of 25 to 50 minutes. Increasing the exposure duration from 25 to 50 minutes had a greater effect on threshold shifts than increasing the exposure level from 80 SL (137 to 159 dB_{rms} re 1 μPa) to 95 dB SL (152 to 174 dB_{rms} re 1 μPa); SELs resulting in TTS onset ranged from about 183 to 206 dB (re 1 μPa^2 s). Kastak et al. (1996) reported TSS in California sea lions exposed to airborne noise from nearby construction.

No information on noise response levels and/or effects on sea otters were identified from the literature review.

5.3.2.7 Artificial Lighting

Sediment management projects may require use of lights if work schedule includes night operations. Artificial lighting may affect wildlife behavior and result in the following types of impacts:

- Attraction.
- Avoidance.
- Increased movement.
- Delayed migration.
- Increased predation.
- Reduced foraging efficiency.

Several studies have shown that artificial lights may affect the behavior of coastal species. Visual predators such as large fishes, birds, and marine mammals, have been observed to concentrate foraging on schooling fishes around lighted vessels, presumably because the light illuminates their prey (DFG 2003b, N. Davis, personal observation). Nightengale and Simenstad (2002) reported that night lighting attracted juvenile herring and lances, which were reduced in abundance by attraction of their predators. They also reported observations of predators taking advantage of lighting at fish ladders, spillways and bridges to prey on migrating salmon.

Calfiornia grunion response to artificial lighting appears to vary with life stage. Grunion eggs exhibit reduced hatching success when exposed to light (Hubbs 1965). Juvenile California grunion are attracted to artificial light as bright as 10,000 lux (Reynolds et al. 1977). No scientific studies of effects of artificial lights on spawning behavior of adults were identified

from the literature review. Anecdotal observations are inconclusive. SWRCB (1979) reported that beach lighting appeared to reduce grunion spawning near Scripps Pier, San Diego County. However, grunion runs have been observed in lighted areas near the Pacific Beach Pier, San Diego County (D. Heilprin, 2006 personal communication), Huntington Beach Pier in Orange County (K. Green, personal observation), and in a well lighted area near Sterns Wharf in Santa Barbara (USACE 1993). Steady light sources do not appear to be a deterent, but moving lights (e.g., flashlights) may affect grunion spawning behavior (K. Martin, 2007 personal communication).

Nemeth and Anderson (1992) demonstrated that Chinook and Coho salmon generally are passive at night, but either increase swimming (Chinook) or hide (Coho) in response to strobe lights and/or high-intensity mercury vapor lights, although Chinook salmon display attraction to dim mercury lights. Juvenile chum salmon and larger predators (e.g., hake, dogfish, sculpin, large Chinook and Coho salmon) have been observed to congregate beneath night security lights, with attraction of juveniles potentially delaying outmigration (Nightengale and Simenstad 2002). Atlantic salmon smolts mainly migrate at night, but may exhibit attraction to night lighting while avoiding the point source (e.g., strobe, mercury vapor lights (Larinier and Boyer-Bernard 1991). Nightengale and Simenstad (2002) reviewed that additional study was warranted (due to the limited number of available studies and study limitations) to identify the extent of fish distribution changes, changes in species abundance and/or dominance resulting from increased prey access, and/or real harm posed to fish as a result of artificial night lighting.

Gulls are opportunistic scavengers that may be attracted to vessel lights and lighted beach areas. Artificial lighting is of concern near least tern and snowy plover bird nesting colonies because of the potential for increased gull predation (DFG 2003b). Nocera et al. (1996) documented nocturnal predation by great black-backed gulls (*Larus marinus*) on eggs and chicks of common terns (*Sterna hirundo*) at a restored tern colony on the coast of southern Maine during moderate to low nocturnal light conditions. Keitt et al. (2004) observed increased nocturnal activity of shearwaters in areas exposed to anthropogenic light sources, presumably to reduce predation effects of western gulls. They hypothesized that artificial lighting at nesting colonies could affect seabirds in two ways: (1) increased predation on young, and/or (2) altered behavior resulting in decreased foraging efficiency and ability to feed chicks.

Podolsky (2002) reviewed that artificial lighting may attract and/or disorient seabirds moving between urban resting/nesting sites and forage locations at sea. Artificial lighting has been implicated in reports of seabird collisions and/or increased mortality at artificial structures such as offshore oil rigs, buildings, and transmission towers. Some of those reports have limited relevance to sediment management projects. Varanus (1999) reported that a sudden change in night lighting (i.e., spotlighting from boat, dredge illumination after inactivity) resulted in displacement of California brown pelican roosting on a breakwater in Marina del Rey, California.

Artificial lighting may affect terrestrial species that forage in beach habitats. For example, Bird et al. (2004) found that Santa Rosa beach mice (*Peromyscus polionotus leucocephalus*) exploited fewer food patches and harvested fewer seeds near artificial lights.

Avoidance and/or minimization measures may be employed to reduce artificial lighting effects in areas with sensitive habitats and/or resources (Section 6).

5.3.2.8 Accidental Leaks and Discharges

Minor oil spills and/or leaks from dredges, vessels, vehicles, and equipment used during coastal sediment management projects have the potential to adversely affect water quality and/or habitats.

Leaks and/or breakage of sediment delivery pipelines could result in discharge of sands in sensitive habitats, if present along the pipeline route. Sand release also could occur in the event of accidental collision with a hopper dredge and/or dredge barge. The significance of accidental sand release would depend on existing conditions, with the potential for significant impact if the release occurred onto sensitive reef and/or SAV habitats (Chambers Group 1992). Accidental sand release also would be of concern in commercially important spawning grounds.

Accidential fuel release potentially could occur from equipment operation and/or vessel collision. Chambers Group (1992) reported that forty to fifty thousand gallons of fuel could be spilled from a hopper dredge with a catastrophic collision. Typically, accidental discharges are controlled with best management practices and/or a spill prevention plan, with discharges regulated by water quality 401 certification requirements (Section 5.5). Furthermore, the potential for collisions generally is reduced to insignificant by use of notices to mariners of dredge vessel activity areas and schedule (e.g., Chambers Group 1992, SANDAG and USDN 2000).

5.3.3 Equipment Impacts to Habitats

Potential equipment related impacts are summarized below for each of the ten reviewed coastal habitats, which are organized under umbrella headings according to habitat categories; i.e., coastal dune and/or strand, soft substrate, hard substrate, submerged aquatic vegetation, and embayments.

Tables 5.3-2 and 5.3-3 summarize potential equipment impacts to habitats and associated species. Separate summaries are given for potential impacts associated with beach nourishment (including sediment delivery pipeline routes) (Table 5.3-2) and dredging related activities (Table 5.3-3). At the end of each table is a list of issues considered relevant to potential impact occurrence and/or its relative significance. These issues include considerations associated with habitat suitability, beach morphododynamics, sensitive species, fisheries, season, proximity to nesting sites and/or spawning grounds, and migration routes. Follwing the tables are the summaries of potential impacts to habitats. The habitat summaries reference impact concerns for species associated with equipment use; however, more detailed summaries by type of species are given in Section 5.3.4.

5.3.3.1 Coastal Dune and/or Strand

Potential equipment impacts to the habitat will vary depending on existing conditions, which may range from lower to increasing sensitivity, as follows:

- Unvegetated backshore and dune.
- Limited backshore with coastal strand vegetation transitiong to cliff or urban land.
- Backshore with coastal strand transitioning to dunes.

Table 5.3-2. Potential equipment impact concerns to habitats and species from beach nourishment activities.

	Vehicles	Beach Scraping	Sand Delivery Pipelines	Noise	Beach Lights	Reduce Forage
Habitats						
Coastal Dunes and/or Strand	X	X	X			
Sandy Beaches	X	X	X			
Sandy Subtidal			X			
Rocky Intertidal			X			
Rocky Subtidal			X			
Kelp Beds			X			
Eelgrass Beds			X			
Surfgrass Beds			X			
Shallow Inlet Embayments			X			
Deepwater Inlet Embayments			X			
Species						
Abalone			X			
California Lobster			X	X		
Dungeness Crab			X	X		
Pismo Clam		X	X			
Soft substrate Invertebrates	X	X	X	?		X
Hard bottom Invertebrates			X			
California Grunion	Eggs	Eggs	Eggs	?	?	
Pacific Herring						
Salmonids						
Demersal Fish		X	X	X		X
Pelagic Fish			X	X		
Reef Fish			X	X		
Tidepool Fish			X	X		
California Brown Pelican	X		X	X	X	
California Least Tern	X	X		X	X	
Western Snowy Plover	X	X	X	X	X	X
Shorebirds	X	X	X	X	X	X
Gulls, Terns	X	Gulls	X	X	X	Gulls
Wading Birds	X		X	X		
Waterfowl	X		X	X		
Cetaceans						
Pinnipeds	X		X	X	X	
Sea Otters						
Potential impact issues of Concern						
Habitat Suitability		X				X
Beach Morphodynamics		X				X
T&E Species	X	X	X	X	X	X
Fisheries	X	X	X			
Season	X	X	X	X	X	X
Proximity to Nesting Site	X	X	X	X	X	
Proximity to Spawning Ground	X	X		?	?	
Migration Route						

Note: Blank entries indicate no equipment use impact concerns.

Table 5.3-3. Potential equipment impacts to habitats and species from dredging and sand delivery activities.

	Dredge	Entrain	Vessel /Prop	Anchor	Noise	Dredge Vessel Lights	Reduce Forage
Habitats							
Coastal Dunes and/or Strand							
Sandy Beaches							
Sandy Subtidal	X			X			
Rocky Intertidal							
Rocky Subtidal				X			
Kelp Beds	X		X	X			
Eelgrass Beds	X		X	X			
Surfgrass Beds				X			
Shallow Inlet Embayments	X			X			
Deepwater Inlet Embayments	X			X			
Species							
Abalone				X			
California Lobster				X	X		
Dungeness Crab	X	X		X	X		
Pismo Clam	X			X			
Soft substrate Invertebrates	X			X	X		X
Hard bottom Invertebrates				X	X		
California Grunion				X	X	X	
Pacific Herring	Eggs	X		Eggs	X	X	
Salmonids		X			X	X	
Demersal Fish	X	X		X	X		X
Pelagic Fish		X			X	X	
Reef Fish				X	X		
Tidepool Fish							
California Brown Pelican					X	X	
California Least Tern					X	X	
Western Snowy Plover					X	X	
Shorebirds							
Gulls, Terns					X	X	
Wading Birds					X	X	
Waterfowl	X		X		X		X
Cetaceans	X		X		X		
Pinnipeds	X		X		X	X	X
Sea Otters	X		X		X		X
Potential impact Issues of Concern							
Habitat Suitability							
Beach Morphodynamics							
T&E Species	X		X		X	X	X
Fisheries	X	X		X	X		X
Season	X	X		X	X	X	
Proximity to Nesting Site	X		X		X	X	
Proximity to Spawning Ground	X	X		X	X		X
Migration Route	X		X		X	X	

Note: Blank entries indicate no equipment use impact concerns.

Vehicle use, sand delivery pipeline placement/removal, and/or staging activities on the beach backshore have the potential to result in direct damage and/or removal of coastal strand vegetation, if present. Coastal strand vegetation may consist of non-native and/or native vegetation. Native coastal strand vegetation is designated as rare in California and impacts resulting in loss would be significant. Impacts to non-native vegetation also may be of concern if loss resulted in dune destabilization, which could lead to increased shoreline erosion (SNH 2000, Brooks and Agate 2001, Dahm et al. 2005).

Impact to coastal strand vegetation during beach nourishment has been documented and other relevant reports document sensitivity to damage:

- Hydraulic pipeline placement resulting in damage to coastal strand vegetation (USACE 1998b).
- Vehicle and/or trampling damage (Brodhead and Godfrey 1977, Hosier and Eaton 1980, Rickard et al. 1994, Stephenson 1999).

Recovery of coastal strand vegetation after disturbance will depend on extent of damage.

- Minor damage to coastal strand vegetation may recover within one season (Dahm et al. 2005).
- Extensive damage to dune vegetation may take years to recover if at all (Stephenson 1999, Dahm et al. 2005).
- The feasibility of restoration of coastal strand habitat has been demonstrated (CNPS 1996, Pickart and Sawyer 1998, Brooks and Agate 2001, Dahm et al. 2005).

Other equipment use concerns may include the following types of impacts to wildlife, if present, and depending on project activities.

- Vehicle crushing of early life stages (eggs, chicks) of sensitive bird species.
- Noise and/or activity related disturbance displacement of sensitive bird species during breeding/nesting season.
- Disturbance displacement of non-breeding western snowy plover, gulls, shorebirds, and/or other birds.
- Damage and/or disturbance of sensitive terrestrial insects (e.g., globose dune beetle).
- Light attraction of predators to nest sites of sensitive bird species.

Potential equipment impacts to other sensitive birds are summarized further in Section 5.3.4.3. Potential damage and/or disturbance to sensitive terrestrial wildlife will depend on existing conditions. Avoidance of construction activities in vegetated areas will minimize the potential for significant impacts to sensitive terrestrial insects such as globose dune beetle (USACE 2001).

Seasonal constraints may occur at beaches within and/or adjacent to designated Critical Habitat for snowy plovers and/or with nearby nesting sites for Calfiornia least tern.

5.3.3.2 Soft Substrate

Sandy Beach

Equipment use on the beach has the potential to result in disturbance and/or compaction of sand, which is a temporary impact consideration.

Equipment use has the potential to result in the following types of direct and indirect impacts to wildlife, if present.

- Vehicle crushing and/or removal of invertebrates with reduction of invertebrate forage base for birds and surf zone fish.
- Vehicle crushing of eggs of California grunion.
- Vehicle crushing of early life stages (eggs, chicks) of sensitive bird species.
- Pipeline burial and disruption of benthic invertebrates.
- Activity and/or noise related disturbance displacement during the breeding/nesting season of western snowy plover (March-September) and/or California least tern (April-September).
- Light attraction of predators to nearby nest sites of sensitive bird species.
- Disturbance displacement of non-breeding western snowy plover, California brown pelican, gulls, shorebirds, and other birds.
- Disturbance displacement of pinnipeds.

Impact to sandy beach habitat from equipment use largely depends on response of associated organisms. Potential equipment impacts to wildlife and recovery rates are summarized further in Sections 5.3.5.1 (invertebrates), Section 5.3.5.2 (fish), Section 5.3.5.3 (birds), and Section 5.3.5.4 (marine mammals). Impacts to sandy beach habitat during beach nourishment have been documented with many studies, although most have addressed invertebrate community recovery (Section 3.3.2, Section 4.2.6).

Equipment impacts do not result in loss of sandy beach habitat; therefore, impacts to habitat are temporary and do not extend much beyond the construction period. Potential equipment impacts to sandy beach resources may vary depending on existing conditions and project schedule. Beach morphodynamics influence sand persistence and biological resource development (Hesp and Short 1982, Wright and Short 1982, McArdle and McLachlan 1992, Brown and McLachlan 2002).

- Dissipative beaches with persistent sand cover support a greater diversity of biological resources and year-round habitat suitability for seasonal uses (e.g., grunion spawning, overwintering habitat for birds).
- Intermediate beach types with bar-trough morphology experience considerable seasonal sand mobility and generally have less biological resource development than dissipative beaches. Intermediate beach types display a variety of beach states and biological resource development in California (Dugan et al. 2002).
    - Biological resource use is limited to absent on intermediate beach types that experience winter-spring sand erosion to cobble and/or sand scoured rock (MEC 2000a, SAIC 2006). However, biological

resources and habitat functions are supported as sand seasonally accretes to the beach.

  - Intermediate beach types with persistent sand cover may maintain habitat suitability year-round for biological resource development and seasonal functions (e.g., grunion s spawning, seasonal bird use).

- Reflective beaches with steep beach face, low sand mobility, and coarse sands support relatively fewer biological resources and functions.

Generally, sandy beach habitat functions are less vulnerable to impact during fall-winter than spring-summer. Important exceptions are dissipative and/or intermediate beaches with persistent sand, which may support overwintering foraging and resting habitat functions for shorebirds. An additional environmental constraint is associated with beaches designated as Critical Habitat for overwintering western snowy plovers.

Spring is a transition time between less supported biological functions in winter and more supported functions during summer. An important consideration of equipment use during spring is the quality of the sandy beach habitat. Suitability for California grunion spawning may vary seasonally depending on degree of winter erosion. Grunion spawning is vulnerable to vehicle impacts (Martin 2002). Habitat suitability also influences seasonal use as foraging/resting habitat by threatened western snowy plover, and resting habitat by California brown pelican and California least tern. Of particular concern are beaches within and/or adjacent to designated Critical Habitat and/or adjacent to nest sites for snowy plovers and/or Calfiornia least tern.

Spring also represents the onset of seasonal recruitment of invertebrate populations, which also is tied to habitat suitability. Available reports suggest fewer disturbances to invertebrate forage base development when disturbance occurs prior to spring recruitment and/or early in the recruitment season (Sections 4.2.6). This is because there is still sufficient time remaining in the year for invertebrate forage base to develop after disturbance.

Equipment impacts have the potential to be greater in summer. Besides considerations associated with potential seasonal use by sensitive fish and bird species, summer is a peak period of development of the invertebrate forage base (Section 4.2.6). Therefore, extent of disturbance is a primary consideration with respect to significance of summer equipment use impacts on invertebrate forage base and higher trophic levels. Beach scraping effectively removes invertebrate forage base. If conducted in summer, there is a shorter time period for recovery prior to natural population reduction in fall; thereby, reducing the quality of the invertebrate forage base (age structure, size) for birds and surf zone fish until the next season. This is a similar consideration for beach nourishment projects involving burial of intertidal habitat. In the case of beach nourishment, equipment impacts may be largely masked by impacts associated with sand burial.

Equipment impacts associated with beach nourishment may vary with placement location. For example, equipment impacts may be less when trucks are used for dune placement. Equipment impacts from placement of sand near the back of the beach largely depends on use as resting and/or nesting habitat by birds.

Environmental windows have been used to avoid potential significant impacts to sensitive resources that may use sandy beach habitat (California grunion, western snowy plover)

(Section 6). Because habitat suitability to support functional uses may vary seasonally due to beach morphodynamics, time periods covered by environmental windows may be broader than necessary to protect sensitive resources. Other measures such as assessment of habitat suitability prior to construction and/or use of monitors also have been used to protect sensitive resources from equipment impacts during beach nourishment (Section 6). Depending on existing conditions, alternative measures (i.e., habitat suitability assessment, construction monitoring) to ensure resource protection may be environmentally sound.

Sandy Subtidal

Equipment use in sandy subtidal habitat associated with beach nourishment may include dredging (borrow sites), pipeline placement, and/or anchoring associated with dredging, pipeline discharge to the beach, and/or sand placement (nearshore, profile).

Offshore dredging will directly remove sediment and associated organisms. Dredging also has the potential to entrain organisms as a result of near bottom water being withdrawn along with sediments. Generally, complete mortality is assumed for benthic organisms removed and/or entrained by dredges, although some small percentage may survive depending on equipment used and discharge location (LaSalle et al. 1991). Anchoring and/or pipeline placement may result in localized burial and disruption of habitat and mortality and/or disturbance of organisms.

Equipment use has the potential to result in the following types of impacts to wildlife (Navqi and Pullen 1982, NRC 1995, Newell et al. 1998, Greene 2002, Boyd et al. 2004, Cooper 2005):

- Dredge removal of invertebrates with reduction of invertebrate forage base for fish and marine mammals.
- Dredge entrainment of demersal invertebrates and/or early life stages of fish.
- Removal and/or disturbance of soft-substrate spawning grounds of fishery species (e.g., Dungeness crab, Pismo clam beds).
- Pipeline burial and disruption of benthic invertebrates.
- Activity and/or noise related disturbance displacement of mobile, epifauna invertebrates, fish, and/or marine mammals.
- Light attraction and increased predation on schooling, water-column fish.
- Potential collision with marine mammals.

In the case of offshore borrow site dredging, equipment use results in removal of sand habitat. Therefore, additional concerns include the potential for impacts to alter hydrodynamics and physical and/or chemical characteristics within the area of potential effect. Potential to alter hydrodynamics and waves also is of concern with nearshore and/or profile placement.

Potential equipment use impacts to sandy subtidal habitat associated with wildlife and recovery rates are summarized further in Sections 5.3.5.1 (invertebrates), Section 5.3.5.2 (fish), Section 5.3.5.3 (birds), and Section 5.3.5.4 (marine mammals). Impacts to sandy subtidal habitat and invertebrate communities from offshore borrow site dredging have been

documented with several studies (Sections 4.2.7, 5.3.3.2, 5.3.4.1), fewer studies have been conducted on fish.

Available reports suggest that potential equipment impacts to sandy subtidal resources relate to existing conditions and nature and degree of change from existing conditions. Recovery rates of invertebrate communities in nearshore sandy habitats after dredging typically range from 2 to 3 years unless there is substantial alteration of hydrodynamics and/or substrate characteristics. Impact minimization measures associated with offshore dredging are reviewed in Section 6.

Available information suggests that effects of temporary pipeline placement/removal and/or anchoring on sandy subtidal organisms are short-term.

5.3.3.3 Hard Substrate

Equipment use associated with beach nourishment typically is conducted in soft substrate habitats where sand either is removed and/or placed. Therefore, potential direct impacts to hard substrate habitat from equipement use generally are avoidable. Indirect disturbance impacts to mobile wildlife (fish, birds, marine mammals), if present, may occur if sediment management activities are conducted in the vicinity of hard substrate habitat. Mitgation measures to protect sensitive hard substrate habitat during sediment management activities have included pre-construction surveys to finalize project footprints, vessel routes, anchorages, and/or pipeline routes (Sections 3.3.4, 3.3.5, 5.3.3.4).

Rocky Intertidal

Equipment use has the potential to result in the following types of impacts to rocky intertidal habitat and wildlife, if present.

- Pipeline damage to sedentary invertebrates and vegetation.
- Activity related disturbance displacement of tidepool fish.
- Activity related disturbance displacement of endangered California brown pelican, shorebirds, gulls, waterfowl and/or wading birds.
- Activity related disturbance displacement of pinnipeds.

No reports of equipment impacts to rocky intertidal habitat associated with beach nourishment activities were identified with the literature review.

Potential equipment use impacts to rocky intertidal habitat will depend on existing conditions and extent of disturbance. Temporary placement of sediment delivery pipelines has the potential to damage hard substrate organisms, if present. Equipment use in erosive areas with cobble substrate and/or low relief, ephemeral reefs would be expected to have minimal impact. Disturbance of functional rocky intertidal habitat could result in damage of vegetation and invertebrates. Distubance also could result in temporary displacement of tidepool fish, birds, and/or pinnipeds, if present. Displacement disturbance could result in increased predation of tidepool fish. Impacts to birds and/or pinnnipeds generally would not be significant unless activities occurred at locations with substantial roosting by California brown pelican (Section 5.3.4.3) and/or haul outs by pinnipeds (Section 5.3.4.4).

Rocky Subtidal

Equipment use has the potential to result in the following types of impacts to rocky subtidal habitat and wildlife, if present:

- Dredge and/or anchor damage and/or overturning of rocks and associated sedentary invertebrates and vegetation.
- Pipeline damage to sedentary invertebrates and vegetation.
- Activity and/or noise related disturbance displacement of mobile, epifauna invertebrates, fish, and/or marine mammals.
- Light attraction and increased predation on schooling, water-column fish.
- Potential collision with marine mammals.

No reports of equipment impacts to rocky subtidal habitat from sediment management activities in California were identified with the literature review. However, there are limited reports of equipment damage to coral reefs during beach nourishment on the East Coast of the United States, and to rocky subtidal reefs in California during oil and gas development (Section 5.3.1.4). Generally, temporary displacement of mobile invertebrates and fish may occur from disturbance, while recovery from equipment impacts to sedentary organisms may take months to several years depending on existing conditions and severity of impact (Lissner et al. 1991).

Similar to the above summary for rocky intertidal, potential equipment use impacts to rocky subtidal habitat will depend on existing conditions and extent of disturbance. Equipment use in erosive areas with cobble substrate and/or low relief ephemeral reefs with few biological resources would be expected to have minimal impact. Disturbance of perennial, functional habitat could damage sessile plants and animals and result in temporary displacement of mobile wildlife. Displacement disturbance could result in increased predation of reef fish (Section 5.3.4.2). Mobile, water column fish also may experience short-term disturbance (Sections 5.3.4.2). Impacts to marine mammals would be temporary unless there was accidental collision (Sections 5.3.4.4).

5.3.3.4 Submerged Aquatic Vegetation

Equipment use associated with beach nourishment has the potential to impact sensitive SAV habitat, if present. Direct loss of kelp, surfgrass, and/or eelgrass habitats are not permitted in California without mitigation. Indirect disturbance impacts to mobile wildlife (fish, birds, marine mammals) may occur from equipment use within and/or near f SAV habitat. Mitgation measures to protect sensitive SAV habitat during sediment management activities have included dredge limits, buffers, and/or pre-construction surveys to finalize project footprints, vessel routes, anchorages, and/or pipeline routes.

Kelp Forest and/or Bed

Kelp habitat has the potential to be impacted during transit of dredge vessels and workboats, anchoring associated with offshore dredging of sand borrow areas, nearshore or profile placement, and/or pipeline placement/removal.

Equipment use has the potential to result in the following types of impacts to kelp forest and/or bed habitat and associated wildlife, if present:

- Dredge and/or anchor damage and/or overturning of rocks and associated sedentary invertebrates and vegetation.
- Pipeline damage to sedentary invertebrates and vegetation.
- Entanglement of fronds and/or dislodgement of holdfasts.
- Activity and/or noise related disturbance displacement of mobile, epifauna invertebrates, fish, and/or marine mammals.

No reports of equipment impacts to kelp forests and/or beds from sediment management activities in California were identified with the literature review. However, there are limited reports of equipment damage to rocky subtidal reefs in California during oil and gas development (Section 5.3.1.4). Many of the same above-noted equipment related concerns associated with rocky subtidal habitat apply to kelp forests and/or beds. An additional concern is dislodgement of holdfasts from anchors and anchoring cables and/or from vessel propeller entanglement of surface fronds. The significance of impacts would depend on the degree of impact and variety of kelp affected. Based on reported recovery rates, equipment related impacts to kelp established on hard substrate would be expected to be adverse, but not significant provided the impact was localized. In contrast, recovery rates of the variety of kelp that occurs in sandy substrate in the Santa Barbara Channel are uncertain (Section 3.3.6).

Surfgrass Beds

Anchoring associated with nearshore or profile placement, and/or temporary pipeline placement/removal activities have the potential to overturn rocks and/or damage marine life living on subtidal and/or intertidal reefs, including surfgrass. No reports of damage to surfgrass beds from sediment management activities were identified from the literature review.

Direct and/or indirect impact concerns to habitat and associated wildlife noted above for rocky intertidal and/or subtidal habitat also may apply to surfgrass habitat, if present.

Surfgrass recovery generally is slow unless there is minimal disturbance and rhizomes are not removed (Sections 3.3.7, 5.2.3.6). Experimental studies involving cutting plugs from existing beds provide relevant documentation that removal of patches of rhizome mat can undermine the mat and result in loss of surfgrass in excess of recovery rates (Bull et al. 2004). Therefore, localized damage has the potential to result in significant impacts to surfgrass beds.

Eelgrass Meadows

Eelgrass has the potential to be impacted by dredges, support vessels, and equipment during maintenance dredging, offshore borrow site dredging, nearshore placement, and/or profile placement if present within the footprint of the sediment management project. Dredge equipment and/or anchors used by vessels in embayments or offshore could damage and/or remove eelgrass if present. Damage from pipelines (used to deliver sediments to receiver sites) may result if placed through an eelgrass area. Damage and/or removal of plants by propellers may occur if vessels transit shallow waters in embayments where eelgrass occurs, but would not be expected in deeper waters of embayments or offshore.

Equipment use has the potential to result in the following types of impacts to habitat and/or associated wildlife:

- Dredge removal and loss of habitat and associated sedentary invertebrates.
- Pipeline, propeller, and/or anchor damage and habitat loss.
- Dredge entrainment of demersal invertebrates and/or early life stages of fish.
- Removal and/or disturbance of spawning and/or nursery grounds of fishery species (e.g., Dungeness crab, Pacific herring, salmonids).
- Activity and/or noise related disturbance displacement of mobile, epifauna invertebrates, fish, and/or marine mammals.

Several relevant reports indicate eelgrass recovery may take years if at all from dredging, propeller damage, and/or anchoring depending on extent of impact (Section 5.2.3.6). Eelgrass recovery may occur within one season if damage is minor and rhizomes are not removed (Section 3.3.8).

Several maintenance dredging projects in California were reviewed and found to use a combination of measures, monitoring to protect eelgrass habitat and/or functions. Prescribed dredge limits are used to protect eelgrass during maintenance dredging of Agua Hedionda Lagoon in San Diego County; maps of eelgrass distribution and density are required before and after dredging and impacts to eelgrass outside dredge limits require mitigation (USACE permit 200100328-SKB). No work zones, restriction of propellers in no work zones, and restriction of use of aggregates (sand, gravel, concrete, etc.) to cushion or cover sand delivery pipelines in eelgrass areas were specified for maintenance dredging in Morro Bay (USACE 2001).

5.3.3.5 Embayments

Maintenance dredging may be required to remove sedimentation from deepwater inlet embayments to maintain navigable channels. Removed sediments may include sands that provide opportunity for placement on local beaches. Use of dredged and/or excavated sands from embayments is considered a beneficial reuse because it puts trapped sediments that back into the littoral system. Examples of beneficial reuse projects involving maintenance dredging/excavation and beach nourishment are listed in Table 3.2-2.

Equipment use associated with beneficial reuse projects may include dredging, pipeline placement, and/or anchoring. Equipment use has the potential to result in the following types of impacts to wildlife.

- Dredge removal of invertebrates with reduction of invertebrate forage base for fish and marine mammals.
- Dredge entrainment of demersal invertebrates and/or early life stages of fish.
- Removal and/or disturbance of soft-substrate spawning grounds of fishery species (e.g., Dungeness crab, Pacific herring, salmonids).
- Removal and/or disturbance of SAV habitat.
- Pipeline burial and disruption of benthic invertebrates and/or SAV habitat.
- Activity and/or noise related disturbance displacement of mobile, epifauna invertebrates, fish, birds, and/or marine mammals.
- Light attraction and increased predation on schooling, water-column fish and/or interference with migration of fishery species (Pacific herring, salmonids). .

These types of impact may occur in both shallow and/or deepwater inlet embayments. Potential impact issues are summarized in greater detail by impact factor in Sections 5.3.3.1 through 5.3.3.6. Impacts to sensitive SAV habitats in embayments (eelgrass beds) are not permitted in California without mitigation. Mitgation measures to protect embayment habitats and/or functions during sediment management activities have included environmental windows, dredge limits, buffers, and/or activity restrictions. Potential equipment use impacts to wildlife and recovery rates are summarized further in Sections 5.3.4.1 (invertebrates), Section 5.3.4.2 (fish), Section 5.3.4.3 (birds), and Section 5.3.4.4 (marine mammals).

5.3.4 Equipment Impact Concerns to Species

Similar to the habitat summaries, the summaries for species are organized under umbrella categories, in this case according to taxonomic association; i.e., invertebrates, fishes, birds, and marine mammals. The summaries reference when no reports of impacts from sediment management activities were identified during the literature review, and in that case the potential for impacts considers other relevant reports and species distribution and/or life history strategies.

5.3.4.1 Invertebrates

Invertebrates may be directly damaged and/or killed from sediment removal by dredges and earthmoving equipment, dredge entrainment, vehicles, anchoring, and/or placement/removal of sediment delivery pipelines. Indirect displacement of invertebrates may result from equipment related disturbance. The effects of these impacts on higher trophic levels (birds, fish) are not well understood; therefore, ecological consequences have been largely inferred from recovery rates and/or duration of effect. Review of relevant reports suggest the following generalizations with respect to equipment related impact concerns to invertebrates from sediment management activities.

- Vehicle damage recovery rates to sandy beach invertebrates relate to existing conditions, disturbance location, and frequency of disturbance. Potential damage is

minor for slow moving 4-wheel drive vehicles, but damage increases with increased speed and/or intensity of use. Recovery rates are faster for intertidal biota than supralittoral crustaceans.

- Beach scraping recovery rates relate to existing conditions, project timing, and frequency of disturbance. Few if any impacts would be expected when conducted above the high tide line during fall.
- Dredge, excavation, and/or anchor sediment removal recovery rates in soft substrates relate to existing conditions, post-project degree of change in hydrodynamics and/or substrate conditions, and extent of disturbance (Sections 4.2.6, 4.2.7, 5.2.3.6).
    - Recovery rates generally are faster for frequently disturbed navigational channels and littoral sands than more stable nearshore and/or less frequently disturbed habitats.
    - Recovery rates appear to be faster for shallow dredging than deep pits.
    - Recovery rates generally are faster when disturbance is localized, but may be slower as spatial scale increases due to greater distance from unaffected areas.
- Dredging, anchoring, and/or pipeline placement are of concern in areas where damage may occur to soft bottom spawning and/or nursery grounds of fishery species (Dungeness crab, Pismo clam).
- Dredging, anchoring, and/or pipeline placement activities are of concern where damage may occur to to fishery species in sensitive hard bottom (e.g., abalone, California lobster, sea urchins) and/or SAV habitats (Dungeness crab).
- Entrainment effects are of particular concern in confined areas of embayments during recruitment periods of fishery species (Dungeness crab).
- Invertebrate forage reduction after beach scraping is less of a concern for shorebirds and surf zone fish when disturbance occurs to intermediate beach types in late fall-winter after natural declines of invertebrate populations on the beach, but is of concern if conducted in other seasons, at beaches used as overwintering foraging habitat for western snowy plover, and/or beaches with high use by overwintering shorebirds and gulls.
- Invertebrate forage reduction after dredging is less of a concern for demersal fish in areas where invertebrate recovery is relatively rapid, but is of concern in commercial fishery areas, more stable environments where invertebrate recovery rates are slow, and/or areas where frequency of dredging activity increases.
- Invertebrate forage reduction after dredging generally is of minor concern to marine mammals due to foraging preference on pelagic and/or kelp bed associated invertebrates, but is of concern for clam beds in areas where sea otters are common.
- Activity and noise related disturbances from dredges, support vessels, anchoring, and/or pipeline placement generally are of minor concern to invertebrates, but may be of more concern for mobile epifauna associated with sensitive hard bottom and/or SAV habitats where displacement could result in increased predation pressure and/or interference with breeding/spawning.

Invertebrate Recovery Rates

Recovery rates of benthic invertebrates vary depending on existing conditions and extent of disturbance. Representative ranges of recovery rates based on relevant reports and estimates for Calfiornia habitats potentially affected by sediment management activites are given below. Equipment related impact issues for different coastal habitats are summarized for habitats and species below.

Table 5.3-4. Reported and/or estimated soft substrate invertebrate recovery rates after equipment disturbance.

Equipment Related Impacts	Reported	General Estimate for California
Vehicles	Days to > 1 year	Days to Months
Beach scraping	Months	Months (Intermediate beach type), Years (Dissipative beach type)
Pipeline placement/removal		Days to months
Inlet excavation – littoral sands		Weeks to Months
Offshore borrow site dredging–sands	1 to 10 years	2-3 years
Embayment entrance and navigational channels dredging–sands	Weeks to < 1 year	Months
Embayment basin dredging – high disturbance regime	Months	Months
Embayment basin dredging – low disturbance regime	> 1 to 3 years	Years
Damage to rocky intertidal	Days to > 3 years	Days to years
Damage to rocky subtidal	Weeks to years	Weeks to years

Sources: Oliver and Slattery 1977, McCauley et al. 1977, Dethier 1984, Van Dolah et al. 1984, Johnson and Nelson 1985, Lissner et al. 1991, Newell et al. 1998, Peterson et al. 2000a, Schoeman et al. 2000, Burlas et al. 2001, Dalfsen and Essink 2001, Posey and Alphin 2001, Jutte et al. 2002.

High Interest Species – Hard Substrate

Abalone, California Lobster, Sea Urchins

Potential equipment use impacts to abalone, California lobster, and/or sea urchins may include damage and/or displacement if dredging, anchoring, and/or pipeline placement/removal impacted rocky subtidal habitat where these species occur. Damage likely would be fatal for individual animals (Section 4.2.1, 4.2.2, 4.2.5). Temporary displacement of California lobster from daytime shelters could result in loss from predation.

High Interest Species – Soft Substrate

Dungeness Crab

Dredge entrainment of Dungeness crab results in high mortality; however, rates of entrainment generally are low (reviewed by LaSalle et al. 1991, Reine et al. 1998). Potential entrainment risk is considered greater during the recruitment period and may be significant in restricted water bodies (e.g., narrow channels and/or confined areas in embayments) where mobile organisms may not be able to avoid dredge effects or where early life stages may be concentrated (LaSalle et al. 1991, http://www.deq.state.or.us/wq/401Cert/

ColumbiaRiver/WaterQualityCertification .pdf). Larval settlement occurs between April and June (DFG 2001).

Based on relevant reports of behavior, Dungeness crab may be vulnerable to dredge related impacts when animals congregate to mate and when females are partially buried while brooding eggs (berried) Section 4.2.3). A related species, brown crab, is considered vulnerable to dredging impacts when berried females remain partially buried overwinter (Cooper 2005).

The USACE, San Francisco District uses an environmental window restricted period (May 1 to June 30) to protect Dungeness crab from entrainment of early juvenile stages (http://el.erdc.usace.army.mil/tessp/ windows.cfm?). This restricted period also covers part of the mating season (February through June). Other Northwest Pacific UCACE districts use environmental windows to protect Dungeness crabs both from physical disturbance as well as entrainment (http://el.erdc.usace.army.mil/tessp/).

Dredge removal of eelgrass habitat could adversely affect Dungeness crab by reduction of nursery habitat in embayments where this function is supported. Eelgrass removal requires mitigation replacement in California (Section 3.3.8).

Pismo Clam

Pismo clams beds are considered vulnerable to equipment related disturbance due to limited geographic distribution (i.e., dissipative beaches) and limited larval dispersal (Shaw and Hassler 1989, DFG 2001).

Sandy Beach

Vehicle and equipment use on the beach during beach nourishment and/or beach scraping activities have the potential to result in mortality (crush, bury) of sedentary invertebrates. Studies of vehicle impacts to invertebrates during berm construction for shoreline protection, beach grooming, and/or off road use indicate minor impacts to intertidal biota but potentially significant impacts to supralittoral crustaceans (Wolcott & Wolcott 1984, van der Merwe and van der Merwe 1991, Stephenson 1999, Peterson et al. 2000a, Brown and McLachlan 2002). Semi-terrestrial crustaceans (and other wrack-associated invertebrates) also may be significantly impacted by beach grooming practices (Brown and McLachlan 2002, Dugan et al. 2003).

Recovery rates of sandy beach invertebrates to beach scraping/bulldozing range from weeks to months (Peterson et al. 2000a, Schoeman et al. 2000, Greene 2002). Location on beach (above high tide line) will avoid impact, and seasonal timing (fall-winter) and localized area effect apparently minimize effects by avoiding productive season and promoting fast recovery rates (Section 5.3.3.1).

Sandy Subtidal

Dredging and/or excavation will result in the removal of subtidal invertebrates along with sediment. Dredging also will entrain some invertebrates in near bottom waters. Generally, survival rates of invertebrates from dredging are low with bucket dredges and complete mortality may be assumed with hydraulic dredging (LaSalle et al. 1991, Parr et al. 1978). Dredge recovery rates for inveretebrates in nearshore sands generally range from 2 to 3

years unless there is substantial change in hydrodynamics and/or substrate (Section 4.2.7). Dredge and/or excavation recovery rates of subtidal invertebrates in embayments will depend on existing conditions and may range from <1 year (frequently disturbed areas) to > 3 years (stable habitat).

Entrainment rates for invertebrates generally are low, but may be significant for Dungeness crabs in areas where larvae may concentrate due to physical restrictions of the water body (e.g., channels in embayments) (LaSalle et al. 1992). Although not measured, entrainment potentially could be significant if dredging occurred within and/or adjacent to a Pismo clam bed during the peak spawning period (June to September) based on the limited dispersal of the bottom-dwelling larvae (Section 4.2.4).

Rocky Intertidal

No reports were identified with the literature review of direct impacts to rocky intertidal habitat during sediment management projects in California.

Intertidal invertebrate occurrence varies with respect to reef height and complexity, with few to no species associated with cobble and/or low relief substrate subject to seasonal burial and uncovering to diverse assemblages where reef height and development provide refuges from sand scour (Section 4.3.8). Equipment use impacts to rocky intertidal invertebrates from pipeline placement and/or vehicles may range from minor to nonexistent in ephemeral reef areas to potentially significant in functional reefs areas. Recovery rates would depend on reef type and nature of damage. Recovery of opportunistic species may be < 1 year, but may take several years for mussel patches and/or other long-lived species (Dayton 1971, Sousa 1979b, Morris et al. 1980, Vesco and Gillard 1980, Taylor and Littler 1982, Littler et al. 1983, Dethier 1984).

Rocky Subtidal

No reports were identified with the literature review of direct disturbance of functional rocky subtidal reefs during sediment management projects in California. Equipment use damage to reefs during offshore dredging has been reported elsewhere in the United States (Courtney et al. 1972, Naqvi and Pullen 1982, Goreau 2001).

Equipment use impacts to rocky subtidal invertebrates from dredging, anchoring, pipeline placement/removal would include similar considerations noted above for rocky intertidal; i.e., existing conditions and extent of damage. Similarly, recovery rates could be rapid if damage occurred to opportunistic species, but could take years for recovery of damage to long-lived species (Lissner et al. 1991). Equipment use also could result in temporary displacement of mobile invertebrates (e.g., lobster, sea urchin).

5.3.4.2 Fishes

Fish and/or eggs may be directly damaged and/or killed by dredge removal of sediment and/or dredge entrainment. Indirect disturbance and/or displacement impacts may result from equipment, underwater noise, and/or artificial lighting. Indirect impacts also may occur from reduction and/or alteration in invertebrate forage base from dredging, excavation, and/or beach scraping. Review of relevant reports suggest the following generalizations

with respect to equipment related impact concerns to fish from sediment management activities.

- Vehicle impacts to California grunion relate to existing conditions, timing of disturbance, and disturbance location.
  - Vehicle impacts will depend on whether habitat is suitable to support spawning (i.e., beach width and sand depths sufficient to avoid egg loss during spring tides).
  - Vehicle impacts depend on time of year. Grunion spawning season typically ranges from March through August, but may extend over fewer or more months (e.g., February and/or September).
  - Vehicle impacts may affect both nocturnal spawning fish and eggs at night; whereas effects during the day are limited to eggs buried in the sand.
  - Vehicle impacts may occur within a band extending somewhere between the mean and high tide lines associated with semilunar, spring tides (new and full moons), but do not occur above or below these tide elevations. The zone of potential impact varies each semi-lunar cycle due to unequal wave heights.
- Beach scraping would not be expected to affect California grunion if conducted above the spring high tide line or outside the spawning season, provided the normal beach profile is restored before onset of the spawning season. Beach scraping would be of concern to California grunion if a berm and/or scarp interfered with wave runup of spring high tides or occurred in the high tide zone during the grunion season.
- Dredging, anchoring, and/or pipeline placement are of concern in areas where damage may occur to soft bottom nursery grounds of fishery species (e.g., flatfish).
- Dredging, anchoring, and/or pipeline placement/removal activities are of concern where damage may occur to SAV habitats used as spawning and/or nursery areas by fishery species (e.g., California halibut, Pacific herring, sand bass, salmonids).
- Dredging, anchoring, and/or pipeline placement/removal activities are of concern in areas where there may be interference with commercial fishing (gear and/or activities).
- Dredge entrainment effects are of concern in nursery habitats of fishery species (e.g., Pacific herring, salmonids, and California halibut).
- Invertebrate forage reduction after dredging is less of a concern for demersal fish in areas where invertebrate recovery is relatively rapid, but may be of concern in commercial fishery areas, more stable environments where invertebrate recovery rates are slow, and/or areas where frequency of dredging activity increases.
- Noise levels associated with dredge and/or support vessels are below thresholds of fish injury, but are within levels that may disturb fish. Noise displacement disturbance may be more of concern in areas where fish exhibit high site fidelity (e.g., reef fish, nursery areas in SAV habitat) and/or noise may be important to locating recruitment sites (e.g., reef fish).
- Artificial lighting associated with dredging generally would be expected to have minor effects on fish populations (localized attraction and increased predation pressure), but may be more of a concern in confined areas in embayments where predation

pressure could be concentrated on migratory fishery species (e.g., Pacific herring, salmonids) or forage base for sensitive birds during the breeding season (e.g., California least tern).

- Artificial lighting effects on California grunion spawning associated with beach nourishment are not well understood.

Calfiornia Grunion

California grunion eggs are vulnerable to equipment related disturbance (vehicles, earthmoving equipment, pipeline placement/removal) during beach nourishment and/or beach scraping based on relevant reports of vehicle impacts during beach grooming (Martin 2002). No adverse impacts to the species from beach nourishment have been documented. Avoidance of grunion season and/or use of monitors and construction restrictions have been used as mitigation measures to protect California grunion during beach nourishment projects in California (Section 4.3.1, Section 6).

The effects of artificial lighting during nighttime beach nourishment activities on grunion spawning behavior have not been documented. Anecdoctal reports suggest grunion will use beaches that receive artificial lighting. Therefore, grunion are at risk during night-time beach construction, if spawning occurs.

Juvenile California grunion have been shown to be attracted to artificial lights (Reynolds et al. 1977); therefore, there is the potential for attraction and possibly increased loss from predation during nighttime dredging operations. However, dredging noises also have the potential to result in temporary disturbance displacement. The effect of these counteracting impact factors during nighttime dredge operations is unknown.

Pacific Herring

Pacific herring eggs are vulnerable to equipment related disturbance during dredging. During spawning runs in embayments, eggs may attach on any type of hard substrate, including eelgrass (Section 4.3.2). Dredge removal of eelgrass could reduce spawning habitat in embayments where this function is supported. Eelgrass removal requires mitigation replacement in California (Section 3.3.8).

Pacific herring exhibit “startle” or “start” response to noise stimuli (LFR 2004). Pacific herring are hearing specialists that may be disturbed by noises associated with dredging activities. However, available reports indicate that social mediatiation sound production mainly is at frequency ranges higher (1.7 to 22kHz, most above 2 kHz) than those produced by dredging (20 Hz to 2 kHz) (Reine et al. 1998, Wilson et al. 2003).

Pacific herring are attracted to night lighting and may experience increased loss due to predation (Nightengale and Simenstad 2002); however, no information is available on the possible counteracting effects of light attraction and noise displacement associated with nighttime dredging operations.

Salmonids

Salmonids have the potential to be directly and indirectly affected by dredging activites during sediment management projects. Salmonids apparently are most at risk in

embayments. Limited entrainment impacts have been documented (LaSalle et al. 1991, Reine and Clarke 1998). Generally, entrainment is not an issue because dredging occurs below the depth where salmonids migrate (Larson and Moehl 1990, Carlson et al. 2001, NMFS 2002). However, entrainment rates are of concern in constricted waterways and/or river channels where it may be difficult for juvenile salmonids to avoid the dredge operation (LaSalle et al. 1991, Reine and Clarke 1998). Restrictions on water depth where dredging may occur and depth above the bottom at which dredge pumps may be activated have been implemented to reduce potential entrainment impacts (LaSalle et al. 1991, NMFS 2002).

Nightengale and Simenstad (2002) reviewed several relevant studies that indicate that artificial lighting may attract juvenile salmonids, resulting in delayed outmigration and/or increased loss from predation; adult migration is less vulnerable to disruption. Those studies have more relevance to dredging projects in embayments than offshore borrow site dredging. Reine and Clarke (1998) stated that there was no conclusive documented evidence that dredging operations impede migration of salmonids, although no studies were referenced.

Noise levels may disturb salmonids near the dredge. The counteracting effects of light and noise on salmonids during nighttime dredging operations have not been studied. Dredging noises have the potential to result in temporary disturbance displacement.

Dredge removal of eelgrass habitat could adversely affect salmonids by reduction of nursery habitat in embayments where this function is supported. Eelgrass removal requires mitigation replacement in California (Section 3.3.8).

<u>Demersal Fish</u>

Demersal fishes have the potential to be directly impacted by dredge entrainment. They also may be indirectly affected by activities and/or noise associated with dredging, activities associated with anchoring and/or pipepline placement/removal, and invertebrate forage reduction from dredging and/or beach scraping (Section 4.3.4). Available studies have documented limited equipment related effects on demersal fish.

All demersal life stages are susceptible to entrainment by suction dredges (see Section 5.3.1.3). Generally, entrainment rates are low, but are of concern in areas of known spawning grounds (LaSalle et al. 1991, Reine and Clarke 1998).

Temporary attraction and/or avoidance of dredge areas by demersal fish have been reported (Section 4.3.4). Recovery rates of demersal fish populations after borrow site dredging vary. Similar communities were reported within 1 year of offshore dredging at borrow sites off New Jersey and South Carolina (Van Dolah et al. 1994, Burlas et al. 2001). Longer term changes in abundance (depressed, enhanced) of some demersal species were reported at a borrow site off Florida (Courtenay et al. 1980). Species-specific enhancement or reduction have been reported at and in commercial aggregate mining areas in the United Kingdom (Boyd et al. 2004, Cooper 2005).

Noise from dredging activities may result in temporary disturbance displacement. Anchoring and/or pipeline placement would be expected to have temporary disturbance effects based on otherf relevant studies (Sections 4.2.7, 5.2.3.4-5.2.4.6).

Invertebrate recovery after dredging will reduce potential forage base for demersal fish. Based on invertebrate recovery rates, this may be less of a concern for demersal fish in areas where invertebrate recovery is relatively rapid (e.g., frequently disturbed embayment entrance and navigational channels) or area of disturbance is relatively small compared to foraging range of populations (e.g., localized borrow sites). However, forage reduction effects on demersal fish may be of concern in commercial fishery areas, more stable environements where invertebrate recovery rates are slow, and/or in areas where there is a change (increase) in frequency of dredging activity (Sections 5.2.3.6, 5.3.3.1).

Generally, beach scraping would be expected to have minor effect on demersal-feeding surf zone fish based on rapid recovery rates of sandy beach invertebrates (Section 5.3.3.1). However, seasonal timing and localized effect are considered important factors to fast invertebrate recovery rates after beach scraping. Invertebrate forage reduction after beach scraping is less of a concern for surf zone fish when disturbance occurs to intermediate beach types in late fall-winter after natural population declines of invertebrates on the beach, but could be a concern if conducted during spring-summer when sandy beach invertebrate forage production is highest.

Water-Column Fish

Pelagic fish have the potential to be directly affected by dredge entrainment and indirectly impacted by activities, noise, and/or lights associated with dredging, anchoring, and/or pipeline placement/removal activities. Available reports suggest limited equipment related effects to pelagic fish from sediment management activities (Naqvi and Pullen 1982).

Pelagic water-column fishes have the potential to be directly impacted by dredge entrainment, although vulnerability is relatively low due to position in the water column (Reine and Clarke 1998). They also may be indirectly impacted by activities and noise associated with dredging activities (Section 5.3.3.6). Suzuki et al. (1980) indicated that large and/or high speed vessels can frighten fish schools or cause them to change their migration routes.

If sediment management activities are conducted at night, artificial lighting could have a localized impact on pelagic fish. Predatory fish have been observed to concentrate foraging on schooling fishes around lighted vessels, presumably because the light illuminates their prey (Nightengale and Simenstad 2002, DFG 2003b, N. Davis, personal observation). However, no information is available on the possible counteracting effects of light attraction and noise displacement that may occur at night.

Demersal eggs of pelagic species (e.g., Pacific herring) are vulnerable to dredge removal, entrainment, and/or other equipment related impacts during dredging and/or beach nourishment (nearshore placement, profile placement, mooring at a mono buoy during beach placement) (Reine and Clarke 1998).

Reef Fish

Reef fish have the potential to be indirectly impacted by noise and activities associated with dredging, anchoring, and/or pipeline placement/removal associated with sediment management activities. Direct effects from activities would not be expected based on fish mobility, and direct entrainment would not be expected with dredging located away from hard substrate habitats.

No reports of impacts to reef fish from sediment management activities in California were identified with the literature review. However, temporary displacement effects to reef fish were reported from localized damage to coral reefs during offshore borrow site dredging off Florida (Courtenay et al. 1972). Similar displacement effects would be expected from localized disturbances associated with anchoring and/or pipeline placement. Temporary displacement may result in some increased loss from predation, particularly early demersal stages (Lindeman and Snyder et al. 1998).

Studies of reef fishes indicate sensitivity to noise as a cue for orientation and recruitment to reefs (Montgomery et al. 2006). Relevant reports indicate that changes in noise levels may affect feeding and reproductive activities (noted by Hammer et al. 2005). Noise disturbance from dredging operations on reef fish have not been studied. Based on other relevant reports, reef fish may temporarily scatter from sudden vessel noise (Chambers Group 1988), but display high site fidelity even with exposure to very loud noise (seimic air guns) (Wardle et al. 2001 cited in Hastings and Popper 2005). Therefore, reef fish may experience some temporary displacement, but would not be expected to leave a reef due to dredge noises. A potential concern with dredging near reefs is that fish may experience longer duration noise disturbance as a result of their high site fidelity; thereby, increasing potential vulnerability to impacts. This likely would be more of an issue for fixed location rather than mobile dredging operations.

Rocky Intertidal Tidepool

No reports of equipment associated impacts to tidepool fish or rocky intertidal habitat during sediment management projects were identified from the literature review (Section 5.3.4.3). However, based on fish behavior and extent of disturbance, effects could range from short-term disturbance to increased vulnerability to predation if displaced from shelters.

5.3.4.3 Birds

Birds have the potential to be directly impacted by equipment during early life stages (eggs, chicks). Indirect disturbance and/or displacement impacts may result from equipment, noise, and/or artificial lighting. Indirect impacts also may result from reduction and/or alteration in invertebrate forage base from beach scraping. Review of relevant reports suggest the following generalizations with respect to equipment related impact concerns to birds from sediment management activities.

- Direct equipment impact concerns mainly apply to western snowy plover and California least tern using sandy beach and/or coastal strand and/or dune habitat for nesting.
- Disturbance from dredges, support vessels, and/or pipeline placement may result in indirect displacement effects of shorebirds and seabirds.
- Artificial lighting associated with night-time dredging and/or beach nourishment activities may attract gulls and increase predation effects at shorebird and seabird nesting sites, if nearby.
- Noise impacts are of most concern in the proximity of nesting sites of sensitive species (e.g., California least tern, western snowy plover).

- Invertebrate forage reduction after beach scraping is less of a concern for shorebirds when disturbance occurs to intermediate beach types in late fall-winter after natural declines of invertebrate populations, but is of concern if conducted in other seasons, at beaches used as overwintering foraging habitat for western snowy plover, and/or beaches with high use by overwintering shorebirds and gulls.

California Brown Pelican

California least tern may be indirectly impacted by equipment use associated with dreding and/or beach nourishment, if located near roosting sites. Temporary displacement (shifts in position, short-term fly off and return) of pelicans at a breakwater roost area was documented during dredging operations at Marina del Rey, California (Varanus 1999). Relevant studies indicate California brown pelican react to sudden changes in noise and nighttime lighting, but habituate to repetitive and/or prolonged activities (Section 4.4.1). Pelicans did not exhibit disturbance from heavy equipment operation and rip-rap installation to control erosion within 328 ft (100 m) of a roost site, but did flush and relocate a short distance away in response to approach by people and/or dogs (Jaques et al. 1996).

California Least Tern

California least tern may be indirectly affected by equipment use associated with sediment management activities, if located near breeding sites. No reports of impacts to least tern were identified with the literature review. Relevant reports have reported declines in reproductive success of least terns from prolonged human disturbance (Fancher et al. 1988, Obst and Johnson 1990). Artificial lighting is of concern near least tern and snowy plover bird nesting colonies because of the potential for increased gull predation (DFG 2003b). Relevant reports also have documented increased predation by gulls on eggs of common terns from artificial lighting (Nocera and Kress 1996).

Western Snowy Plovers

Western snowy plovers may be indirectly affected by equipment use associated with sediment management activities, if located near foraging areas and/or breeding sites. Monitoring studies during dredging and beach placement of dredge materials have documented avoidance of the immediate area of construction activities and moving away from vehicles, but no apparent effect on foraging on neighboring beach areas (Chambers Group 2001, Worden et al. 2002, Worden and Smith 2004, Chambers Group 2005). These observations are consistent with those of Lafferty (2000) who observed few disturbances to snowy plovers occurred at distances greater than 98 ft (30 m). However, relevant studies have documented declines in feeding rates and reproductive success of snowy plovers from prolonged human activity disturbance (Burger 1991, Lafferty 2000). As noted above, artificial lighting is of concern near snowy plover nest sites (DFG 2003b).

Shorebirds

Equipment use associated with beach nourishment may similarly indirectly disturb other shorebirds, as reported above for snowy plover. AMEC (2002) noted shorebirds (sandpipers, godwits, curlews) at receiver sites during beach discharge of sediments at San Diego County beaches. Relevant studies indicate that shorebirds typically move a short distance away (walk, fly) from human approach (Burger and Gochfeld 1991, Mc Crary and

Pierson 1999). Hubbard and Dugan (2003) suggest that movements may cumulatively result in significant energy deficiencies. However, the consequences of such effects are poorly understood.

Generally, beach scraping would be expected to have minor effect on shorebird foraging based on rapid recovery rates of sandy beach invertebrates (Section 5.3.3.1). However, seasonal timing and localized effect are considered important factors to fast invertebrate recovery rates. Invertebrate forage reduction after beach scraping is less of a concern for shorebirds when disturbance occurs to intermediate beach types in late fall-winter after natural population declines of invertebrates on the beach, but could be a concern if conducted during spring-summer when sandy beach invertebrate forage production is highest. Beach scraping also would be of concern at beaches with persistent sand that supports invertebrates throughout the season, particularly at beaches used as overwintering foraging habitat for western snowy plover, and/or beaches with high use by overwintering shorebirds and gulls.

Wading Birds

Noise and activites during sediment management activities has the potential to indirectly affect nesting colonies of herons and egrets that breed in trees at harbors and/or near the beach in California (Cogswell 1977, Zeiner et al. 1990). No reports of impacts to wading birds from equipment use from sediment management activities were identified with the literature review.

Waterfowl

Operation of dredges and/or support vessels has the potential to indirectly affect sea ducks and seabirds. No reports of impacts to waterfowl from equipment use from sediment management activities were identified with the literature review. Relevant reports document that Brandt's cormorants, canvasback ducks, loons, and marbled murrelts are relatively sensitive to vessel approach (Korschgen et al. 1985, Strong 2005). Noise levels associated with dredging activities are below injury threshold, but within disturbance thresholds developed as part of the USFWS biological opinion for the Olympic National Forest program (Section 5.3.3.6).

5.3.5.4 Marine Mammals

Marine mammals have the potential to be directly injured by vessel strikes. Indirect disturbance and/or displacement impacts may result from equipment and/or noise associated with dreding and/or beach nourishment.

- Underwater noise generated by dredges is below current NMFS exposure criteria for Level A (injury), but may produce Level B harassment (potential to disturb) depending on distance from the source (Section 5.3.3.6).
- Airborne noise generated by vehicles, earthmoving equipment, pumps, and generators are below Level B harassment levels.
- Strikes from dredges and support vessels are a potential concern where marine mammals concentrate or are common in occurrence.
- Noise disturbances may be more of concern in areas near pinniped rookeries and/or sea otter nursery areas.

- Artificial lighting associated with nighttime dredging may attract marine mammals, which may opportunistically prey on similarly attracted, schooling fish.
- Invertebrate forage reduction after dredging generally is of minor concern to marine mammals due to foraging preference on pelagic and/or kelp bed associated invertebrates, but is of concern for clam beds in areas where sea otters are common.

Some USACE Districts require one or more of the following measures to avoid and/or minimize direct impacts to marine mammals, including use of monitors and vessel speed restrictions (4 kn) when whales are known to be in the area and avoidance of intentional approaches within 300 ft (91 m) of marine mammals (Reine et al. 1998).

Cetaceans

Equipment associated impacts to whales from sediment management activites have been documented, although reports are limited. Laist et al. (2001) reported one record of a whale fatality from collision with a hopper dredge. Reviews indicate that risk of vessel collision damage to whales may be lessened at vessel speeds less than 10 kn (Laist et al. 2001).

Observations in Alaska suggest whales initially avoid dredge noises but may become adapted to continuous noise operations (Richardson et al. 1995). Numerous reports demonstrate whales may move from vessel noises (Laist et al. 2001). However, whales may be less responsive to sound when sleeping or actively feeding. Avoidance reactions to vessels may vary due to underwater sound reflections, sounds of multiple vessels, and/or hull blockage of engine and propeller noise in front of vessels. Therefore, there is not threshold distances at which whales change course relative to approaching vessels (Section 4.5.3).

Pinnipeds

No reports of disturbance to pinnipeds from equipment related sediment management activities were found with the literature review. Relevant reports indicate pinnipeds are killed and/or injured by vessel strikes each year off California (Carrett et al. 2004). Generally, pinnipeds are relatively tolerant of vessel traffic (Richardson et al. 1995), and may not react until a vessel approaches within 328 to 656 ft (100 to 200 m) (Bowles and Stewart 1980). Relevant reports indicate pinnipeds on land may react by retreating into the water when disturbed by vessel approach and/or people walking near and/or in rookeries and haul out areas (Richardson et al. 1995).

Sea Otters

One anecdotal report suggests equipment-related sediment management activites may affect sea otters. Bodkin and Rathbun (1988) observed a decline in sea otter abundance in Morro Bay after harbor maintenance dredging started. Subsequent reports of sea otter presence in Morro Bay suggest the impact was temporay (USACE 2001). Richardson et al. (1995) reviewed that sea otters appear to be relatively tolerant of vessel activity, but may avoid heavily disturbed areas. Collisons have been reported for fast moving vessels (Harvey 2004).

5.4 Burial and Sedimentation Impacts

Beach nourishment in aquatic habitats (beach placement, nearshore placement, profile placement) will include benthic effects associated with direct sediment deposition (burial) and indirect sedimentation from deposition of suspended sediments. Indirect sedimentation also may occur after beach nourishment from transport of placed sediments. Dredging will result in indirect sedimentation associated with sediment resuspension and deposition.

This section reviews relevant background information on benthic effects of sediment burial and sediment deposition, which also has been referred to as sedimentation, embedded sediments, and/or bedded materials (Berry et al. 2003, Germano and Cary 2005, Wilber et al. 2005). Water column effects associated with sediment resuspension and transport (e.g., turbidity) are reviewed in Section 5.5.

The following questions of interest to the CSMW are reviewed in this section.

- *What types of transient or long-term impacts on nearshore biota (especially rocky bottom habitats) have been associated with fate and transport of fine-grained sediment in natural landslide areas (e.g., Palos Verdes Peninsula)?*
- *How are kelp beds, eelgrass, and other critical habitats affected by sedimentation? Is there a critical level of thickness of sedimentation that causes adverse impacts?*
- *What types of species are vulnerable to burial, and what depth of sediment can the species of concern burrow through to avoid "smothering"?*
- *How does sedimentation affect herring eggs, salmon runs, and other similar critical species? Is there a critical volume or rate of sedimentation, or seasonality that causes adverse impact?*
- *What evidence documents that burial, sediment scour or any other adverse impacts associated with movement of sediment occurred as a result of beach nourishment activities?*

This section is organized in four subsections. Section 5.4.1 provides background overviews of impact issues associated with burial and sedimentation. Section 5.4.2 reviews lessons and/or insights gained from review of large-scale, natural (e.g., landslides, storms, red tides) and human-induced (accelerated runoff, discharges) sedimentation impacts. Sections 5.4.3 and 5.4.4 summarize burial and sedimentation issues with respect to California habitats and species, respectively.

5.4.1 Overview of Burial and Sedimentation Impact Issues

Reviews by LaSalle et al. (1991), Airoldi (2003), Berry et al. (2003), Germano and Cary (2005), and Wilber et al. (2005) provide the most recent syntheses of available information on sedimentation. Additional information available from publications and monitoring studies associated with beach nourishment, laboratory and/or field studies examining effects of sedimentation, and/or studies that provide insight into effects of chronic and/or large-scale pulses of sedimentation (e.g., landslides, storms). These studies document a broad range of organism response to sedimentation. Adverse impacts may range from temporary

disturbance to mortality and/or habitat loss. However, limited information is available on biological impact thresholds associated with burial and sedimentation.

Reviews indicate there are several mechanisms by which introduction of sediments may directly and/or indirectly affect coastal habitats and species (Devinny and Volse 1978, Naqvi and Pullen 1982, Nelson 1989, LaSalle et al. 1991, NRC 1995, Lindeman and Snyder 1998, Greene 2002, Berry et al. 2003, Airoldi 2003, Germano and Cary 2005, Wilber et al. 2005), including:

- Crush and/or smother sedentary organisms and/or life stages.
- Change physical substrate characteristics, which may enhance or reduce habitat functions (foraging, spawning/nesting, and resting) and/or change community composition.
- Change chemical microenvironments of the substrate (e.g., oxygen, nutrients, hydrogen sulphide), which may depress and/or enhance certain species and/or alter community composition.
- Change hydrodynamics (sediment transport and erosion rates), which may alter environmental disturbance regimes, alter beach morphodynamics, and/or change community composition.
- Change light regime, which may reduce and/or enhance establishment, growth, distribution, and/or species composition of vegetation.
- Change bottom surface from hard to soft substrate, which may result in loss of settlement habitat for hard substrate species, decrease in species abundance or cover, and/or change community composition.
- Reduce vertical height of hard bottom substrate, which may displace and increase predation of mobile reef associated animals.
- Increase scour/abrasion, which may damage and/or remove organisms, alter recruitment, and/or change community composition.

Beneficial aspects of increased sediment and/or sedimentation are reviewed in Section 5.1. Impact concerns associated with burial and changed environmental conditions apply to both soft and hard-bottom habitats; whereas, changes in substrate surface and height are primarily associated with hard substrate habitats. Scour/abrasion is a primary disturbance factor for hard substrate habitats, but also may influence soft substrate populations in areas with ridge-swale topography (Boyd et al. 2004).

Type of project determines whether impacts will be direct and/or indirect. For example, both direct burial and indirect sedimentation concerns apply to beach nourishment; whereas, indirect sedimentation concerns apply to dredging activities. Spatial and temporal scales of impact may vary depending on, project design and size, equipment and methods used, project location, and existing environmental conditions. Many of these factors are reviewed in Section 5.2.

Several additional factors specific to the influence of burial and/or sedimentation impacts are reviewed in the following subsections and include:

- Placement Method.

- Rates of sedimentation.
- Sediment load and thickness.
- Duration of sedimentation.
- Natural biological adaptations to burial and sedimentation.

In addition, there may be several interacting effects related to other environmental factors that may covary with sedimentation (e.g., turbidity, organic and inorganic pollutants, reduced salinity associated with storms, hydrodynamics), which may be difficult to separate with respect to causal relationships associated with sediment-related impacts (Airoldi 2003). Impacts associated with turbidity are reviewed in greater detail in Section 5.5. Confounding effects associated with pollutants are not reviewed herein because of the focus of this document on sediment management activities associated with use of "clean" sediments for beach nourishment.

5.4.1.1 Source Materials and Placement Method

Beach nourishment may be accomplished with different types of source sediments and a variety of methods, as follows:

- Sand sources - offshore borrow sites, embayments, and terrestrial.
- Methods - hydraulic dredge and placement, mechanical dredge and release, and earthmoving equipment.
- Placement locations - dune, beach, nearshore, and profile.

The physical characteristics of the source materials and placement location influence spatial and temporal scales of burial and sedimentation. Sand sources may differ in with respect to several properties, including grain size and shape, surface texture, shear resistance, moisture content, and sand compaction (NRC 1995). Some of these differences relate to source location and method used to obtain the material. For example, moisture content is high with hydraulic methods that place sand-water slurries, moderate with mechanically dredged and/or excavated sandy sediments from embayments, and low with terrestrial sediments. Fluid discharge spreads over a larger area than sediment mounds with less moisture content. Environmental issues associated with sand compatibility are further summarized in Section 5.2. .

Sand placement method influences the rate of sand introduction into the littoral system, which together with existing hydrodynamics influence factors such as turbidity during construction, rate and thickness of sand transport movement and sedimentation away from the placement location, and duration of burial effects. Different placement methods are described below with emphasis on differences related to burial and/or sedimentation. Illustrations of the different placement methods are given in Figure 2.2-1 (Section 2.2).

Dune Placement

Dune placement generally involves use of earthmoving equipment to place sands in a berm (dike) near the landward edge of the backshore (C. Webb, 2006 personal communication). The dike is placed adjacent to back cliffs, revetment, or seawall and allows for gradual "feeding" of sediment to the surf zone during extreme high water wave conditions (Moffatt &

Nichol 2005b). This method is considered effective in protecting upland development against storm waves (DBW and CCC 2002). A sand dike method is identified as a concept design for several southern California opportunistic beach fll programs (Moffatt Nichol 2000a,b, 2001).

- This approach represents the slowest method of sand introduction to the littoral system.
- This approach provides sand source for aeolian transport to adjacent dunes, if present.

<u>Beach Placement</u>

Beach placement may include three methods, which are described below:

Dry beach (berm) placement – This method involves placing sand on the dry portion of the beach and along a slope towards the ocean. This method is a very common approach and results in immediate increase in beach width (NRC 1995, DBW and CCC 2002). This approach has been implemented using hydraulic placement of dredged materials for moderate to large beach nourishment projects in California and elsewhere (e.g., USACE 1995a, SANDAG and USDN 2000, Burlas et al. 2001, Versar 2004). This approach also may be accomplished by trucks and earthmoving equipment for small to moderate size projects. This method is identified as a concept design for several southern California opportunistic beach fll programs (Moffatt Nichol 2000a,b, 2001), and for use of optimum sands with the SCOUP project (Moffatt & Nichol 2005b).

- This method involves substantial burial of existing beach face and intertidal. The rate at which the material is reworked and incorporated into the littoral system is influenced by seasonal coastal processes and wave climate.

Swash zone placement – This method involves placing a 2 to 3 ft (0.6 to 1 m) sand mound or piles below the mean high tide line depending on tide conditions at the time of placement (Moffatt & Nichol 2005b). The amount of placed material may be placed in increments if the sand volume exceeds the rate of daily reworking by waves. This method has been used for small-scale volume placements such as inlet maintenance at San Elijo Lagoon, San Diego County (K. Green, personal observation). Placement of beach fill below the mean high tide at the water's edge is identified as a potential placement method for small projects as part of several southern California opportunistic sand programs (Moffatt & Nichol 2000a,b, 2001), and is identified as a concept design for use of less-than-optimum sands with the SCOUP program (Moffatt & Nichol 2005a).

- This method rapidly incorporates placed sediments into the littoral system and disperses fines.
- Placement location avoids impact to the upper high tide zone.
- It is expected that with this method, the sand mound is quickly eroded and dispersed by waves; thus, effectively reducing the effects of burial on sandy beach invertebrates, many of which are adapted to shifting sand elevations across tidal cycles (Section 4.2.6).

Surf zone discharge involves hydraulic pipeline discharge of fluidized sand into the swash zone. The pipeline may be moved to different points within the receiver site, or a single-point discharge may be confined within a specified beach segement (e.g., 500 ft, 152 m). The single-point surf zone discharge method sometimes has been used by the USACE to minimize potential impacts to snowy plover and/or or gunion if construction schedule extends into March and April (e.g., USACE 1993, USACE 1994a, USACE 1999b, USACE 2000b). A small-scale surf zone discharge (3,000 cy) was conducted in Santa Cruz using mixed sands with a high silt/clay content (40%) (Watt and Greene 2005).

- This method rapidly incorporates placed sediments into the littoral system and disperses fines.
- Placement location avoids impact to the upper high tide zone.
- Boundaries between direct (placement) and indirect (sand transport) impacts may not be distinct based on consideration of rates of delivery (i.e., pump rate) and littoral transport.
- Because sands are pumped to the surf zone, rate of burial of sandy beach invertebrates will be higher than with swash zone placement (i.e., sand mound or piles eroded by waves).

Nearshore Placement

With nearshore placement, the characteristics of the placement depend on the method of discharge, the physical characteristics of the source material, and the hydrodynamics of the placement location. Dredged material may be placed in open-water sites using hydraulic pipeline placement, hopper dredge discharge of fluized sediment slurry, or release of mechanically dredged material from a bottom-release dump scow (Figure 5.4-1). The objective of nearshore sediment release is to supplement the beach profile and renourish the beach; whereby, coarser materials are added to the littoral system and fines (silt/clays) move offshore (Williams 1998).

Nearshore release of sediments has been conducted in association with several maintenance dredging (e.g., Marina del Rey Harbor, Oceanside Harbor) and channel deepening (San Diego) projects in California. A slurry discharge to the nearshore to a maximum depth of 30 ft (9 m) is identified as a concept design for use of less-than-optimum sands with the SCOUP program (Moffatt & Nichol 2005a).

The physical characteristics of the source material will vary in bulk density and cohesion depending on source material characteristics (Williams 1998).

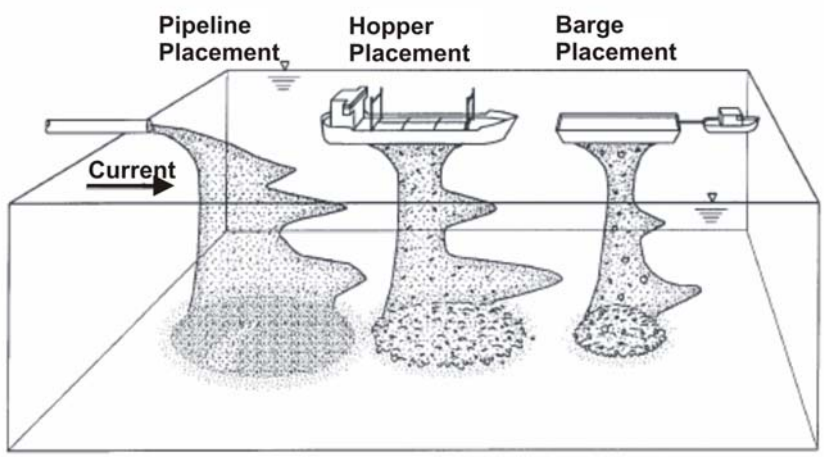
- Mechanically dredged tends to maintain bulk densities, which contributes to a more cohesive mound feature at the placement location.
- Mechanically dredged (or excavated) coarse-grained material (sands) loses coherence during descent through the water column, but is more conducive to mound formation than fluidized sediments.
- Hydraulically dredged sediments are fluidized, which significantly reduces bulk densities.
- Fluidized material is more susceptible to dispersion during descent through the water column.

Based on the above considerations of bulk density and cohesion, the following differenes in potential burial and sedimentation may occur depending on method used.

- A thicker overburden of burial is expected with release of mechanically dredged material than fluidized sediments.
- Fine sediments will winnow offshore faster with release of fluidized than mechanically dredged material.

Profile

This method combines dry beach with nearshore placements to add sediment across the subaerial and submerged portions of the beach profile. This method is less commonly used and is considered more difficult to implement (DBW and CCC 2002). Modified profile placements may include discrete beach and nearshore placements (e.g., Rakocinski et al. 1996).



Source: USACE and EPA 2004 (from USEPA 1992)

Figure 5.4-1. Illustration of different open water placement methods.

5.4.1.2 Rates of Sedimentation

Rates of sedimentation associated with dredging and disposal operations may substantially differ. Dredging operations generally move past an area of potential impact on the order of days; whereas, dredge disposal operations would potentially last longer with episodic plumes or density currents depositing fresh layers of sediment (Germano and Cary 2005).

Beach nourishment results in rapid burial impacts, and depending on method of placement, relatively rapid or slower post construction sediment transport sedimentation rates. Rates of sedimentation after beach nourishment are on temporal scales associated with coastal processes, which include seasonal and interannual components tied to oceanographic and storm conditions (Parr et al. 1978, Naqvi and Pullen 1982, NRC 1995). Depending on where

sand is placed, those factors may have immediate and/or delayed influence on the placement fill. For example, sand placed higher on the beach (dune placement) would be expected to winnow and redistribute at a slower rate than sand placed directly in the surf zone or nearshore (Chambers Group 2002, Moffatt & Nichol 2002, 2004, 2005a).

Resuspension of dredged material overburdens is influenced by grain size of the deposited sediments, degree of sediment consolidation, bottom current velocities, critical shear stresses, and interactions of biological organisms that rework the sediment (bioturbators) (Germano and Cary 2005, Wilber et al. 2005). Fine particle aggregation (flocculation) also may affect sediment deposition rates (see Section 5.5.5.2).

Natural sedimentation rates depend on a variety of environmental conditions and are variable both within and between habitats (Wilber et al. 2005). Most shallow benthic habitats in embayments are subject to resuspension and sedimentation events across tides on a daily basis (Oviatt and Nixon 1975 cited in Wilber et al. 2005). Germano and Cary (2005) reported that ambient sedimentation rates and associated near bottom TSS concentrations based on published sources range from 0.1 to 0.3 cm/year (TSS of 10 to 100 mg/L) in estuarine SAV habitats and 0.3 to 1.0 cm/year (TSS of 100 to 20,000 mg/L) in turbid estuaries.

Methods used to detect sediment deposition may include sediment traps, acoustic techniques, sediment cores, tracers, and sediment profile cameras. Different techniques vary considerably in sensitivity and precision (Thomas and Ridd 2004 cited in Germano and Cary 2005). Furthermore, isolation of dredge and/or disposal sedimentation from ambient sources (runoff, storms) may be difficult because they may be of the same order of magnitude. Germano and Cary (2005) recommended that laboratory and field studies to determine effects of sedimentation should be designed at appropriate time and spatial scales, as follows:

- Laboratory study durations – minutes to hours for immediate behavioral and acute responses, and days to weeks for longer-term effects on development, growth, and physiology.
- Laboratory study sediment volumes - millimeters for effects on eggs and embryos, and liters to mesocosm scale for larvae and juveniles.
- In situ study durations – 3 to 5 days for direct effects, months to years for indirect effects.
- In situ spatial scales – base on initial mixing zone and extent of density flows adjacent to dredging and/or disposal event. For example, spatial scale may range from 656 to 3,281 ft (200 to 1,000 m) away from source with strongest effects examined within 984 ft (300 m) from source.

5.4.1.3 Sediment Load and Thickness

The thickness of sediment deposition layers may vary over a broad range depending on sediment management activity, equipment used, sediment characteristics, and environmental conditions. The thickness of sedimentation associated with direct burial and indirect sedimentation may vary by two to three orders of magnitude. Beach nourishment entails direct placement and/or discharge of thick mounds of sediment on the order of several feet (meters), although the thickness may vary across the placement area depending on the quantity of placed material and/or slope of the beach fill (Moffatt and Nichol 2006).

Sediment thickness also may relate to sediment characteristics at the time of placement. For example, beach nourishment sand that is finer or coarser than native sand generally will result in equilibrium profiles that are of flatter or steeper slopes than the native beach, respectively (NRC 1995).

Indirect sedimentation during and after beach nourishment may range from several feet associated with sand migration from the receiver site to thin layer deposits associated with water column dispersal and/or increased distance from the placement location. Indirect sedimentation of downcoast beaches with several feet of sand was measured by profiles and sand depth measurements after the San Diego Regional Beach Sand Project (Coastal Frontiers 2004, SAIC 2006). Sherman et al. (1998) measured elevated suspended sediment plumes over a distance of 1.8 mi (3 km) during a small beach nourishment project involving pushing sediments (18% silt/clay) into the swash zone with bulldozers, but considered the probable zone of deposition more likely 6 miles (10 km) long and 984 ft (300 m) wide based on review of aerial photographs. Based on the small volume of sediments (20,000 cy) and silt/clay content, sedimentation in the nearshore was estimated at approximately 0.02. in (0.5 mm) thick over an area of 6.2 mi by 984 ft wide (10km long by 300 m wide) (Sherman et al. 1998).

Hydraulic dredging and pumping of sand to the beach entails discharge of a sediment/water slurry with a lower bulk density due to the addition of water (LaSalle et al. 1991). During beach nourishment, the slurry may be unconfined with discharge directly to the swash zone and/or on the beach. While coarser sands rapidly settle, finer sediments are transported in the turbidity plume, and as noted above, silt/clays are carried offshore and settle in the nearshore.

In other cases, the slurry may be confined behind a temporary sand dike or swales to consolidate sands on the beach and minimize turbidity. This measure may slow the release of fines during and after beach nourishment. This method was used in California during the 1997 Surfside-Sunset Beach Nourishment Project (MEC 1997a) and 2004 Goleta Beach Demonstration Project (Moffatt & Nichol 2005c). During the 2001 San Diego Regional Beach Sand Project, sand was hydraulically pumped behind temporary sand dikes to control turbidity (SANDAG and USDN 2000). At some beaches, sand first had to be pumped to the beach to provide sufficient sand for construction of the temporary dikes.

Unconfined hydraulic discharge

Hydraulic discharge behind dike

Photos from SANDAG

Beach nourishment may result in an increased silt/clay content of nearshore sediments from indirect sedimentation. Review of available monitoring reports suggests that the amount of silt/clay loading and its persistence may vary with respect to silt/clay content of source materials, project volume, and hydrodynamics of the receiving environment (Parr et al. 1978, Burlas et al. 2001, Rakocinski et al. 1996).

Sediment thickness after open water discharge of dredged sediments may be on the order of several feet in the immediate discharge zone. For example, Hydraulic discharge may result in an initial deposit thickness of 39.5 in (100 cm) at the discharge location (Halka 1999). Near-field sedimentation associated with transport and deposition of suspended sediments during open water discharge may be on the order of inches (cm). For example, sediment profile cameras documented overburden depths of 2 in (5 cm) from sedimentation pulses resulting from open-water pipeline discharge of dredged material in Corpus Christi Bay, Texas (Wilber et al. 2005).

Dredging results in resuspension of sediment from equipment disturbance and transport and deposition over near- to far-field gradients associated with sediment grain size characteristics and local hydrodynamics (see Section 5.5 for further discussion). Generally, the majority of resuspended sediment settles within 165 to 328 ft (50 to 100 m) and turbidity plumes extend less than 3,281 ft (1,000 m) from the dredge (LaSalle et al. 1991). Newell et al. (1998) reviewed a study by Poiner and Kennedy (1984), who reported that concentrations of suspended sand-sized material rapidly decayed to background levels over a distance of 656 to 1,640 ft (200-500 m) during dredging in Moreton Bay, Australia.

Wilber et al. (2005) reviewed that sedimentation from dredging may be acute (> 2 in, 5 cm rapidly deposited) at near-field distances, but at increasing distance become thin veneers on a scale of less than several millimeters. The above-noted study by Poiner and Kennedy (1984) reported deposition estimates of 23 mm/m^2 at 1,640 ft (500 m), 16 mm/m^2 at 0.62 mi (1 km), 12 mm/m^2 at 0.93 mi (1.5 km), 8 mm/m^2 at 1.2 mi (2 km), and < 6 mm/m^2 at 1.5 mi (2.5 km) from a commercial aggregate dredger.

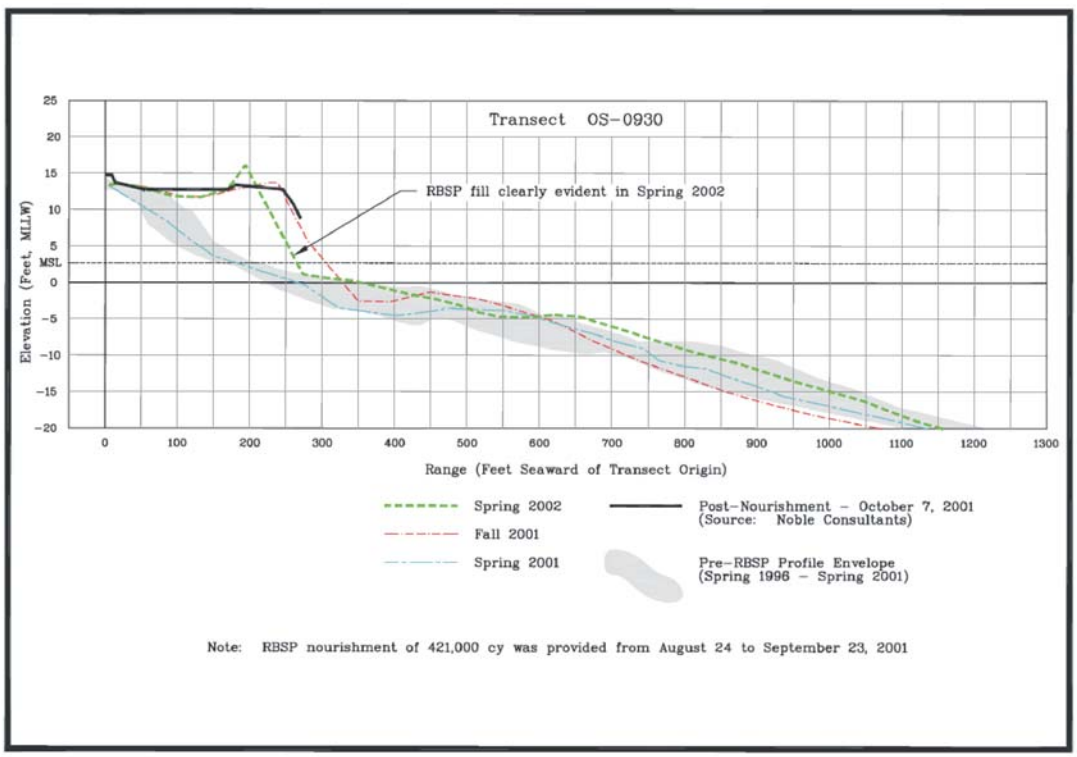
5.4.1.4 Sedimentation Duration

The duration of accumulated sediment will decrease over time due to hydrodynamic processes that influence sediment resuspension, erosion, and transport. Biological processes also may affect how quickly deposited sediments become incorporated into ambient sediments and/or become re-transported (Germano and Cary 2005). Environmental conditions of the receiving environment (hydrodynamics, biological community) and sediment characteristics greatly influence the persistence of sedimentation (NRC 1995, Germano and Cary 2005).

After beach nourishment, placed sands will undergo seasonal erosion and accretion associated with coastal processes. For example, relatively thick sand layers (e.g., 2 to 3 ft, 0.6 to 1 m) may be moved during storms, and sand accumulation of 1 ft (0.3 m) may occur over a few successive days during summer accretion (Shepard and Inman 1951, Straughan 1982). Method of sand placement, sediment characteristics, and wave climate will influence beach nourishment erosion rates.

Beach nourishment erosion will occur in the cross shore and longshore dimensions from processes termed profile equilibration and alongshore spreading, respectively (NRC 1995). Indirect sedimentation along the subtidal portion of the beach profile will decrease with increasing distance offshore and will decease with distance alongshore. Wave climate also is influential to where sedimentation accumulates along the beach profile. Longshore bars tend to occur further offshore under high wave conditions and inshore during low waves (Alexander and Holman 2004). Sands may be transported outside the normal depth of closure by extreme storm and wave heights associated with El Niño events (Seymour et al. 1984, Inman and Masters 2005).

Sediment beach profiles have been used to determine project performance after beach nourishment. Sedimentation along the profile from post construction sand transport may range from several feet (m) along the inshore and bar portions of the profile to inches (cm) near the depth of closure. For example, beach profiles showed an increase in spring sand thickness across a beach profile of approximately 4 ft (1.2 m) at 0 MLLW, 1 to 2 ft (0.3 to 0.6 m) between -5 and -15 ft (1.5 and 4.6 m) MLLW, and < 1 ft (0.3 m) at depths ≥ -15 ft (≥ 5 m) MLLW one year after placement of 421,000 cy at Oceanside, San Diego County (Figure 5.4-1).



Source: Coastal Frontiers 2002 (reproduced with permission)

Figure 5.4-2. Example beach profile one year after beach nourishment.

Modeling often is used to predict project performance (persistence and sand transport) and fate and transport associated with beach nourishment design (e.g., NRC 1995). Several

models have been developed by the USACE to predict coastal sediment fate and transport (http://chl.erdc.usace.army.mil/chl.aspx?p=i&a=Software!0):

- CEDAS (Coastal Engineering and Design System) - CEDAS is an interactive Windows 95/98/NT/2000 based system that includes a comprehensive collection of coastal engineering design and analysis software, which includes products developed by or for the ERDC Coastal and Hydraulics Laboratory. CEDAS includes ACES, EST, Reliable, NMLong-CW, DYNLET, SBEACH, BMAP, NEMOS, GENESIS, and RCPWAVE.
- BMAP - A collection of automated and interactive tools to analyze morphologic and dynamic properties of beach profiles. BMAP is dynamically linked with SBEACH to support beach erosion analysis.
- GENESIS (GENErialized model for SImulating Shoreline change) Simulates the long-term platform evolution of the beach in response to imposed wave conditions, coastal structures, and other engineering activity (e.g., beach nourishment).
- NEMOS (Nearshore Evolution MOdeling System) - Includes GENESIS, RCPWAVE, STWAVE - A set of models used for simulating long-term beach evolution in response to imposed wave conditions, coastal structures, beach nourishment, and other engineering activity.
- SBEACH (Storm induced BEAch CHange model) - Simulates cross-shore beach, berm, and dune erosion produced by storm waves and water levels.

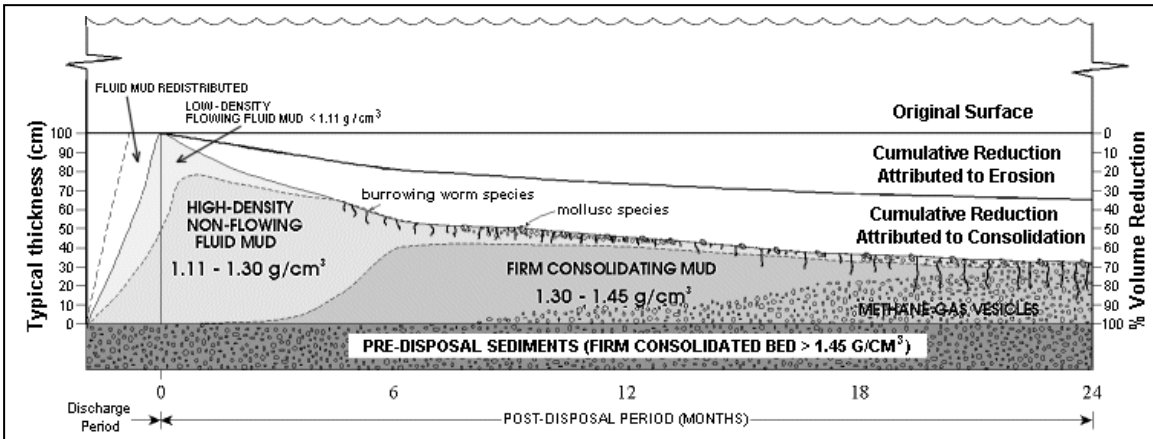
Equilibration of the beach profile after beach nourishment is generally on the order of a few years and duration of project benefit per stretch of shoreline may span several years depending on project size (length and volume), sediment grain size, and wave environment (NRC 1995). Beach profiles, which measure sand elevation change along the cross-shore profile, generally are used to document sand erosion, movement, and persistence. Consequently, beach profiles are a method for documenting project performance after beach nourishment (NRC 1995).

Movement of sands after beach nourishment is of concern for shorelines with rocky and/or coral reefs in the nearshore (e.g., Nelson 1989, SANDAG and USDN 2000). Available monitoring of beach nourishment projects conducted in the vicinity of rocky habitats in California has not reported significant impacts (Chambers Group 2004, AMEC 2005). Sedimentation damage to reef habitats has been reported for some beach nourishment projects elsewhere in the United States (e.g., Lindeman and Snyder 1998, Goreau 2001, Coastal Planning & Engineering 2004c).

Predicting sand increase along beach profiles after beach nourishment when there are reefs offshore is beyond the capability of existing models, and remains a serious deficiency. Application of engineering models of equilibrium profiles and nearshore sediment transport that were developed for sandy beaches (e.g., GENESIS) do not include valid assumptions for shorefaces with different geologic characteristics (e.g., outcropping mud or rock) (Pilkey et al. 1993, 1994). Rock outcrops can control the shape of the beach profile, strongly impact shoreline retreat rates, and may affect the local wave climate by reducing energy absorption and by wave refraction (Pilkey et al. 1994).

Monitoring of beach profiles provides information useful for model verification and/or development. Use of empirical data to test is recommended as a sound approach when the nearshore includes other features besides sand (Pilkey et al. 1994). However, model verification and/or refinement using beach profiles does not appear to be commonly applied in California (Boudreau, R., D. Cannon, 2007 personal communications). .

After open water discharge of hydraulic dredged sediments, sediment thickness may decrease substantially due to erosion and consolidation associated with the decreased sediment bulk density of the material (Halka 1999, Teeter 2002). For example, hydraulic dredging and discharge of fluidized muddy sediments with an initial thickness of 39.5 in (100 cm) may be less than half that after one year due to erosion and consolidation (Figure 5.4-2). In contrast, mechanical dredges (e.g., clamshell bucket) maintain much of the integrity of the sediments; therefore, sediment thickness and slope of the deposit is more persistent than for hydraulically discharged sediments (Halka 1999).



Source Halka 1999 (http://www.mgs.md.gov/coastal/dredge/sedstudy.html).

Figure 5.4-2. Sediment thickness and volume reduction after hydraulic discharge.

5.4.1.4 Natural Environmental Adaptations

Many organisms have attributes and/or adaptations for coping and/or taking advantage of conditions associated with sedimentation, which is a natural process in estuarine and coastal environments. The following behavioral, morphological, physiological, and reproductive attributes have been associated with species exhibiting tolerance to sand inundation and/or scour (Daly and Mathieson 1977, Littler et al. 1983, Airoldi 2003, Wilber et al. 2005):

- Behavior responses, including burrowing, crawling, and/or swimming to escape sedimentation, closing of shells and/or retreating into tubes and/or burrows to reduce exposure to sedimentation, elongation of body to maintain feeding and/or respiratory surfaces above sediment, and/or reducing feeding and/or pumping rates to minimize sediment ingestion.
- Morphological attributes such as shells, thickened cuticles, tough and wiry thalli or bodies that provide protection from physical abrasion and burial, apical meristems

that maintain dividing cells above the sediment, erect morphology that prevents sediment deposition, and/or a rhizomatous root system that binds sediment.

- Physiological tolerance to darkness, anaerobic conditions, and/or high hydrogen sulfide concentrations.
- Reproductive strategies including opportunistic life histories that enable rapid colonization after disturbance, capacity to propagate vegetatively, regeneration of upright fronds from remnant bases, and/or incomplete alternation of generations with asexual life histories.

Organisms differ in their response to burial, sedimentation, and/or scour. Adverse effects may occur when these physical factors exceed natural tolerances and/or adaptations of species. Organism tolerance to sedimentation undoubtedly relates in part to natural environmental conditions where they occur. For example, organisms living in soft substrate sandy beach habitat generally are competent burrowers adapted to shifting sands. More sedentary life styles may be supported on less energetic, lower sloped dissipative beaches, subtidal habitats, and on more stable estuarine flats. Thus, organism tolerance to sedimentation in soft substrate habitats may be expected to decrease with increasing sediment stability.

5.4.2 Lessons Learned from Large-Scale Sedimentation Events

Large-scale natural sedimentation events provide information on community response, recovery, and/or alteration at spatial and/or temporal scales that may be relevant to sediment management activities. Extreme weather associated with storms and/or high waves result in pulse impacts of high turbidity and/or widespread sedimentation (Ogston and Sternberg 1999, Warrick and Milliman 2005). Monitoring from landslide areas provide relevant information on both acute and chronic effects associated with sedimentation and/or turbidity (Bence et al. 1989, Shaffer and Parks 1994, Konar and Roberts 1996, Pondella et al. 1996). In addition, monitoring associated with point source discharges provide additional information on degree of modification of communities that may occur with chronic sedimentation and/or turbidity. Generally, coastal rocky subtidal and kelp bed habitats are relatively resistant and resilient to large-scale episodic pulses of sediments and turbidity, but communities may be altered with chronic exposures.

<u>Landslides</u>

Monitoring at landslide locations indicate that the degree and duration of impact may vary depending on magnitude and frequency of disturbance. In addition, other environmental conditions may influence severity of impact and/or recovery rates. Large-scale pulses of sedimentation may result in mortality and changed community composition of rocky substrate and kelp bed habitats (Bence et al. 1989, Konar and Roberts 1996, Pondella et al. 1996). Recovery after disturbance has been documented as occurring within few to several years, indicating these nearshore sensitive habitats are relatively resilient to temporary, substantial

Palos Verdes Landslide Area showing nearshore turbidity
Photo credit: USGS

disturbance. However, recovery of plants such as giant kelp may be delayed if other local populations that represent a potential source supply of spores do not occur nearby (Bence et al. 1989). Results of monitoring studies in the vicinity of landslides are summarized in more detail below.

Rocky intertidal and subtidal habitats in the vicinity of the Portuguese Bend landslide have been substantially modified by chronic sedimentation and associated turbidity (Pondella et al. 1996). This area of the Palos Verdes Peninsula, southern California, received a sediment load of 8,940,000 metric tons between 1956 and 1986, and has continued to receive sediment since then due to unstable geology. Comparison of the landslide affected site (Portugese Bend) with partially affected Abalone Cove (0.75 mi, 1.2 km upcoast), and unaffected Palos Verdes Point (4 mi, 6.4 km upcoast) indicated that habitats have been substantially modified by landslide sedimentation and turbidity. Results showed:

- A gradient of decreasing diversity of plants and animals associated with rocky intertidal and subtidal areas with proximity to the landslide area.
- Substantial alteration of community composition occurred with proximity to the landslide area that included a reduction in plant diversity, herbivores, and filter/suspension-feeders.
- Reduced plant diversity extended nearly a mile from the active slide area, whereas reduced numbers of invertebrates were mainly confined to the active slide area. These results suggest that plants are more sensitive to turbidity plumes and thin deposit sedimentation than invertebrates.
- Giant kelp and large understory brown algae exhibited greater spatial impact than low growing turf species of algae.

In landslide areas where chronic turbidity effects have been localized, greater impacts to large canopy-forming species of brown algae than to small species of algae have been reported. Relevant examples are provided below (see Section 3.3.6 for further descriptions).

- The Lone Tree landslide, northwest of San Francisco, northern California, has been characterized by periods of gradual and acute slide activity. Over 1,000,000 cy of material extending 200 to 230 ft (60 to 70 m) seaward was deposited one year prior and an additional 760,000 cy was deposited during a three-year study of algae (Konar and Roberts 1996, Komar 1997). The number of species of algae in an area influenced by turbidity plumes offshore the slide area was similar to nearby unaffected areas, except Bull kelp was not observed at the impact area.
- The Big Sur landslide in central California moved nearly 5,228,000 cy of soil approximately 246 ft (75 m) into the marine environment during and after a major slide in 1983. Konar and Roberts (1996) conducted a study of algae eight years after the slide occurred, comparing species composition offshore the slide area where elevated turbidity plumes occurred with that at unaffected nearby areas. The number of species of algae was similar between turbidity plume influenced and unaffected areas; however, giant kelp was less abundant and percent cover of encrusting coralline algae was greater at the impact area.

In areas where landslide activity was episodic, loss of kelp beds was immediate but recovery occurred over time.

- Airoldi (2003) reviewed a study by Shaffer and Parks (1994) who found immediate reductions in kelp beds adjacent to the slide area, but differences between affected and unaffected sites were no longer evident after a few years.
- Bence et al. (1989) reported that it was 7 years before kelp bed recovery was noted after a landslide in north San Diego County, which the authors suspected was influenced initially by sedimentation inhibiting recruitment and then later from a reduced local source of spores due to loss of adult plants.

Hurricanes

Airoldi (2003) reviewed a study by Moring (1996), who reported immediate responses of rocky intertidal assemblages to severe disturbance by sediments following a hurricane, but assemblages recovered to pre-disturbance appearance the following year when excess sand was removed by winter turbulence.

5.4.3 Burial and Sedimentation Impact Concerns to Habitats

Potential burial and sedimentation impacts are summarized below for each of the ten reviewed coastal habitats, which are organized under umbrella headings according to habitat categories; i.e., coastal dune and/or strand, soft substrate, hard substrate, submerged aquatic vegetation, and embayments.

Table 5.4-1 summarizes burial and sedimentation impact factors by habitat and species. At the end of each table is a list of issues considered relevant to potential impact occurrence and/or its relative significance. These issues include considerations associated with habitat suitability, beach morphododynamics, sensitive species, fisheries, season, proximity to nesting sites and/or spawning grounds, and migration routes. Follwing the tables are the summaries of potential impacts to habitats. The habitat summaries reference impact concerns for species associated with burial and sedimentation; however, more detailed summaries by type of species are given in Section 5.4.4.

5.4.3.1 Coastal Dunes and/or Strand

Placing sand at the backshore (dune placement) will result in burial of existing substrate and change in physical characteristics of the receiver site. Beneficial impacts associated with adding sand to sandy beach and dune habitats are discussed in Section 5.1.1.1 and 5.1.1.2 .

Dune placement may directly bury coastal strand habitat, if present. Several of the same potential impact concerns summarized for equipment use also apply to burial considerations (Section 5.3.3.1).

- Recovery of coastal stand habitat from burial may take years if at all.
- Burial of early life stages (eggs, chicks) of sensitive bird species (western snowy plover, California least tern), if present.
- Burial of sensitive terrestrial invertebrates (e.g., globose dune beetle), if present.
- Displacement disturbance of birds.

Table 5.4-1. Potential burial and sedimentation impacts to habitats and species from sediment management activities.

	Burial	Sand Transport	Turbidity Deposition	Reduce Forage	Displace
Habitats					
Coastal Dune and/or Strand	X				
Sandy Beach	X				
Sandy Subtidal	X				
Rocky Intertidal	X	X	X		
Rocky Subtidal	X	X	X		
Kelp Forest and/or Bed	X	X	X		
Surfgrass Bed	X	X	X		
Eelgrass Meadow	X	X	X		
Shallow Inlet Embayment		X			
Deepwater Inlet Embayment		X			
Species					
Abalone		X			X
California Lobster		X		X	X
Dungeness Crab					X
Pismo Clam	X				
Soft substrate Invertebrates	X				
Hard bottom Invertebrates	X	X		X	X
California Grunion	Eggs				
Pacific Herring			Eggs		
Salmonids				X	X
Demersal Fish			Eggs	X	
Pelagic Fish			Eggs		
Reef Fish			Eggs		X
Tidepool Fish					X
California Brown Pelican					
California Least Tern					
Western Snowy Plover				X	
Shorebirds				X	
Gulls and Terns				Gulls	
Wading Birds, Waterfowl				X	
Cetaceans					
Pinnipeds					
Sea Otters				X	X
Potential impact Issues of Concern					
Habitat Suitability	X				
Beach Morphodynamics	X	X	X	X	
T&E Species	X			X	X
Fisheries	X	X	X	X	X
Season	X	X	X	X	X
Proximity to Nesting Site				X	
Proximity to Spawning Ground	X	X	X		
Migration Route					

Note: Blank entries indicate no burial and/or sedimentation impact concerns.

.

Avoidance of vegetated areas eliminates concern for significant impacts to strand habitat and associated sensitive insects, if present.

Proximity to nesting sites of California least tern and western snowy plover (and/or Critical Habitat) may be important seasonal impact considerations depending on exisitng conditions. Potential burial impacts to sensitive birds are summarized further in Section 5.4.4.3.

5.4.3.2 Soft Substrate

Sandy beach and sandy subtidal substrates are the primary habitats directly affected by beach nourishment activities. Primary impact issues of concern include forage reduction for secondary consumers, recovery rates after disturbance, and potential to impact other sensitive resources. Impact concerns specific to sandy beach and sandy subtidal habitats are summarized below.

Sandy Beach

Sand placement on the beach will result in burial of existing substrate and change in physical characteristics of the receiver site (NRC 1995, Greene 2002). Sand placement has the potential to result in the following types of direct and indirect impacts to wildlife, if present.

- Burial crushing and smothering of invertebrates, resulting in indirect forage reduction for birds and surf zone fish.
- Burial of eggs of California grunion.
- Burial of early life stages (eggs, chicks) of sensitive bird species.
- Indirect forage reduction for birds and surf zone fish.

Burial and sedimentation impacts to sandy beach habitat have been documented with many studies. Most report relatively rapid recovery rates of benthic invertebrates unless there is a substantial change to substrate or the project occurs during the peak recruitment period (Section 3.3.2, Section 4.2.6). Adverse impacts to other wildlife may vary with respect to existing conditions, sand placement location on the beach, invertebrate recovery rates, and nature of changed physical characteristics.

Direct burial of intertidal habitat results in mortality of sandy beach invertebrates, which represent important forage base to birds and surf zone fish. Generally, impacts from reduced forage base would be expected to be tied to the time period associated with recovery of invertebrate populations after beach nourishment. Invertebrate community recovery rates are a year or less unless there is interference with recruitment and/or sediment incompatibility (Section 5.4.4.1, also see Table 4.2-1 in Section 4.2.6).

Sediments with a relatively high content of silt/clays, coarse materials, and/or shell debris may adversely affect invertebrate community development. Beach nourishment sediments containing lenses of silt/clay generated elevated nearshore turbidity, which was considered a causal factor associated with delayed invertebrate recruitment (Reilly and Bellis 1983). Deposition of coarse sediments (0.5 to 0.8 mm) may alter community development (McLachlan 1996). Reduced shorebird foraging after beach nourishment at Boque Banks,

North Carolina was attributed to sediment incompatibility due to relatively high silt/clay content and shell debris (Peterson et al. 2002).

Beach (berm) placement has the potential to bury grunion eggs too deeply for them to hatch, if present. As mentioned for equipment, impacts to grunion have been avoided and/or minimized by either restricting the construction schedule outside their spawning season or monitoring and implementing protective measures during construction. Impact concerns generally are limited to the construction period. Sediment compatibility and beach slope may be important beach nourishment impact considerations for grunion.

Proximity to nesting sites of California least tern and western snowy plover (and/or Critical Habitat) may be important seasonal impact considerations depending on exisitng conditions. Potential burial impacts to sensitive birds are summarized further in Section 5.4.4.3.

Indirect sedimentation of downcurrent beaches will occur as fill material erodes and reworked sands are transported with littoral drift, indirect sedimentation also will occur along the subtidal profile of the beach as fill material redistributes to a more stable profile. Beneficial effects of indirect sedimentation to sandy beach habitat are summarized in Section 5.1.1.2). Adverse impact concerns relate to sediment compatibility issues, sedimentation of sensitive reef, and/or sedimentation of SAV habitats in the vicinity (see below).

Potential burial and/or sedimentation impact concerns to wildlife are summarized further in Sections 5.4.5.1 (invertebrates), Section 5.4.5.2 (fish), and Section 5.4.5.3 (birds.

<u>Sandy Subtidal</u>

Sediment management activities may directly impact subtidal sand habitat from burial associated with nearshore and/or profile placement. Recovery of sandy subtidal invertebrate communities may take one to several years after burial impacts (Section 5.4.4.2, also see Table 4.2-2 in Section 4.2.7).

Indirect sedimentation of nearshore benthic communities may occur from beach, nearshore, or profile placement as coastal processes winnow and transport placed sediments within the littoral zone.

Limited impacts and/or relatively rapid recovery rates (several months) generally have been reported for nearshore invertebrate communities adjacent to beach nourishment sites with placement volumes ranging from several hundred to several million cubic yards (Parr et al. 1978, Gorzelany and Nelson 1987, Burlas et al. 2001, Versar 2004). Storm activity was considered influential to the dispersion of silts deposited in the nearshore off California (Parr et al. 1978) and New Jersey (Burlas et al. 2001).

In contrast, Reilly and Bellis (1983) hypothesized that silt loading resulted in mortality of *Emerita* and *Donax* in nearshore, overwintering habitat because of lack of older individuals and delayed recruitment after beach nourishment. Rakocinski et al. (1996, 2001) documented substantial alteration of inshore benthic communities associated with silt loading after a several million cubic yard beach nourishment project at Perdido Key, Florida. In this case, dredging from Pensacola Pass may have encountered lenses with higher silt/clay content (Rakocinski, personal communication 2006). Although not reported by the authors, it is considered possible that the relatively low, wave energy of the receiving environment in the Gulf of Mexico contributed to the persistence of the silt/clay loading in the nearshore.

Although potential impacts to surf zone and/or nearshore fish from forage reduction have been hypothesized, adverse impacts to fish populations have not been demonstrated with monitoring studies. Naqvi and Pullen (1982) reviewed that effects of beach nourishment burial on food resources of motile nearshore populations has not been demonstrated to be of major significance. The NRC (1995) cited two studies in Florida that showed no evidence of adverse effects to the composition or abundance of fish after beach nourishment compared to before (Holland et al. 1980, Nelson and Collins 1987). Other than localized attraction and avoidance by two surf zone fish species, no other significant differences were detected in surf zone fish assemblages attributable to a large scale (> 3.6 million cm) beach nourishment project off New Jersey (Burlas et al. 2001, Wilber et al. 2003). However, the authors did note that because of the measured variability associated with mobile surf zone populations, a 3-fold difference in mean fish abundance would have been required to detect a significant effect. No significant decreases in fish abundance or diversity were detected during, up to 8 weeks after, and one year following beach nourishment at sites in North Carolina (Versar 2004). Similarly, no substantial changes to fish were observed from sand bypassing at Oceanside, California (Chambers 1994).

Indirect sedimentation also may occur from suspended sediment deposition in the vicinity of dredging activities.

5.4.3.3 Hard Substrate

Organisms associated with rocky and other hard substrate habitats differ in their adaptations and tolerances to sedimentation. Periodic sand inundation is a common feature of intertidal and nearshore rocky habitats due to re-suspension and transport from adjacent soft-bottom areas associated with natural coastal processes and storms (Littler et al. 1983, Stewart 1983, Airoldi 2003, Engle 2005). The degree of sand inundation may be extremely variable across season and between years.

Important factors associated with the potential sedimentation impacts to rocky subtidal areas include:

- Existing habitat conditions.
- Hard substrate height relative to sand inundation level.
- Persistence of sedimentation in sensitive reef habitats.

Reef height and quality as well as project size appear to be an important considerations with respect to potential beach nourishment impacts on hard bottom habitats. However, potential sedimentation is difficult to predict, being related to not only to project volume, but also site-specific environmental characteristics and temporal oceanographic conditions. In addition, organisms living in rocky habitats have different morphology, behavior, and life history characteristics with differing levels of tolerance to sedimentation impacts. Because of potential impact uncertainties, monitoring has been required with some beach nourishment projects when sensitive rocky habitat occurs in the vicinity.

Monitoring studies indicate that beach nourishment sedimentation may have no, limited, or substantial effect on rocky habitats depending on site- and project-specific factors.

Rocky Intertidal

Five types of species have been identified as occurring in rocky habitats influenced by sediments, with relative abundance of these types related to substrate characteristics and degree of sand inundation (Daly and Mathieson 1977, Littler et al. 1983, Murray and Bray 1993, Airoldi 2003):

- Sand enhanced and/or psammophytic ("sand loving") species, which have morphological, growth, and/or reproductive attributes that give them competitive superiority over other species in the presence of sand.
- Opportunistic species, which rapidly colonize space following mortalities caused by burial and/or scour.
- Migratory species, which move from areas of sand inundation to areas of refuge as sand gradients change.
- Stress tolerant species, which because of their physiological, behavioral, and/or morphological adaptations are able to survive levels of sedimentation where other potentially superior competitors cannot survive or reproduce.
- Sediment binding and/or trapping species, which have morphological and life histories adapted to burial and scour and show a strong association with sediments.

Other species, termed biologically-competent strategists, generally live in physiologically-favorable environments where competition and predation are primary factors that influence community composition. Biologically-competent strategists prevail where rock contours and/or heights provide refuge from sand deposition (Littler et al. 1983).

Rocky coastal habitats experience varying levels of sand scour and sedimentation depending on rock relief height, wave climate, and seasonal on- and offshore sand volume. Areas naturally subject to sediment scour and inundation sedimentation provide insight with respect to potential sedimentation impacts that may occur from beach nourishment activities performed in the vicinity of rock outcrops and reef habitats. Rocky areas the experience sand scour and/or burial generally develop subclimax associations consisting of opportunistic, stress-tolerant, and/or psammophyte (sand loving) species (Daly and Mathieson 1977, Taylor and Littler 1982, Littler et al. 1983, Murray and Bray 1993, Airoldi 2003). The degree of resource development declines with increased sand disturbance.

Low lying rocky substrate in the littoral zone may lack vegetation entirely or have cover by opportunistic or tolerant species due to recurrent sand scour and inundation. Rock reefs that do not experience substantial sand stress have more diverse algal assemblages (Stewart 1989.

Examples of intertidal species that may be found in of sand disturbed habitats in California include: aggregating sea anemones, mossy chiton, black turban snail, surfgrass, calcified coralline algae (*Corallina, Lithothamnion, Lithorhrix*), crustose *Ralfsia,* opportunistic algae (e.g., *Enteromorpha, Gelidium, Ulva*), and a variety of psmmophyte algae (e.g., *Ahnfeltia plicata, Chaetomorpha linum, Chondria nidifica, Gigartina papillata, G. volans, Gracilaria* spp*., Gymnogongrus leptophylluss, Neohodomela larix, Phaeostrophion irregulare, Pterocladia media, Taonia lennebackeriae,* and *Zonaria farlowii*) (Abbott and Hollenberg 1976, Littler et al. 1983, Turner 1985, Murray and Bray 1993).

Quality of rocky habitats may vary depending on disturbance stress associated with natural sand scour and inundation, noted above, as well as turbid runoff and human pressures (e.g., intertidal collecting, trampling) (Thompson 1993, CRM 1997, Murray et al. 2000). Understanding habitat sensitivity and potential constraints to recovery (e.g., altered population structure towards juveniles in human exploited areas, chronic turbidity disturbance) should be considered as part of sediment management impact assessments, as appropriate. Background turbidity concentrations under different environmental conditions are reviewed in Section 5.5.

Direct sand placement over rocky intertidal habitat would result in change of hard substrate to sandy habitat. Placement of sand over cobbles and/or scoured low relief rocks with few biological resources resulted in functional sandy beach habitat with the 2001 San Diego Regional Beach Sand Project (SAIC 2006).

Direct sand placement on rocky intertidal habitat with diverse plant and invertebrate communities and/or with tidepools supporting fish would be a significant concern, and is unlikely to be permitted. Burial could result in sensitive habitat loss for years until coastal processes removed excess sand, and several years more to recover lost habitat functions.

Indirect sedimentation of rocky intertidal habitat from post-construction sand transport from a receiver site is of potential concern with any placement method, depending on project volume and proximity to this habitat. Sand inundation and scour can substantially modify species assemblages, causing displacement of some mobile species and dominance by opportunistic, sand-tolerant, and/or sand-loving species. This disturbance naturally affects rocky intertidal habitats to varying degrees throughout California on a seasonal basis. Lower relief reefs are more vulnerable to sand disturbance, while higher relief reefs tend to remain above the sand. Impact concerns relate to the potential for indirect sedimentation occurring above natural levels and adversely impacting sensitive rocky intertidal habitat and resources.

No examples of direct burial of sensitive rocky intertidal as a result of California sediment management activities were identified from the literature review. Several California beach nourishment projects have been designed during project planning to avoid direct placement of sand in areas with persistent rocky intertidal (Tekmarine and Analytic Planning Service 1990; Chambers 1992; USDN 1997a, b; SANDAG and USDN 2000; Moffatt & Nichol 2001).

Two relevant monitoring studies indicate that impacts to rocky intertidal habiat were temporary and/or limited with beach nourishment volumes ranging from 79,000 to 101,000 cy and the receiver sites were located approximately 3,400 to 6,500 ft (1,000 to 2,000 m) upcurrent.

- Increased sand cover was transient during the first year of monitoring at intertidal sites 6,500 ft (2,000 m) and 7,874 ft (2,400 m) downcoast of the Goleta Beach Nourishment Demonstration Project, which placed 79,000 cy of sand onto the beach and was followed by an additional project with 20,000 cy of sand placement (Moffatt & Nichol 2005c). Chambers Group (2004) concluded sand cover rapidly moved out of the area and changes in sand and surfgrass cover were within natural variability shown at the site prior to beach nourishment (also see Section 3.3.7). Chambers Group (2004) concluded that the beach nourishment project may have had a temporary impact on rocky intertidal habitat, but does not appear to have caused any long term change (also see Sections 3.3.4, 3.3.7).

- No direct burial of intertidal reefs occurred with the 2001 San Diego Regional Beach Sand Project, although some placement occurred in areas with cobble and/or sand scoured low relief rocks with few biological resources (SANDAG and USDN 2000). No obvious sedimentation impact to rocky intertidal reef attributable to the 2001 San Diego Regional Beach Sand Project was reported based on comparison of pre-construction and four years of post-construction monitoring data (Engle 2005). Monitoring was conducted at an intertidal rocky reef 3,400 ft (1,000 m) downcoast of a receiver site that received 101,000 cy of sand and at comparative locations outside the littoral cell where beach nourishment occurred. Although some changes in densities of target species (algae, invertebrates) were observed and attributed to changes in sand levels, the effects were considered within the range of measured natural variation and no obvious impacts from the beach nourishment project were reported (Engle 2005).

A project on the East Coast showed significant impacts when the beach fill occurred immediately adjacent to reef outcroppings.

- Lindeman and Snyder (1999) reported persistent burial and sedimentation impacts at worm reef outcroppings in intertidal to nearshore waters up to 15 months after a 457,800 cy beach nourishment project off Florida.

Rocky Subtidal

Several factors affect the distribution and abundance of marine life on subtidal hard bottom habitats. Important substrate qualities include size (boulder, bedrock), vertical relief (low, high), composition (sandstone, basalt, granite), surface texture (smooth, pitted, cracked), and orientation relative to waves (Pequegnat 1964, Dayton et al. 1984, Ambrose et al. 1989, Ambrose 1994). Generally, there is a positive correlation between marine life diversity and substrate diversity. Hard bottom areas with a range of rock sizes, heights, and surface textures provide multiple shelter opportunities for motile organisms and surface areas for attachment by sessile organisms. Overall diversity of hard bottom areas also relates to development of vegetation. Macroalgae provides food, structural complexity, refuge from predation, and spawning/nursery sites for invertebrates and fish (Foster and Schiel 1985, Levin and Hay 2002).

Nearshore and/or profile placement potentially could result in direct burial of rocky subtidal habitat, if present. Burial could be partial and/or complete depending on height of rocky substrate and sand overburden depth. Generally, higher relief reefs support more diverse communities than low relief reefs that experience excessive siltation or sand scour (Ambrose et al. 1989). Direct burial of sensitive rocky subtidal habitat as a result of beach nourishment has not been documented in California, and is unlikely to be permitted.

Indirect sedimentation of rocky subtidal habitat from post-construction sand transport from a receiver site is of potential concern with any placement method, depending on project volume and proximity to this habitat. Sand inundation and scour naturally affects nearshore rocky subtidal habitats to varying degrees throughout California on a seasonal basis. Lower relief reefs are more vulnerable to sand disturbance, while higher relief reefs tend to remain above the sand. Sand channels within reef features may facilitate sand movement subtidally and reduce sedimentation effects on nearshore reefs (AMEC 2005).

No significant biological effects attributed to indirect sedimentation were reported for nearshore reefs in the vicinity of beach receiver sites with placement volumes ranging from 101,000 to 225,000 cy of sand in north San Diego County (AMEC 2005). Nearshore reefs included low to high relief (< 3 to > 3 ft, < 1 to > 1 m). It was suggested that sand channels between reefs may have provided avenues for sand movement, decreasing the likelihood of impacts from sand scour and burial of nearshore reefs.

No adverse impacts to nearshore hard bottom habitats were reported for several projects conducted on the East Coast of the United States with beach nourishment volumes ranging from approximately 500,000 to 1.9 million cy. Reefs included low relief, ephemeral patch reefs or sensitive species were on higher relief above the influence of sedimentation (Coastal Planning and Engineering 2004a, c).

- No sedimentation impacts to patch reefs occurring at depths of 35 to 70 ft (11 to 21 m) attributed to borrow site excavation or placement of 500,000 cy from the Central Boca Raton, Florida, Beach Nourishment Project were noted during and immediately post project compared to pre-project conditions (Coastal Planning and Engineering 2004c). Patch reefs ranged from low (~ 1 ft) to moderate (~ 3 ft) relief, with greater occurrence of scleractinian corals associated with higher relief. Patch reefs were subject to consistent presence of sediment both before and after construction, with no apparent trend relative to project activities.
- A 1.9 million cy beach renourishment project at Anna Maria Island, Florida, did not indicate any obvious impacts to nearshore hard bottom community during the first two years after construction (Coastal Planning & Engineering 2004a). Hard bottom consisted of low relief (<1 to < 2 ft) limestone rock platforms in water depths of ≤ 8 ft (≤ 2.4m). Seasonal sand inundation of the low relief habitat in the nearshore zone was similar or less than pre-project levels. The ephemeral hard bottom communities were dominated by species that rapidly colonize newly available habitat (e.g., green algae, turf algae, hydroids), and included few invertebrates and fish.

Several reports of beach nourishment damage to nearshore hard bottom habitats have been reported with project volumes ranging from 268,000 to 2.2 million cy.

- Sedimentation and partial burial of low profile coral reefs resulted from beach nourishment off the Florida East Coast (Courtenay et al. 1980 cited in Naqvi and Pullen 1982).
- A total of 12 to 14 acres (4.9 to 5.7 ha) of nearshore with hardbottom outcroppings was buried at Carlin Park, Florida from a 457,800 cy beach nourishment project, which extended the fill approximately 200 ft (60 m) seaward (Lindeman and Snyder 1998). Hard bottom consisted of limestone outcrops at depths between 0 and 13 ft (0 to 4 m). Significant reductions in fish species and abundance were noted immediately after beach nourishment and over the 15 month post-construction monitoring period. A 3.7 acre (1.5 ha) artificial reef was constructed three years after the project.
- Burial of coral reefs from dredge-fill projects off Broward County, Florida was reported by Goreau (2001).

- Burial of nearshore hard bottom was reported for beach nourishment projects at Anna Maria Island (2.2 million cy) and Boca Raton, Florida; artificial reefs were required as mitigation for those projects (Coastal Planning & Engineering 2004a, b).

Sediment management activities represent a concern when sensitive rocky subtidal habitat is in the vicinity. Nelson (1989) made a case for caution when conducting beach nourishment in proximity to hard bottom habitats in Florida because of their ecological productivity and the unknown specific effects of borrow area dredging and fill placement on the vast majority of hard bottom flora and fauna. A risk-averse approach to hard bottom burial in Florida also was recommended by Lindeman and Snyder (1999). This caution also is considered appropriate for California in areas where sensitive rocky subtidal habitat occurs.

5.4.3.4 Submerged Aquatic Vegetation

Vegetation differs in tolerance to sedimentation. Some species are quite tolerant and/or have opportunistic reproductive strategies characterized by annual recruitment and ability to rapidly colonize open space. Some algae are crustose or calcified and tolerant of sand abrasion and scour, and seagrasses have morphological and physiological adaptations to sedimentation that differ among species.

In contrast, a number of species are sensitive and may be adversely affected by sedimentation preventing attachment of early life stages and/or dislodgement due to abrasion and damage to basal stipes. Airoldi and Cinelli (1997) suggested that small-scale spatial variability of depositional environments may affect within-habitat diversity either through direct effects on individual species or on their propagules, and through indirect effects mediated by competitive interactions. Summaries of available information on sedimentation effects on sensitive SAV habitats in California are presented below.

Kelp Forests and Beds

Beach nourishment with nearshore and/or profile placement has the potential to directly impact this habitat, if present. Indirect sedimentation impacts from beach, nearshore, or profile placement will occur in the littoral zone with the potential to impact klep beds and/or the inshore limit of kelp, if present. Giant kelp and bull kelp forests generally occur at depths outside the beach depth of closure; however, the inshore portion of the kelp forest may extend into inshore waters during years without major storm disturbance. The following references review impacts to kelp from burial and/or sedimentation.

- Burial and/or sedimentation impacts have the potential to scour and increase mortality of adult and juvenile giant kelp (Aleem 1973, North 1986, Foster and Schiel 1985, Murray and Bray 1993).
- Light sedimentary deposits may inhibit recruitment of early life stages of giant kelp and other algae (Airoldi 2003, Germano and Cary 2005). Laboratory studies demonstrated that sediment cover as low as 10 mg/cm^2 over substrate precluded spore attachment and sediment overburdens of 108 mg/cm^2 (0.45 mm thick) reduced gametophyte survival of giant kelp by 90% (Devinny and Volse 1978).
- Reduction of canopy-forming giant kelp and bull kelp beds have been reported in areas affected by turbidity and thin layer sedimentation from landslides (Konar and Roberts 1996, Pondella et al. 1996, Bence et al. 1989).

- The 2001 San Diego Regional Beach Sand Project involved placement volumes ranging from 101,000 to 245,000 cy on beaches where kelp beds occurred offshore. No significant impacts were reported at monitoring sites within kelp beds (AMEC 2004).
- The Goleta Beach Nourishment Project, in Santa Barbara County, placed 79,000 cy of sand onto the beach and was followed by an additional project with 20,000 cy of sand placement (Moffatt & Nichol 2005c). Results of monitoring conducted before and quarterly for one year after beach placement indicated no obvious sedimentation impacts to kelp beds (see Section 3.2.6).

Understory species

- Understory brown algae such as feather boa kelp, bladder chain kelp, and winged kelp appear to be more tolerant of sedimentation than larger, canopy species such as giant kelp and bull kelp (North 1986, Konar and Roberts 1996, AMEC 2005).

Turf Algae

Algae differ in their tolerance to sedimentation with some considered sensitive, while others are considered opportunistic, sand tolerant, or sand loving (psammophyte) (Daly and Mathieson 1977, Sousa 1979a, Littler et al. 1983).

Turf algae that may be found in of sand disturbed habitats in California include: calcified coralline algae (*Corallina, Lithothamnion, Lithorhrix*), crustose *Ralfsia,* opportunistic algae (e.g., *Enteromorpha, Gelidium, Ulva*), and a variety of psmmophyte algae (*Ahnfeltia plicata, Chaetomorpha linum, Chondria nidifica, Gigartina papillata, G. volans, Gracilaria* spp*., Gymnogongrus leptophylluss, Neohodomela larix, Phaeostrophion irregulare, Pterocladia media, Taonia lennebackeriae,* and *Zonaria farlowii*) (Abbott and Hollenberg 1976, Littler et al. 1983, Turner 1985, Murray and Bray 1993).

The following laboratory and/or experimental studies demonstrate that several of the above-noted species may be negatively affected by prolonged sand burial, but can survive and regrow from basal remnants.

- Experimental studies of sedimentation (up to 7 mm for 2 to 3 months) on colonization of new substrate (bricks) indicated reduced number of plant species, reduced plant and animal cover, but favoring a few small opportunistic taxa (e.g., *Ulva* and *Enteromorpha*) compared to unstressed bricks (Thomsen and McGlatery 2005).
- Laboratory experiments demonstrated little to no loss of biomass of several species of algae after burial by 2 to 5 cm of sand over periods ranging from 4 to 5 weeks for *Ahnfeltiopsis linearis* (as *Gymnogongrus linearis*), and *Neorhodomela larix* (Trowbridge 1996 cited in Airoldi 2003). Although reduced biomass was observed for *Codium setchelli*, the laboratory result differed from field observations and it was suggested that the laboratory findings may have been influenced by use of pieces of the plant (Airoldi 2003).
- *Ahnfeltiopsis linearis* (as *Gymnogongrus linearis*) and *G. platyphyllus* displayed different responses to sand burial, with *G. linearis* surviving and producing new

branches after 6 months of sand burial whereas *G. platyphyllus* did not survive 1 month of burial (Newroth 1972 cited in Airoldi 2003). .

- *Gracilariopsis lemaneiformis* (as *Gracilaria lemaneiformis*) thalli (approximately 10 cm long) survived burial in vertical or horizontal position under 2 and 10 cm of sand for 90 days, but no growth was observed (Santelices et al. 1984 cited in Airoldi 2003).
- *Neorhodomela larix* (as *Rhodomela larix*) holdfast and basal crusts survived 3 months of 15 to 20 cm of sand burial, but upright portions decayed and epiphytes (*Microcladia borealis, Cryptosiphonia woodii, Gipartina papillata, Ulva* sp.) did not survive 4 to 6 weeks of burial (D'Atononio 1986 cited in Airoldi 2003). Coralline crusts were reduced in size and slightly discolored compared to control specimens after burial.
- Experimental studies have shown filamentous red algae (e.g., *Polysiphonia*) to be tolerant of sedimentation, although growth was enhanced at lower sedimentation rates (Airoldi and Cinella 1997).
- *Zonaria farlowii* growth ceased shortly after sand burial and tissue degenerated as burial time increased; however, growth resumed from basal proliferations that survived over 6 months (Dahl 1971 cited in Airoldi 2003).
- Erect coralline algae (e.g., *Lithothamnion*) is sensitive to sedimentation (Maughan 2000).

Although sand tolerant species may survive and regrow after prolonged sand burial, early life stages of algae generally are vulnerable to sedimentation.

- Laboratory experiments demonstrated that *Fucus serratus* embryos respond negatively to deposition with fine and organically enriched sediments, particularly with hydrogen sulfide (Chapman and Fletcher 2002 cited in Airoldi 2003 and Germano and Cary 2005).
- Spores of *Saccorhiza polyschides* and *Laminaria saccharina* were able to germinate and grow, but could not attach on top of silt and spores were produced few gametophytes and no sporophytes when covered by sediment (0.3 mg/mm2) (Norton 1978 cited in Airoldi 2003).
- Settlement of *Laminaria saccharina* on slides was inhibited by silt (Burrows 1971 cited in Airoldi 2003).
- Laboratory experiments showed that light dusting of sediment reduced the percentage of zygote attachment to primary substrate for the fucoid alga (*Hormosira banksii*) and bull kelp (*Durvillaea antarctica*) by 34 and 71%, respectively, in New Zealand (Schiel et al. 2005).
- Laboratory experiments demonstrated decreased adhesion of zoospores of *Ecklonia cava* and *Undaria pinnatifida* by 50% at 0.5 mg/cm^2 and 3 mg/cm^2 prevented adhesion (Arakawa and Matsuike 1992 cited in Airoldi 2003). Survival of gametophytes was reduced to 40% at 1 mg/cm^2 and was prevented at 10 mg/cm^2.

<u>Seagrasses</u>

Different species of seagrasses display a variety of adaptations to sedimentation, including long leaves, regrowth of leaves from rhizomes, energy reserves stored in leaves and

rhizomes, transformation of buried leaves to rhizomes, and/dor elongration of buried growth meristems to proper sediment level (Thorhaug et al. 1973, Stewart 1989, Harrison 1990, Zimmerman et al. 1995, Burke et al. 1996, Duarte et al. 1997). In addition, oxygen is supplied to the rhizomes from the leaf blades; therefore, rhizomes are adapted to anoxic conditions created by substrate cover (Phillip and Menez 1988). However, plants may be adversely affected and/or die when thresholds of sedimentation are exceeded.

Seagrasses also may be adversely affected by increased turbidity associated with sedimentation and possibly fine particulate coatings that may impact photosynthesis (Kirkman 1997). Effects of sedimentation and turbidity may be interrelated, particularly in embayments. Turbidity effectcs on seagrasses are reviewed in Section 5.5 (Subsection 5.5.3.1).

Natural burial and/or sedimentation of seagrass beds may occur from seasonal sand movement along the beach profile, storms, and/or watershed erosion and runoff (Littler et al. 1993, Onuf and Quammen 1983, MBNEP 2000, 2004). Available reports indicate that seagrasses may tolerate complete burial if it is not prolonged and substantial sedimentation if sufficient leaf length is exposed to support metabolism (Gibbs 1902, Littler et al. 1983, Thorhaug et al. 1973, Fonseca et al. 1988, Stewart 1989, Harrison 1990, Chambers Group 2004).

Wilber et al. (2005) reviewed that seagrasses have the ability to withstand limited burial depending on species-specific growth form, depth of burial, and properties of the sediment (particularly depth of the anaerobic layer), and indicated that mortality may result if plant elongation and growth rates are insufficient to surpass sediment accretion rates. Plant survival of sedimentation has been linked to growth rate and size (Duarte et al. 1997). There may be an exponential relationship between plant loss and percent of blade buried for some species (Fonseca et al. 1988). Percent burial also may be important from the perpective of recovery after disturbance. Regrowth from rhizomes may occur if there is sufficient carbon reserves; however, reserves may be inadequate if there is continuing low productivity (Stewart 1989).

Seagrass recovery time after disturbance generally depends on whether the rhizome system remains intact (Dethier 1984, Turner 1985, Engle et al. 1998, Reed et al. 1988, Stewart 1989). Because burial and/or sedimentation do not remove the rhizome system, recovery would be expected from temporary impacts. However, complete habitat loss as a result of prolonged burial could potentially take years to recover.

Limited information is available regarding impact thresholds to seagrasses from burial and/or sedimentation. Another important consideation is exposure of sufficient blade lengths to support structural habitat functions of providing spawning and/or nursery habitat for fishes and invertebrates. Therfore, critical impact thresholds should consider both duration and depth of burial.

Sediment characteristics also may be an important consideration with respect to potential impacts. Studies of different species of seagrasses suggest sensitivitiy to siltation when silt/clay content exceeds 15% (Terrados et al. 1998).

No reports of significant impacts to seagrasses from beach nourishment projects were identified with the literature review. Several reports document dredge-related effects to seagrassess in embayments, mainly from impacts associated with removal (Section 5.3.2.4)

and turbidity (Section 5.5.3.1). Few reports of impacts from burial and/or sedimentation from dredge discharges have been reported (Harrison 1990, Fonseca et al. 1992).

Differerences in the nature of burial and sedimentation resulting from beach nourishment or dredging may be an important impact consideration. For example, Fonseca et al. (1992) pointed out that seagrasses almost never are buried in an upright position from dredging operations, but rather bend over with the typically rapid addition of sediments and become completely buried even with the addition of only a few centimeters of sediment. Blois et al. (1961) also found lateral shifting of sediments to result in complete cover of eelgrass leaves by as little as 4 inches (10 cm), which resulted in their loss. These examples may be relevant to sediment management activities involving beach nourishment and/or in-bay discharge, if seagrasses were present within the project footprint.

In contrast, Harrison (1990) found eelgrass to survive partial burial when sedimentation resulted from currents carrying released sediments into eelgrass beds. This example may be relevant to sediment management activities involving beach nourishment and/or dredging, if seagrasses are located farther away.

Calfiornia seagrasses (surfgrass, eelgrass) are reviewed in greater detail in Sections 3.37 and 3.3.8. Information relevant to burial and sedimentation are summarized below for surfgrass and eelgrass, and following that additional relevant information for different species of seagrasses that was considered in this summary is provided.

Surfgrass

Surfgrass adaptation and tolerance to partial sand burial and/or sedimentation have been established. However, surfgrass is vulnerable to damage and/or loss with complete and prolonged burial.

- Several morphological adaptations contribute to surfgrass sand tolerance, including long leaves that may extend above the sand surface, rhizomatous root system that binds sediment, and fibrous leaf sheaths and thick-walled roots that provide protection from sand abrasion (Littler et al. 1983, Cooper and McRoy 1988, Stewart 1989, Barnabas 1994).
- Because of the long length of surfgrass blades, generally 1.5 to 3 ft (0.5 to 1 m) intertidally and 2 to 6.5 ft (0.6 to 2 m) subtidally, surfgrass theoretically can withstand substantial sedimentation before complete burial.
- Growth rates of surfgrass are moderate for leaf blades and slow for rhizomes. Leaf growth rates vary during the year; clipping experiments in San Diego County demonstrated leaf re-growth of nearly 1 ft (30 cm) in two months (Stewart 1989), representing approximately 0.2 in/day (0.5 cm/day). Annual rhizome growth rates are similar between Oregon and Baja California, ranging from 3.1 in (8 cm) to 3.4 inches (8.6 cm) per year (Turner and Lucas 1985, Ramirez-Garcia et al. 1998).
- Surfgrass is considered sand tolerant and may experience natural sand inundation covering a portion of the blade length (Littler et al. 1983, Turner 1985, Stewart 1989).
- Stewart (1989) reported that for many months wet sand keeps rhizomes and developing leaf shoots damp.

- Gibbs (1902) reported that as long as the tips of the leaves are free the plant thrives, and observations of tufts of leaves apparently growing in the sand are in reality anchored to rock a meter, perhaps, below.
- Leave clipping experiments suggest regrowth from reserves stored in rhizomes; however, rhizome reserves may be inadequate to support regrowth of leaves if there is continuing low productivity (Stewart 1989).
- Phillips (1979) reported healtlhy surfgrass beds with sand depths of 3 in (8 cm).
- Complete and prolonged sand burial was suspected as causing widespread loss of surfgrass near Santa Barbara (Reed et al. 2003).
- Reed et al. (2003) reported substantially lower seedling survival of intertidal surfgrass when persistently buried by sand with cover depths of 2 to 10 inches (5 to 25 cm).

Limited information is available with respect to the degree of sand burial surfgrass can withstand, but is likely dependent on the duration and extent of burial. Critical impact thresholds have not been established for surfgrass.

CEQA/NEPA significant impact thresholds for California beach nourishment projects have included substantial burial for ≥ 1 year (i.e., spanning more than one season) (MEC 2000a) or > 2/3 burial for > 6 months (CRM 2000). Both of these thresholds consider that substantial burial for more than one season may affect the ability of new rhizome shoots to survive and grow. This seems reasonable given that sand accretion and erosion occur on a seasonal basis and surfgrass may normally experience seasonal periods of sedimentation and re-emergence.

The threshold used by MEC (2000a) for the 2001 San Diego Regional Beach Sand Project did not set a fixed sand depth in its definition of substantial burial of surfgrass, but instead compared sand thickness predictions for beach fill projects ranging from 88,000 to 240,000 cy (from Moffatt & Nichol 2000) to reef heights and surfgrass blade lengths; maximum sedimentation estimates in localized surfgrass areas were 7 to 11 in (17 to 28 cm), representing < 30% burial of surfgrass blades. CRM (2000) established the 2/3 burial threshold as a consideration of the need for a portion of the blades to remain above the sand level to provide the rhizomes with oxygen in order to limit long-term damage. The threshold used by CRM (2000) for the San Clemente Replenishment Program was not exceeded; < 50% burial of surfgrass blades was estimated based on consideration of reef heights and sand thickness predictions for beach fill sites with volumes ranging from 45,000 to 125,000 cy (Moffatt & Nichol. 2000a).

Whether a 2/3 burial threshold is sufficiently protective of surfgrass has not been demonstrated. Gibbs (1902) reported that surfgrass thrives as long at the “tips of the leaves wave free”; although this description is imprecise it does suggest some blade height above the substrate to accommodate movement of the blades tips. Survival of surfgrass seedlings in the intertidal apparently is limited by prolonged burial of up to 10 in (25 cm) (Reed et al. 2003). Therefore, a 2/3 burial threshold applied to adult blade lengths may not be protective of seedling survival. For example, 2/3 burial of intertidal surfgrass with blades ranging from 1.5 to 3 ft (45 to 90 cm) represents burial depths of 1 to 2 ft (30 to 60 m).

As noted above, another important consideration with respect to sedimentation is protection of habitat functional values. Surfgrass is nursery habitat to commercially important California

spiny lobster and provides shelter and foraging habitat for a variety of other species (Engle 1979, Stewart and Meyers 1980, DeMartini 1981). Based on this consideration, a 2/3 burial threshold is considered minimally protective of habitat functions. A lower significance threshold (e.g., > 50% burial of average blade lengths for > 6 months) may be more appropriate to consider.

No reports of significant impacts to surfgrass from burial and/or sedimentation associated with beach nourishment projects were identified with the literature review.

- Surfgrass tolerated short term exposures to sand overburden depths (i.e., most surfgrass leaves covered with sand) of approximately 5 in (11.6 to 12.5 cm) after the Goleta Beach Nourishment Demonstration Project (Chambers Group 2004). This project involved placement of 97,600 cy of sand onto the beach from three sources between 2003 and 2004. Surveys were conducted before and at approximately 1, 3, 6, and 12 months after the initial placement. Low percent cover of surfgrass and high percent cover of sand were noted during one survey each at two transects located 6,500 ft (2000 m) and 7,874 ft (2,400 m) downcoast, but not on the following survey indicating sand cover was transient and did not result in loss of surfgrass. The duration of sand cover between surveys was not monitored. The transect location closest to the project site showed greater variability in surfgrass cover among surveys than the farther downcoast transect. Chambers Group (2004) concluded that changes in surfgrass and sand cover may have been related to the project, but were within the variability at the site prior to beach nourishment.
- No long-term adverse impacts to surfgrass beds were reported for the 2001 San Diego Regional Beach Sand Project. AMEC (2005) concluded that short term impacts were observed at several locations, but no long-term adverse environmental impacts were observed. A total of 984,000 cy was placed between Carlsbad and Solana Beach, an area of coastline with patchy occurrence of low to high relief reefs, some with surfgrass (see Section 3.3.5). Post-construction monitoring of 18 rocky subtidal sites showed no change in sand cover or surfgrass at 8 sites, sand cover increased without apparent change to surfgrass at 5 sites, and 5 sites had changes in surfgrass cover and/or density (AMEC 2005). Of the 5 sites where there was a change in surfgrass, 2 sites were controls, 1 site had no change in sand cover, and 2 sites had changes in surfgrass possibly influenced by change in sand cover. One of the affected sites may have been influenced by other projects, and the other site had a change in surfgrass density but not cover. AMEC (2005) concluded that short term impacts were observed at several locations, but no long-term adverse environmental impacts were observed.

Eelgrass

Eelgrass occurs in relatively protected habitats, but has adaptations that contribute to tolerance to sedimentation. Eelgrass mainly occurs in embayments, but may be found along some protected areas of coastline along the mainland and Channel Islands of California. Its distribution along the coast suggests adaptation to some level of sedimentation. Although eelgrass may be tolerant of some sedimentation, it appears to be sensitive to complete burial and/or substantial sedimentation. Sedimentation with a high silt/clay content that increases turbidity also would be of concern (Section 5.5.3.1).

- Morphological adaptations include long, buoyant leaves, rhizomatous root system, and storage of carbohydrate reserves in leaves, rhizomes, and roots (Zimmerman et al. 1995, Burke et al. 1996). Field studies demonstrate that buried leaf bundles may transform into rhizomes a few centimeters below the sediment surface (normal position) (Harrison 1990).
- Eelgrass occurs outside the surf zone and generally outside the active area of littoral transport along the mainland, although inshore portions of beds may extend as shallow as -16 ft (5 m) (Ware 1993).
- Eelgrass has relatively high growth rates. During active growth (e.g., spring through summer), eelgrass may rapidly expand with vegetative growth rates up to 8 cm^2/day for leaves and 1.2 cm/day for rhizomes (Merkel unpublished cited in MEC 2000b).
- Onuf and Quammen (1983) reported loss of eelgrass in Magu lagoon after a storm. A sedimentation depth of 4 in (10 cm) was reported to result in loss of short-blade eelgrass. At a deeper water site, eelgrass survived 6 in (15 cm) of sedimentation from the first storm, but subsequently deteriorated. From a lagoon-wide perspective, eelgrass showed a gradual recovery after the first major storm, but had not recovered to pre-storm levels over the subsequent four years of the study. It is possible that other factors besides sedimentation thickness may have differentially affected eelgrass in this shallow embayment. (e.g., increased silt/clay content, continued accretion disturbance, greater sediment resuspension and turbidity associated with increased fines and shallower depths, depth of the anaerobic layer, increased thermal stress).
- Blois et al. (1961) found complete cover of eelgrass leaves by as little as 4 in (10 cm) resulted in their loss.
- Eelgrass distribution in Morro Bay has been substantially reduced by sedimentation from watershed inputs (MBNEP 2000, 2004).

Limited information is available with respect to the degree of partial burial and/or sedimentation eelgrass can withstand. No critical impact thresholds have been established.

- Field studies showed that eelgrass plants were able to survive partial burial where rhizomes were buried 4 to 6 in (10-15 cm) deeper than normal and some leafy material remained above the sediment surface (Harrison 1990). Laboratory experiments, including burial of rhizomes with 1 to 6 inches (2 to 15 cm) of sand and trimming leaves so that 2 to 12 inches (5 to 30 cm) remained exposed above the sand surface demonstrated that eelgrass was able to survive with as little as 2 inches (5 cm) of the leaf bundle above the sediment (Harrison 1990).

Eelgrass meadows are used as spawning and/or nursery areas for many commercially and recreational important finfish and shellfish species, including California halibut, California spiny lobster, Dungeness crab, Pacific herring, rockfish, and juvenile salmon (Hoffman 1986, Ware 1993, MEC 2000b, LFR 2004). Eelgrass meadows also are used as nursery areas for small forage fish (anchovies, silversides), which are favored prey of the endangered California least tern.

Dredge area restrictions and dredge and disposal environmental windows have been used to minimize potential sedimentation/turbidity impacts on species using eelgrass habitats as

nursery areas in some embayments in California; e.g., Crescent City Harbor (USACE 1998c) and San Francisco Bay (USACE et al. 2001).

No reports of significant impacts to surfgrass from burial and/or sedimentation associated with beach nourishment projects were identified with the literature review.

- Chambers Group (2004) reported seasonal die-back and recovery of eelgrass was normal and eelgrass density and cover one year after the BEACON Goleta Beach Nourishment Demonstration Project was similar or greater than the pre-project condition. This project involved placement of 97,600 cy of sand onto the beach from three sources between 2003 and 2004.

Eelgrass has been substantially affected by dredging in embayments from removal, burial, erosion, and turbidity (Phillips 1984, Zieman and Zieman 1989, Giesen et al. 1990, Harrison 1990, Hoffman 1990, Nitsos 1990, Fonseca et al. 1992, Onuf 1994). Limited information is available with respect to effects attributed solely to burial and/or sedimentation.

Other Seagrass Species

- Fonseca et al. (1992) pointed out that seagrasses almost never are buried in an upright position from dredging operations, but rather bend over with the typically rapid addition of sediments and become completely buried even with the addition of only a few centimeters of sediment.
- Turtle grass (*Thalassia testudium*) lost leaves but not the rhizome system with 4 in (10 cm) of overburden, and re-growth occurred after currents carried away sediment (Thorhaug et al. 1973 cited in Wilber et al. 2005).
- Shoalgrass *Halodule wrightii* may exhibit good (75%) survival when only 25% of blade is buried, but only 5% survived when 75% of blade was buried (Fonseca et al. 1988 cited in Wilber et al. 2005). Shoalgrass leaf blades may reach lengths of approximately 1 ft (32 cm) (NOAA 2001b).
- Sedimentation experiments in a mixed Philippine seagrass meadow with sediment additions ranging from 1 to 6 in (2 to 16 cm) was monitored over time intervals extending to 10 months (Duarte et al. 1997). There was a gradient in survival that the authors linked to plant growth rate and size. The pattern of species loss following sediment disturbance corresponded to the following sequence from least to most tolerant species: *Thalassia hemprichii* -> (*Cymodoce rotundata*, *Syringodium isoetifolium*, *Halophila uninervis*) ->*C.serrulata*-> *Enhalus acoroides*.
- Terrados et al. (1998) compared patterns of change in species richness and biomass of Southeast Asian seagrass communities along siltation gradients in the Philippines and Thailand and found that seagrass species richness and community leaf biomass declined sharply when the silt and clay content of the sediment exceeded 15%. The pattern of species sensitivity to siltation corresponded to the following sequence from least to most tolerant species: *Syringodium isoetifolium → Cymodoce. rotundata →Thalassia hemprichii →Cymodocea serrulata →Halodule uninervis →Halophila ovalis →Enhalus acoroides*.
- Declines of *Zostera* and *Heterozostera* have been linked to smothering by sediment, accumulation of sediment and the consequent shallowing of the water, increased

turbidity associated with sedimentation, and possibly fine particulate coatings from suspended sediment preventing photosynthesis in Australia (Kirkman 1997).

- Wilber et al. (2005) reviewed that a seagrass adaptation to moderate levels (undefined) of sediment deposition can lead to increased vertical growth relocating growth meristems closer to the sediment surface such that growth can occur in the proper light regime. The authors referenced work by Duarte et al. (1997), who showed that vertical growth is triggered by a light-sensitive mechanism in the shoot meristem. In addition, buried seedlings of European seagrass, *Cymodoce nodas*, responded differently when the shoot meristem was exposed or not to artificial light, with greater mortality and less vertical internodal growth when artificially illuminated (Duarte et al. 1997).

5.4.3.5 Embayments

Burial and/or sedimentation concerns are similar for both shallow inlet and deepwater inlet embayments. A primary concern of beach nourishment projects is the potential for sediment transport of placed materials to accelerate the infilling of downcurrent navigational channels, which could increase dredging frequency to maintain the channels (NRC 1995). Embayments may be vulnerable to sedimentation as a result of beach nourishment involving nearshore, beach, or profile placement in the vicinity. The degree of vulnerability will depend on a number of factors including, but not limited to: proximity to sediment management activity, volume of placed sands, prevailing current direction, outflow characteristics (including tidal prism as appropriate) of water body, and inlet stability. Historic records of inlet closures and/or maintenance dredging requirements generally provide relevant information regarding potential vulnerability to sedimentation effects.

A special concern for shallow inlet embayments is the potential for beach nourishment to increase the risk for inlet closure. This was a stated concern for the 2001 San Deigo Regional Beach Sand Project, Goleta Beach Pilot Demonstration Project, and South Central Coast Beach Enhancement Program (SANDAG and USDN 2000; Chambers 2000b, Moffatt & Nichol 2005a, Moffatt & Nichol 2005c). Monitoring of inlet status and commitments to remove excess sedimentation was specified in the above-referenced projects.

- Monitoring during and after construction of the Goleta Beach Nourishment Pilot Demonstration Project (97,600 cy) did not document inlet closure and/or sedimentation problems at Goleta Slough (Moffatt & Nichol 2005c).
- The BEACON South Central Coast Beach Enhancement Program, which has not yet been implemented, specifies as a mitigation measure the monitoring of downcurrent inlets (e.g., Carpinteria Creek and Marsh, Goleta Slough, and with removal of excess sedimentation until inlets are stabilized, if necessary.
- Monitoring for four years after the 2001 San Deigo Regional Beach Sand Project demonstrated that the two jetty-stabilized lagoon entrances, Agua Hedionda and Batiquitos, remained open to the full range of tidal exchange with only minor variations in water depth and a post-project dredge rate 10% lower than pre-project (Coastal Engineers 2004). Closure frequency varied for unstabilized inlets. Elijo entrance channel remaining open for a greater percentage of time (91% vs. 43% historically), the San Dieguito channel remaining open for a lesser percentage of time (51% vs. 77% historically), and the Los Peñasquitos channel remaining open for a comparable percentage of the time (86% vs. 93% historically).

Dredge-related sedimentation and/or in-bay disposal is a concern in areas with sensitive habitats (LaSalle et al. 1991, NRC 1985, Wilber and Clarke 2001, Germano and Cary 2005, Wilber et al. 2005). Burial and/or sedimentation concerns for eelgrass habitats are summarized above (Section 5.4.3.4). Dredge area restrictions and environmental windows have been used to minimize potential sedimentation/turbidity impacts to eelgrass habitats as nursery areas in some embayments in California; e.g., Crescent City Harbor (USACE 1998c) and San Francisco Bay (USACE et al. 2001).

5.4.4 Sedimentation Impact Concerns to Species

The species summaries are organized by higher order categories (i.e., invertebrates, fishes, birds, and marine mammals). For species with no reports of impacts based on the literature review, potential impacts consider other relevant reports and species biology.

5.4.4.1 Invertebrates

The following direct and indirect impacts to invertebrates from burial and/or sedimentation associated with sediment management activities have been reported (Navqi and Pullen 1982, LaSalle et al. 1991, Greene 2002, Germano and Cary 2005, Wilber et al. 2005):

- Direct burial and/or indirect sedimentation of early life stages of commercial shellfish species.
- Direct burial and loss of benthic invertebrate populations.
- Direct burial and/or sedimentation loss of rocky substrate invertebrates
- Indirect sedimentation impacts to local populations.
- Indirect reduction in forage for secondary consumers.
- Indirect displacement.

LaSalle et al. (1991) suggested that frequent repositioning and/or increased burrow maintenance activities associated with response to sedimentation could result in energy deficits for growth and reproduction in shellfish based on consideration of studies of energy costs for burrowing (cited Trueman and Foster-Smith 1976).

Invertebrates may be directly affected by burial and/or indirectly affected by sand transport sedimentation and deposition of resuspended sediments. These impacts may be more or less of a concern depending on habitat and/or species, as follows:

- Burial recovery rates in soft substrates relate to depth of overburden, location of disturbance, and sediment characteristics.
    - Recovery rates generally are faster for sandy beach than nearshore sands.
    - Recovery rates may be faster when overburdens are < 3 ft (1 m).
    - Recovery rates may be faster when source sands closely match existing sediment characteristics and slower when substantially coarser or higher silt/clay content.

- Placement activities are of particular concern where burial and/or sedimentation may occur to spawning and/or nursery grounds of fishery species (Abalone, California lobster, Dungeness crab, Pismo clam, Sea Urchins).
- Placement activities are of particular concern where burial and/or sedimentation may occur to invertebrates in sensitive hard bottom and/or SAV habitats.
- Invertebrate forage reduction concerns for shorebirds and surf zone fish are less when disturbance occurs prior to spring recruitment, but concerns increase as the season progresses and/or frequency of disturbance increases.
- Invertebrate forage reduction concerns for demersal fish and marine mammals are less understood, but concerns increase as recovery rates decrease and/or frequency of disturbance increases.

<u>Direct Burial and/or Indirect Sedimentation of High Interest Shellfish Species</u>

Abalone

Beach nourishment has the pontentital to impact abalone, if present in the vicinity (Section 4.2.1). Limited information indicates that abalones are capable of tolerating some partial and/or temporary burial, but may move from sanded-in reefs (Cox 1962, CDFG 2001). Larval settlement and/or small juvenile abalones may be more vulnerable to sedimentation effects because of their occurrence on the underside of rocks. Potential impacts would depend on the nature and duration of sedimentation of rocky reefs and presence of abalone. No reports of impacts to abalone from sediment management activities were identified with the literature review.

Lobsters

Beach nourishment has the potential to affect Califiornia spiny lobster, if present in the vicinity (Section 4.2.2). Calfiornia spiny lobsters may be more vulnerable to impact in nearshore waters between March and October based on migration, although juveniles spend their first two years in surfgrass beds (Engle 1979, DFG 2001). Because lobsters forage nocturnally across a range of habitats, vulnerability to burial/sedimentation impacts may be greater for day-time shelter and/or nursery habitats where lobsters are more sedentary (rocky subtidal, kelp beds, surfgrass beds, Sections 5.4.3.3 and 5.4.3.4).

Reports for other species indicate a general sensitivity to silty sedimentation.

- Post-pueruli larvae of spiny lobster (*Panulirus argus*) avoid settling in heavily silted algal beds (Herrnkind et al. 1988).
- Juvenile American lobster (*Homarus americanus*) avoid gravel shelters covered with silt/clay (Pottle and Elner 1982 cited in Wilber et al. 2005).

Limited information is available with respect to impacts to lobster from sediment management activities.

- No strong correlations between lobster abundance and percent cover of sand, low-relief substrate, and high-relief substrate were observed after the 2001 San Diego Regional Beach Sand Project (AMEC 2005). Observations suggested that lobsters were patchy in distribution and there was no consistent pattern in abundance relative

to habitat characteristics. No substantial loss of surfgrass nursery habitat was reported for that project (Section 5.4.3.4).

Dungeness Crabs

Dungeness crabs have the potential to be affected by burial associated with beach nourishment and/or in-bay disposal, if present (Section 4.2.3). Burial may be of greater concern when early life stages settle (April to June) and/or adults congregate to mate (March to July).

Indirect sand transport sedimentation from beach nourishment and/or thin-layer dredge sedimentation generally would not be expected to adversely affect adult crabs because of their burrowing capabilities and physiological adaptations to sedimentation (DFG 2001, McGraw 2003). Sedimentation is more of a concern for nursery habitat such as eelgrass, which may be adversely affected (see Section 5.4.3.4). Sedimentation also may reduce value of other sheltering habitats. For example, yellow shore crabs out-competed Dungeness crabs, aggressively excluding them from shelter and adversely affecting their recruitment when sedimentation and turbulence reduced the three-dimensionality of a mitigation oyster-shell reef (Visser et al. 2004).

Pismo Clams

Pismo clams have the potential to be affected by beach nourishment, if present in the vicinity (Section 4.2.4). Burial effects may be of greater potential concern to Pismo clams with nearshore placement rather than beach placement given the current distribution of the species (Section 4.2.4). Pismo clams are adapted to living in shifting sands and may rapidly change vertical position in sediment (Herrington 1930, Haderlie and Abbot 1980, DFG 2001). However, there have been cases of Pismo clams being buried so deeply by shifting sand that they were apparently unable to dig out (Herrington 1930). Therefore, Pismo clams may be adversely affected by rapid burial, but indirect sand transport sedimentation following natural coastal process rates would not be expected to result in adverse effects.

Only one report was found with respect to effects of beach nourishment on Pismo clams, and monitoring was inconclusive.

- Pismo clams may be found buried up to 12 in (30 cm) (DFG 2001). Therefore, they may be tolerant of some sedimentation. The average density of Pismo clams in the low intertidal significantly declined (from 1.2 to 0.14 per square meter) after the 1977 beach nourishment project at Imperial Beach, California. However, the authors cautioned that the result was based on very few individuals (Parr et al. 1978).

Sea Urchins

Beach nourishment has the potential to affect sea urchins, if present in the vicinity (Section 4.2.5). Complete burial would result in mortality, but some individuals may be able to escape burial depending on sediment thickness. Sea urchins would not be expected to be impacted by sedimentation due to their mobility; however, sedimentation could indirectly affect sea urchins by potentially reducing algal food supply and/or adversely impacting larval settlement locations. Studies in the vicinity of landslides indicate that sea urchins may be eliminated in areas with frequent and persistent sedimentation (Pondella et al. 1996). Therefore, indirect

sand transport sedimentation after beach nourishment would be of concern in rocky and/or kelp bed habitats used by sea urchins.

No significant impacts to sea urchins have been reported from beach nourishment projects.

- Abundances of red and purple sea urchins were monitored in kelp beds before and after the 2001 San Diego Regional Beach Sand Project, which involved beach placement volumes ranging from; no changes in abundance attributed to beach nourishment were reported (AMEC 2005).

Mariculture Species

Burial and/or sedimentation may adversely affect larval attachment and adult survivorship of mussels and oysters in the vicinity of dredging activities.

- Oyster larvae attachment may be impaired by 1 to 2 mm of deposited sediment (Galtsoff 1964 cited in LaSalle et al. 1991). American oyster require a clean, hard substrate for attachment, but can tolerate thin layer sediment deposits of perhaps up to 1 mm (R. Mann personal communication cited in Germano and Cary 2005).
- LaSalle et al. (1991) reviewed that mortality of market-sized oysters was reported around dredging in Chesapeake Bay (cited Rose 1973). However, little detrimental impact was reported in cases where settled material was dissipated by currents (cited Wilson 1950 and Ingle 1952).
- Mortality of mussels around disposal operations when the deposited material remained in place for some time was reported was reported in the Rhode Island Sound (Saila et al. 1972 cited in LaSalle et al. 1991).

<u>Direct Burial and Loss of Sandy Beach Invertebrates</u>

Beach nourishment will adversely affect benthic invertebrates that live within the sediment (infauna). Generally, burrowing ability and potential to escape overburdens declines over relatively short time frames (e.g., 3 days) (Mauer et al. 1986). Sediment compatibility between native and overburden sediments may affect burrowing and survival. Large, mobile macroinvertebrates that live above the sediment surface may be able to escape burial effects.

- Mortality of infauna is generally assumed to be complete when burial exceeds 3 feet (0.9 m); survival of shallower overburdens depends on species and sediment characteristics (Kranz 1975, Maurer et al. 1986, Nelson 1985, LaSalle et al. 1991, Lynch 1994, NRC 1995, Greene 2002).
- Experimental studies show that vertical migration rates slow and mortality increases when overburdens have silt/clay contents ranging from 17 to 99 percent depending on species (Turk and Risk 1981, Maurer et al. 1986, Cummings et al. 2003). Juveniles may be adversely affected by silt/clay layers < 0.4 in (< 1 cm) thick and substantial impact may occur from 30 to 60% silt/clay layers up to 4 in (10 cm) thick.
- Substantial reductions in infauna species and abundance have been documented during and immediately after several beach nourishment projects involving hydraulic placement of sands on beaches (Parr et al. 1978, Reilly and Bellis 1983, Gorzelany and Nelson 1987, Burlas et al. 2001, Rackcinski et al. 1996 and 2001, Versar 2004). Recovery rates may be within natural seasonal patterns when construction is

completed prior to and/or early in spring prior to peak recruitment. Recovery rates may be delayed if construction spans peak recruitment and productive periods (spring-summer) and/or there is a substantial change in surbstrate conditions (Section 4.2.6).

Sedimentation Impacts to Sandy Subtidal Populations

Elevated silt/clay loading may occur in nearshore habitat as a result of indirect sedimentation resulting from beach nourishment. For example, the fine content of placed materials may disperse offshore during hydraulic placement and/or as waves erode and rework placed sediments. Dispersed fines settle in the nearshore outside the turbulent surf zone. Depending on placement method and location, this transport and deposition of fines may be relatively rapid (e.g., hydraulic beach placement, nearshore placement, profile placement, surf zone placement) or occur in pulses over time (e.g., dune beach placement). Based on project volume and fine content of placed materials, potential silt loading may range from low to high. For example, placed materials with a 10% fines content would yield 100,000 cy of fines with a 1 million cy project or 10,000 cy with a 100,000 cy project. Review of available monitoring reports suggests that effects of silt/clay loading may relate to project volume and hydrodynamics of the receiving environment (Parr et al. 1978, Van Dolah et al. 1984, Rakocinski et al. 1996).

Reports vary with respect to sedimentation impacts to nearshore invertebrates from indirect sand transport after beach nourishment. Relatively few studies have examined indirect sand transport effects on nearshore invertebrate communities adjacent to beach nourishment sites. Three studies detected temporary elevations in silt/clay levels in nearshore sediments as a result of hydraulic placement of project volumes ranging from approximately 1 million to 8.1 million cy on beaches in California, New Jersery, and North Carolina. Silt/clay levels dissipated after storms and/or were not apparent after one year; no long-term adverse effects to nearshore benthic communities apparently resulted from the temporary silt-clay loadings (Parr et al. 1978, Burlas et al. 2001, Versar 2004). Little evidence of offshore sand movement and effects on nearshore benthic communities were noted one year after a 540,204 cy beach nourishment in Brevard County, Florida (Gorzelany and Nelson 1987). No long-term effects of sand transport sedimentation or effects on benthic communities were observed three years after a 306,000 cy beach nourishment project off Panama City, Florida (Culter and Menhadevan 1982).

In contrast, silt/clay loading and altered benthic community in the shallow nearshore was documented for two years following hydraulic placement of 5.36 million cy on the beach and approximately 3.9 million cy farther offshore at Perdido Key, Florida (Rakocinski et al. (1996, 2001). Insufficient background information is available to conclude which factor may have been more influential to the difference in result for the Perdido Key, Florida project compared to other available studies, but may have related to some combination of silt/clay content of source sediments, project volume, and hydrodynamics.

- Hydraulic discharge of 1,000,620 cy of dredged sands onto the beach at Imperial Beach, San Diego was found to have little effect on nearshore invertebrates (Parr et al. 1978). Some enhanced abundance and diversity were observed at 3.7 m and 6.1 m water depths attributed to increased silts and associated organics, but were short-lived (generally less than 2 months); population fluctuations due to seasonal storms and sand movement were more pronounced than observed from beach nourishment.

- Culter and Mahadevan (1982) found similar sediment characteristics in 1979 (mean grain size 2.05-2.34 phi and 0.01-0.05% silt/clay) compared to values measured in 1974-1975 (1.84-2.17 phi with 0.06-0.09% silt/clay) prior to beach nourishment in 1976. The project involved hydraulic placement of 306,000 cy of material dredged from offshore borrow sites on beaches in Panama City, Florida. A similar to greater variety of species was observed in 1979-1980 compared to 1974-1975; however, densities and species composition varied between years, which the author's considered temporal fluctuations.
- Gorzelany and Nelson (1987) found little evidence of offshore sand movement effects on benthic invertebrates over a one-year period following placement of 540,204 cy of terrestrial sands on a 2.1 mi (3.4 km) stretch of beach in Brevard County, Florida beach. Similar trends in number of species and abundance were observed at shallow subtidal sites (≤ -10 ft, ≤ -3 m water depths) using a before-after-control-impact (BACI) sampling deign.
- Burlas et al. (2001) did not report any changes in nearshore benthic populations attributed to changed sediment conditions associated with hydraulic placement of approximately 8.1 million cy on approximately 10 mi (16 km) stretch of beach in New Jersey. Sediment conditions were reported as being dynamic before and after beach nourishment. Variations in number of taxa, abundance, and biomass were considered within the range of natural variation and not attributed to beach nourishment. Temporary reductions in abundance of a clam (*Donax*) and polychaete (*Asabellides oculata)* were attributed to beach nourishment.
- Versar (2004) documented similar invertebrate communities (abundance, biomass, number of taxa, Shannon Wiener diversity) at four surf zone and nearshore beach sites before and after hydraulic placement of 5.6 million cy of dredged material on four beaches in North Carolina. Delayed recruitment occurred at one of the surf zone sites, presumably due to the construction schedule, otherwise remaining surf zone and all other nearshore sites were similar before and one year after construction. One of the four nourishment sites (Bald Head) showed an elevated silt/clay concentration immediately after nourishment, but substrate was not significantly different from prenourishment one year later. Although, total abundance and biomass were lower one year later at Bald Head, the author's attributed the difference primarily to one species of polychaete that after nourishment had abundance similar to that at a reference site.
- Rakocinski et al. (1996, 2001) monitored benthic recovery following hydraulic placement of a total of approximately 9.3 million cy (7.1 million cm) of sand on the beach and in subtidal waters 6.7 m (-22 ft) off Perdido Key, Florida; a total of 5.36 million cy was placed on the beach. Intertidal and subtidal communities in the areas of direct placement displayed substantial recovery, although not complete within the first year of beach nourishment. However, inshore 3.7 m (-12 ft) benthic communities not directly impacted by the project displayed greater change that persisted over the two year monitoring program. The result was attributed to silt/clay loading that ranged from <4 to 100% over the study area depending on location. Sediments on the beach had <4% silt/clay, which suggests that the fines associated with the source sediments (dredged from Pensacola Bay) rapidly winnowed and deposited inshore. Sedimentation was lower towards the ends of the fill, presumably due to less volume placement. Although other reviews have referenced the impact as an example associated with high silt/clay content in the fill material (Greene 2002, Peterson and

Bishop 2005), it also seems plausible that persistence of silt/clay resulted from local hydrodynamic processes that seasonally reduced but did not eliminate the sedimentation effect.

- Chambers Group (1992) documented substantial reduction in infauna but no obvious differences in trawl-caught macroinvertebrates after nearshore sand placement.
- Diaz and Boesch (1977) documented detrimental effects of discharge of low-density fluid mud on benthic communities, but reported recovery within a few months (cited in LaSalle et al. 1991).

Sedimentation Impacts to Hard Substrate Invertebrates

Invertebrates on hard substrate habitats vary in their tolerances and/or behavioral adaptations with respect to sand inundation. Low lying rock reefs that experience recurrent sand scour and/or inundation may lack or have a reduced invertebrate assemblage of tolerant and/or opportunistic species (Taylor and Littler 1982, Littler et al. 1983, Ambrose et al. 1989, MEC 2000a). Higher relief rock reefs generally have a diverse invertebrate community, partly because reef heights may be above the sand inundation layer and partly because animals may move from lower rock areas to higher elevation areas in response to sand inundation. Sand elevation level represents the lower distribution limit of several species of invertebrates in rocky habitats (Littler et al. 1983). Studies in the vicinity of landslides indicate lower diversity of invertebrates, particularly herbivorous species (e.g., Pondella et al. 1996). Therefore, important considerations with respect to potential beach nourishment sedimentation effects to rocky habitats (intertidal, subtidal) relate to location (i.e., proximity to hard bottom), existing conditions (e.g., reef heights, habitat quality), and project volume (e.g., duration and extent of sand elevation increase).

- Littler et al. (1983) reported that intertidal opportunists include barnacles (e.g., *Chthamalus fissus/dalli*, *Tetraclita rubescens*) and the colonial sand tube worm (*Phragmatopoma californica*). Mobile species such as the black turban snail (e.g., *Tegula funebralis*) was found to migrate to and from sand inundated areas. Sand stress-tolerant species included the aggregating sea anemone (*Anthopleura elegantissima*) and mossy chiton (*Mopalia muscosa*).
- Aggregating sea anemones have behavioral (may extend column so oral disc and tentacles remain above sand layer), reproductive (asexual clones), and physiological (metabolize body tissue) adaptations to seasonal sand burial that may span several months (Sebens 1980, Taylor and Littler 1982).
- The California reef building worm (*Phragmatapoma californica*) tolerated short-term sedimentation, but experienced 95 percent mortality after 5 days (Taylor and Littler 1982 cited in Main and Nelson 1988).
- The Florida reef building worm (*Phragmatapoma lapidosa*) tolerated burial depths of 7 in (18 cm) of sandy to silty sediments for up to 25 hours (1 day) during summer and up to 3 days during winter, but survival decreased over longer durations with higher mortality from silty than coarse sediments (Main and Nelson 1988).
- Duggins et al. (1990) documented that several species of encrusting invertebrates in kelp beds are sensitive to sedimentation, including serpulid and spirobid polychaetes, *Membranipora* bryozoans, and *Tubulipora* bryozoans.

Invertebrate Recovery After Sediment Management Activities

In coastal nearshore habitats, there is a cross shore gradient of community development that increases from the more disturbed intertidal towards the deeper portion of the profile (Parr et al. 1978, Rakocinski et al. 1996). Community development also differs based on type of beach with dissipative beaches displaying greater species diversity throughout the beach profile than intermediate or reflective beaches (McLachlan 1990, Nelson 1993, Dugan et al. 2000a, Brown and McLachlan 2002, Dugan et al. 2003, Defeo and McLachlan 2005, McLachlan and Dorvlo 2005). Type of substrate also is influential. Hard substrate may support more or less developed invertebrate assemblages than sandy substrates depending on height and structural aspects of the hard substrate. Variable height rocky substrates with numerous microhabitats support more species of invertebrates than sandy substrates. Low-relief rock subject to substantial sand scour generally supports few biological resources.

The time it takes for recovery may relate to several factors, including environmental conditions, disturbance frequency, extent of disturbance, and timing of disturbance (Table 5.4-2). Reviews indicate a positive relationship between community resilience and environmental variability (e.g., higher environmental variability, faster recovery) (LaSalle et al.. 1991, Newell et al.. 1998). For example, frequently disturbed communities may quickly recover to an opportunist-dominated species composition. In stable environmental conditions, recovery to a mature community that may take several years.

Table 5.4-2. Generalized invertebrate community recovery rates after beach nourishment.

Factor	Faster	Slower
Beach Type	Reflective Intermediate	Intermediate Dissipative
Depth	Intertidal	Nearshore
Frequency	Frequent	Infrequent
Magnitude	Localized	Extensive
Sediment	Compatible Sandy	Coarser, Finer Functional Hard substrate
Timing	Winter/Spring	Summer

Invertebrate recovery begins almost immediately after disturbance from some combination of larval recruitment, immigration, and possible survival of some residents (Simon 1976, Parr et al. 1978, Santos and Simon 1980, Grant 1981, Reilly and Bellis 1983, Levin 1984). Recovery after beach nourishment generally occurs on the order of weeks to months unless there is interference with recruitment and/or sediment incompatibility (Table 4.2-1, Section 4.2.6). Rapid recovery of number of species and abundance have been reported for beach nourishment projects completed prior to the onset and/or early in the spring recruitment period (Parr et al. 1978, Gorzelany and Nelson 1987, Versar 2004), or later in the season when some recruitment was possible prior to winter decline (Burlas et al. 2001, Versar 2004).

Recovery of population size structure and biomass generally takes longer. For example, populations may be skewed towards smaller, younger individuals if disturbance occurs during primary recruitment periods and/or later in the season and there is insufficient time for community development prior to the onset of the winter season (Reilly and Bellis 1983, Peterson et al. 2001). Size structure and biomass would be expected to take longer to recover for diverse assemblages associated with dissipative beaches and/or long-lived species such as Pismo and northern razor clams. Slower recovery, if at all, may occur when there is a a poor match in grain size or substantial change to coarser or finer substrate (Nelson 1993, NRC 1995, McLachlan 1996, Rackoscinski et al. 1996). Persistent effects have been reported even with thin layer deposition of fine sediments (e.g., Cummings and Thrush 2004, Lohrer et al. 2004). Nelson (1993) summarized that community level effects tend to occur only where inappropriate sediments are used, particularly with a poor match in grain size or those in high organic matter or fine particles.

Benthic invertebrate communities in more stable subtidal waters generally are more developed and take longer to recover than beach communities. Recovery generally follows a similar pattern, including colonization and enhanced abundance of opportunistic species (peak of opportunists), followed by a transitional community composed of opportunists and some longer-lived species, and then recovery of an equilibrium community (Pearson and Rosenberg 1978, Naqvi and Pullen 1982, Soloman et al. 1982, Newell et al. 1998, Van Dalfsen and Essink 2001). Recovery of subtidal invertebrate communities after dredging and/or nearshore placement may take several months to years depending on existing frequency of disturbance and degree of change in physical and hydrodynamic factors with respect to pre-distrubance environmental conditions (Table 4.2-2, Section 4.2.7).

5.4.4.2 Fishes

The following direct and indirect impact concerns have been reported for fish with respect to burial and/or sedimentation associated with sediment management activities (Navqi and Pullen 1982, LaSalle et al. 1991, Lindeman and Snyder 1998, Germano and Cary 2005, Wilber et al. 2005):

- Direct burial and/or indirect sedimentation loss of hard substrate habitat for tidepool fish, and hard substrate and/or kelp habitat for subtidal reef fish.
- Direct burial and/or sedimentation of demersal eggs.
- Indirect avoidance and/or failure of spawning due to sudden presence of sediments.
- Indirect reduction of soft substrate invertebrate and/or vegetative forage base.
- Indirect displacement and increased vulnerability to predation.
- Indirect interference with migratory patterns.

Nearshore demersal and pelagic fish have several behavioral and life history attributes that may reduce vulnerability to impact from many of the effects of sediment management activities. Available studies indicate that surf zone and nearshore fish are highly mobile, display natural seasonal shifts in abundance, and dietary flexibility (Burlas et al. 2001). Impact concerns from burial and/or sedimentation impacts mainly concern reduction in forage base for demersal fish. However, some pelagic species have demersal eggs (e.g., Calfifornia grunion, Pacific herring) that are vulnerable to burial and/or sedimentation impacts.

Sedimentation issues for salmonids during beach nourishment concern interference with migration as a result of sand transport sedimentation blocking entrance to shallow inlet embayments used during migration to and from spawning grounds. Sedimentation concerns during dredging include potential reduction and/or degradation of nursery habitat (eelgrass) and/or reduction of invertebrate forage base.

Subtidal reef fishes and all of the resident tidepool fishes are closely associated with their habitats. Many subtidal reef fishes and most of the tidepool fishes have adhesive eggs that are laid on substrate. In addition, some reef fishes such as kelp surfperch, kelp bass, giant kelpfish, and kelp rockfish are closely associated with giant kelp (Cross and Allen 1993). Therefore, fishes associated with rocky intertidal, rocky subtidal, and/or kelp bed habitats may be vulnerable to burial and/or sedimentation impacts affecting their primary habitat, food resources, and/or early life stages.

Potential burial and sedimentation impacts to fishes are reviewed further below according to impact issue of concern.

<u>Burial and/or Sedimentation of Hard Substrate Habitat</u>

Intertidal Tidepool Fish

Habitat burial and/or sedimentation may be detrimental to tidepool fish. Sedimentation and sediment instability have been correlated with lower numbers of intertidal fish species (Cross 1982). Direct burial of rocky intertidal habitat as a result of sand placement has not been documented in California. Two Calfiornia beach nourishment projects involving approximately 100,000 cy of beach placement did not result in significant indirect sedimentation effects to rocky intertidal habitat at distances ranging from 3,400 to 7,874 ft (1,000 to 2,400 m) downcoast (Chambers Group 2004, Engle 2005).

- The Goleta Beach Nourishment Project, in Santa Barbara County, placed 79,000 cy of sand onto the beach and was followed by an additional project with 20,000 cy of sand placement (Moffatt & Nichol 2005c). Monitoring was conducted at two intertidal sites 6,500 ft (2000 m) to 7,874 ft (2,400 m) downcoast. Increased sand depth and cover was documented during one of the quarterly serveys at each site during the first year of monitoring, but was not persistent. Chambers Group (2004) concluded that the beach nourishment project may have had a temporary impact on rocky intertidal habitat, but does not appear to have caused any long term change. Although no monitoring was done of intertidal fishes, any impact would have been temporary since sand moved out of the area within a few months.

- The 2001 San Diego Regional Beach Sand Project included monitoring at an intertidal rocky reef 3,400 ft (1,000 m) downcoast of a beach site that received 101,000 cy of sand and at comparative locations outside the littoral cell where beach nourishment occurred. Monitoring was conducted before and for four years after beach placement. Although some changes in densities of target species (algae, invertebrates) were observed and attributed to changes in sand levels, the effects were considered within the range of measured natural variation and no obvious impacts from the beach nourishment project were reported (Engle 2005). Because no significant change in habitat quality of the intertidal reef was reported, there is no reason to suspect a significant impact occurred to tidepool fish from the project.

Subtidal Reef Fish

Direct burial of rocky subtidal habitat as a result of sand placement has not been documented in California. Two Calfiornia beach nourishment projects involving approximately 100,000 to 225,000 cy of beach placement did not result in significant indirect sedimentation effects to nearshore rocky subtidal habitat or kelp bed habitat (Chambers Group 2004, AMEC 2005).

- The Goleta Beach Nourishment Project, in Santa Barbara County, placed 79,000 cy of sand onto the beach and was followed by an additional project with 20,000 cy of sand placement (Moffatt & Nichol 2005c). Results of monitoring conducted before and quarterly for one year after beach placement indicated no obvious sedimentation impacts to subtidal reefs with kelp beds (see Section 3.2.6).
- Monitoring of the SANDAG Beach Nourishment Project in San Diego did not detect substantial sedimentation in nearshore reef and/or kelp bed habitats that resulted in biological effects to target species of invertebrates or vegetation (AMEC 2005). Volumes ranging from 101,000 to 225,000 cy were placed at beach sites in areas of coastline with nearshore reefs and offshore kelp beds. Nearshore reefs included low to high relief (< 3 to > 3 ft, < 1 to > 1 m). AMEC (2005) suggested that the sand channels may have provided avenues for sand movement, decreasing the likelihood of impacts from sand scour and burial of nearshore reefs. No substantial sedimentation was observed in offshore kelp beds, which experienced increased recruitment after sand placement probably in response to oceanographic conditions.

A sigificant impact to nearshore reef fish was reported from a beach nourishment project involving placement of 457,800 cy (350,000 cm) of sand from an offshore borrow site along 1.1 mi (1.8 km) of shoreline at Carlin Park, Florida (Lindeman and Snyder 1999). Bulldozers extended the fill seaward to an estimated width of 197 ft (60 m). It was estimated that the project impacted 12 to 14 acres (4.9 to 5.7 ha) of nearshore with hard bottom outcroppings.

- Lindeman and Snyder (1999) concluded that habitat burial effects on nearshore reef fish in Florida may be amplified if reef burial occurs prior to and during spring and summer periods of peak larval recruitment. Impacts were considered exacerbated by limited alternate nearshore hard bottom in the vicinity of the impact site; the closest natural reef was at depths of at least ft (10 m), the nearest shallow water hardbottom was at least 4 km to the south, and artificial hard bottom (jetties) was located 2 km to the north. A total of (1.6 ha) of mitigation reefs were constructed three years later to compensate for impacts. They also suggested that in areas where hard bottom is limited, construction of mitigation reefs prior to construction may provide refuge for displaced fish as well as sites for recruitment; however, even with prompt construction, many factors can limit artificial reef net productivity and biomass. A risk-averse approach to hardbottom burial was recommended.

- Adverse impacts to fishes were documented from direct burial of 12 to 14 acres of nearshore hard bottom habitat in southeast Florida (Lindeman and Snyder 1999). After one year the number of individual fishes was reduced by 30 times and the number of species by 10 times compared to before project and a control site. .

Lindeman and Snyder (1999) reviewed that their monitoring study of nearshore reef fish offshore a beach nourishment project did not support many of the impact assumptions stated in the project EIS. Primary predicted impacts to fish included (1) short-term displacement during construction, and (2) temporary loss of food resources. The EIS also reported that impacts would be reduced by (1) the fishery value of impacted species being low, (2) some hardbottom would remain or would be constructed for mitigation if needed, and (3) construction would take place when fish populations were at their lowest. The monitoring study showed that many of the fish associated with the hardbottom habitat were early life stages of economically and ecologically valuable species, displacement was considered permanent for most individuals because of the substantial reduction in hardbottom habitat and distance from other alternate hard bottom that probably contributed to high mortalities, and project timing during a seasonal low was insignificant since habitat was buried during the spring-summer recruitment period. In addition, loss of reef-associated food resources from burial was considered substantial.

Burial/Sedimentation of Demersal Eggs and/or Interference with Spawning

Fine sediments are detrimental to incubating demersal fish eggs since blockage of interstitial spaces by silt may prevent adequate oxygenation of eggs, removal of waste metabolites, and/or armoring of the sediment surface and trapping of larvae (NMFS 1996, Martin and Swiderski 2001, Berry et al. 2003, Wilber et al. 2005, NCRWQCB 2006).

California Grunion

There is a concern that beach nourishment could adversely affect species such as California grunion (Navqi and Pullen 1982). Grunion spawn at the spring high tide zone on suitable beaches between March and August (sometimes earlier or later); eggs are normally buried several inches (up to 8 in, 20 cm) below the sand surface but hatch approximately 10 days after spawning when the next spring tide series uncover and expose the eggs to water. .

- Burial during beach nourishment likely would result in egg mortality. Various methods (environmental windows, monitors, protective dikes) have been used and/or identified to protect spawning activities for beach nourishment projects where schedule had a potential to overlap the spawning season (e.g., AMEC 2002).
- Substrate characteristics and beach slope may be important project design considerations with respect to habitat suitability for spawning. Sediments should be sandy to enable adequate oxygenation of eggs; fine sediments potentially could interfere with oxygenation of eggs (Martin and Swiderski 2001). Grunion do not spawn on beaches with steep slopes

Pacific Herring

Lassuy (1989) expressed the concern for avoidance of activities (e.g., dredging) that would cause silting in spawning grounds immediately before, during, and two to three months following the spawning season. Pacific herring require a “clean” surface for egg attachment (Ogle 2005).

Salmonids

Hatching success of salmon and trout decrease with increasing percent fines, as follows: coarse gravel > fine gravel > sand > silt and/or mud (Wilber et al. 2005).

Other Species

- Winter flounder eggs will have reduced hatching if buried by only one half an egg diameter (Nelson personal communication in Germano and Cary 2005 and Wilber et al. 2005).
- Hatching success of demersal eggs of white perch (*Morone americana*) were not affected by sediment layers ≤ 0.45 mm, but layers > 0.5 to 1 mm thick resulted in 50% mortality, and a layer of 2 mm resulted in 100% mortality (Morgan et al. 1983 cited in LaSalle et al. 1991).

Forage Reduction

Demersal feeding fish have the potential to be affected by reduction in forage base associated with dredging and/or beach nourishment (Navqi and Pullen 1982, Reilly and Bellis 1983, LaSalle et al. 1991, NRC 1995). Although studies have shown reductions in the benthic invertebrate community as a result of beach nourishment and/or dredging, impacts on fish foraging, abundance, number of species, and/or species composition have not been documented to-date (Naqvi and Pullen 1982, NRC 1995, Burlas et al. 2001, Greene 2002, USACE 2002b, Versar 2004). Short-term attraction has been reported in the vicinity of dredging and offshore active beach nourishment, presumably to exposure of invertebrate prey (Burlas et al. 2001, Greene 2002). Detection of adverse impacts to fish is complicated by natural variability in abundance due to mobility (Wilber et al. 2003). However, diet flexibility also may minimize potential impacts to fish in areas where other forage habitats (e.g., groins) occur (Wilber et al. 2003). The duration of potential limitation to food availability is related to recovery times of benthic invertebrates, which has been reported to be generally less than one year for beach nourishment projects involving compatible sand; but may more than one year in cases where substrate is substantially changed. Invertebrate recovery from dredging may be rapid in frequently disturbed navigational channels but may take two or more years in more environmentally stable areas (Section 5.4.4.1).

- No evidence of adverse effects to species composition and abundance of fish were detected based on comparisons before and after beach nourishment in Florida (Holland et al. 1989, Nelson and Collins 1987 cited in NRC 1995).
- Greene (2002) referenced several studies on the East Coast of the United States that documented short tem attraction of fish to offshore borrow sites, presumably due to an increase in release of nutrients and infauna (Saloman 1974, Applied Biology 1979, Courtenay et al. 1980, Turbeville and Marsh 1982, Nelson and Collins 1987, Coastal Science Associates 1990).
- No adverse impacts to surf zone fish were detected during and up to two years after a several million cy beach nourishment project off New Jersey (Burlas et al. 2001, Wilber et al. 2003). Short-term attraction (northern kingfish) and displacement (bluefish) were observed for some species during beach nourishment operations. However, impacts were considered short-lived. No significant decrease in stomach fullness and prey biomass, and/or difference in relative composition of prey items

were detected in stomachs of target species that feed on benthic invertebrates (rough and Atlantic silversides, northern kingfish) one and two years after nourishment. Wilber et al. (2003) considered fish mobility and flexible diets (e.g., prey taken from variety of habitats and/or including non-benthic prey) may have contributed to a lack of change in fish diet and consumption patterns. Fish mobility resulted in a high degree of natural variability in fish communities that would have required a minimum of a 3-fold difference in mean fish abundance to detect change between reference and treatment areas.

- Monitoring of the invertebrate community following a small (18,000 cy), beach nourishment project on Lincoln Park Beach in Seattle found that the overall density of invertebrate prey items of salmonids along the nourished beach was similar to a control beach (USACE, Seattle District 2002b).
- Versar (2004) did not detect any significant depression in abundance or diversity of nearshore fish during, 2 months after, or 1 year after a 5.6 million cy beach nourishment project in North Carolina. When significant differences were observed either an enhancement was indicated or seasonal differences between the nourished beach and the reference beach were inconsistent. The fish community's ability to migrate caused a highly variable community in both a temporal and spatial aspect but also indicated that fishes could move in and out of beaches impacted by the replenishment operations.

Interference with Migration

Sand transport sedimentation after beach nourishment has been a reported concern in the vicinity of shallow-inlet embayments and/or rivers for several projects in California (SANDAG and USDN 2000; Chambers 1992, Chambers 2000b, Moffatt & Nichol 2005a, Moffatt & Nichol 2005c). In some areas of the state, part of this concern relates to the potential to impact migration of anadronomous fish. No reports of inlet shoaling adversely affecting salmonid migration were identified with the literature review.

5.4.4.3 Birds

The following direct and impact concerns to birds have been reported with respect to effects from burial and/or sedimentation associated with sediment management activities (LaSalle et al. 1991, NRC 1995, Greene 2002, Peterson et al. 2002):

- Direct burial of vulnerable life stages (e.g., eggs and hatchlings).
- Indirect reduction of soft substrate invertebrate and/or vegetative forage base.
- Indirect reduction in habitat suitability for bird foraging and/or nesting associated with incompatibility of source sands and/or placement design.

Birds are highly mobile, which reduces potential vulnerability to impacts from many of the effects of sediment management activities. Therefore impact concerns mainly relate to less mobile life stages, specific locations where breeding and/or nesting occurs, and/or large-scale beach nourishment projects that have the potential to affect long stretches of coastline. Substrate characteristics have been demonstrated to influence habitat functions associated with bird foraging and/or nesting. Therefore, sediment compatibility of source sands is an important consideration with respect to beach nourishment effects on birds. Sedimentation associated with dredging has little potential to affect birds with the exception of potential

effects to vegetated foraging habitat; most impact concens to birds during dredging are associated with displacement disturbance (Section 5.3.) and/or turbidity (Section 5.5.3.4)

Potential burial and sedimentation impacts to fishes are reviewed further below according to impact issue of concern.

Direct Burial of Vulnerable Life Stages

Sediment management activities have the potential to bury nests, eggs, and/or hatchlings of birds if present within the area of potential effect. Of particular concern are potential impacts to threatened western snowy plover that may nest on beaches in California. Avoidance of sand placement activities during the breeding season or monitoring has been used to avoid direct impacts to snowy plovers during numerous sediment management projects in California (Section 4.4.3).

In addition, several species of birds (e.g., western snowy plover, endangered California least tern, other species of shorebirds and seabirds) may use nesting islands created from beneficial reuse of dredged materials that may require periodic substrate maintenance. Generally, nest site maintenance activities are scheduled to avoid breeding seasons of sensitive species (LaSalle et al. 1991).

Indirect Forage Reduction

Sand placement during beach nourishment may bury intertidal invertebrates resulting in an indirect reduction of the forage base for shorebirds until recovery of the invertebrate fauna has occurred. Recovery of invertebrates after beach nourishment may range from weeks to more than a year depending on a number of factors (Section 5.4.4.1). Invertebrate abundance on a beach varies across season, with increasing development from spring to summer associated witth the period of sand accretion, and decreasing abundance from late summer through winter associated with beach erosion from winter wave climate. Shorebird abundance on California beaches display a seasonality that somewhat lags behind that of their invertebrate prey base. For example, shorebird abundance generally is highest in fall-winter, moderate in summer, and lowest in spring (Dugan and Hubbard 1996, Lafferty 2001b, Gregory 2001, Hubbard and Dugan 2003). The period of greatest competition among shorebirds for prey is in midwinter when there are more shorebirds present and a decline in their invertebrate prey (Baird et al. 1993).

Sand placement burial of macrophyte wrack has the potential to reduce available forage for threatened western snowy plovers. Dugan et al. (2003) found that the mean abundance of western snowy plovers on various sandy beaches in southern California was positively correlated with the amount of macrophyte wrack on the beach.

The seasonal timing of beach nourishment projects is an important consideration with respect to potential impact on the forage base of shorebirds. Several studies have documented rapid invertebrate recovery when beach nourishment is concluded prior to the onset of seasonal invertebrate recruitment and source sands are compatible with existing beach sediments (Section 4.2.6, 5.4.4.1). In contrast, projects completed later in the season have less time to develop invertebrate forage base (abundance, size) prior to natural seasonal decline. Prey availability, quality, and composition are key determinants of habitat use by shorebirds (Hubbard and Dugan 2003, Van Gils et al. 2005). Consequently, any

factor that may reduce end-of-season invertebrate prey availability and quality (abundance, size) has the potential to affect shorebirds.

Shorebirds can cope with reductions in both prey density and in prey quality, as long as the reductions are not too large and do not occur simultaneously (Van Gils et al. 2005). However, a bird may starve if there is a combined reduction in prey density and quality, which are insufficient to meet energy demands.

Burial and/or Sedimentation of Hard Substrate and/or Vegetated Foraging Habitat

Sand placed on receiver beaches may move along the coast resulting in indirect sedimentation. If sedimentation impacted rocky shore and/or intertidal surfgrass habitats, foraging patterns could be affected for several species of shorebirds (e.g., back and ruddy turnstones, surfbirds, black oystercatchers) and wading birds (e.g., great blue heron, great egret, and snowy egret). No studies were identified with the literature review with respect to bird foraging patterns at rocky intertidal habitats in proximity to beach nourishment projects. Avoidance and minimization measures (e.g., proximity, placement volume) that have been used to reduce the potential for impacts to rocky intertdial and surfgrass habitats (Section 5.4.3.3, 5.4.3.4) also are relevant to potential impact reduction considerations for birds that use these habitats.

Sedimentation associated with beach nourishment and/or offshore borrow site dredging has the potential to adversely affect kelp forests and/or beds. Cormorants, gulls, and terns may forage and/or rest in kelp habitat. Therefore, several species of birds have the potential to be affected if sedimentation adversely impacts this SAV habitat (Sections 3.3.6). No studies of bird foraging and/or use patterns in kelp bed habitat with respect to beach nourishment and/or offshore borrow site dredging were identified with the literature review.

Sedimentation associated with embayment dredging has the potential to affect eelgrass meadows. Brant distribtution is related to eelgrass occurrence in embayments; therefore, brant have the potential to be affected if sedimentation from dredging adversely impacts eelgrass habitat (Section 3.3.8). Declines in brant populations have been linked to reduction of eelgrass along the Atlantic coast (Ehrlich et al. 1988).

Reduction in Habitat Suitability

Burial and/or sedimentation associated with beach nourishment have the potential to affect habitat suitability for birds. In some cases, potential impacts may be beneficial when associated with increased beach width and/or change from unproductive rock to functional sandy beach habitat (Section 5.1.2.3). Adverse impacts have the potential to occur if source sands adversely affect functional habitat uses such as foraging and/or nesting.

Sediment compatibility may be an important factor with respect to potential impact to bird foraging from sediment management actitivites. The mechanical interference of substrate to feeding is an important factor that influences a shorebird's choice of feeding location (Baird 1993). Similarity of size between sand grains and target prey may interfere with prey detection and capture (Baird 1993). Soil resistance to bill movement also may be important to shorebird distribution (Quammen 1982). Sediment too coarse or high in shell content can inhibit a bird's ability to extract food from the substrate (Peterson et al. 2000b, Greene 2002). Peterson et al. (2002) considered sediment incompatibility (higher shell hash, fines)

associated with beach nourishment at Boque Banks, North Carolina influential to reduced beach use by sanderlings and willets compared to an unaffected stretch of beach.

Melvin et al. (1991) reviewed that beach nourishment has that potential for adverse effects to endangered piping plovers on Atlantic coast beaches if the material is not suitable for nesting. A similar concern applies to California beach nourishment projects in areas where western snowy plover nest. Important sand placement considerations for piping plovers include low beach slope (≤10:1, horizontal:vertical), compatible sediments (grain size and color), and preservation of wrack vegetation (Fraser and Cohen 2005, Melvin 2005).

Sediment compatibility also is an important consideration in areas where California least tern nest. Substrate should be "beach quality", consisting of sand, sand-gravel, and shell (Golder et al. 2005). Beach nourishment has enhanced nesting areas for least terns on the Atlantic coast of the United States; however, values may decline due to vegetation and predator encroachment a few years afer nourishment if the site is not managed (Jedrey 2005, Melvin 2005).

5.4.4.4 Marine Mammals

Sedimentation associated with beach nourishment and/or offshore borrow site dredging has the potential to adversely affect kelp forests and/or beds. Sea otters tend to be most abundant in kelp beds; therefore, the species could be affected if sedimentation adversely impacts this SAV habitat (Sections 3.3.6, 4.5.1). Burial and/or sedimentation impacts from beach nourishment and/or dredging would not be expected to adversely affect populations of pinnipeds or cetaceans, which forage on a variety of pelagic and benthic invertebrates and fish across soft and hard bottom habitats (Sections 4.5.2, 4.5.3).

5.5 Water Quality Impacts

Protection of water quality during sediment management activities is regulated by the State Water Resources Board through issuance of waste discharge requirements (WDR) and/or special conditions under a Clean Water Act Section 401 water quality certification (Section 2.3.5). The following questions of interest to the CSMW are addressed in this report section:

- *What water quality criteria have been used to regulate projects with beach and/or nearshore sand placement?*
- *How do turbidity plumes associated with sediment management activities compare to natural levels?*
- *How are kelp beds, eelgrass, and other critical habitats affected by turbidity plumes?*
- *Are anecdotal observations indicating increased and concentrated fish (and subsequent bird) feeding along the edge of and within turbidity plumes scientifically supportable?*
- *Can the effects of turbidity on the foraging capabilities of fish and birds be scientifically quantified?*
- *How do turbidity plumes affect herring eggs, salmon runs, and other similar critical species?*
- *Are there critical levels of turbidity that cause adverse impacts?*
- *What have studies investigating the flocculation of clays within turbidity plumes determined with respect to how this phenomenon may have affected biota, ecosystems, and/or habitats?*

The CSMW have several questions related to turbidity because suspended sediment and resuspension are primary concerns during beach nourishment projects. Other water quality issues associated with bacteria release, chemical and nutrient release and updake, and oxygen reduction may be of concern with sediment management projects involving dredging and/or discharges in estuarine and marine environments (NRC 1985, 1995).

Several sources of information were reviewed to address the above questions. The review considered regulatory requirements for several California sediment management projects, relevant reports and literature on environmental effects of dredging and disposal, water quality measurements collected during monitoring of sediment management activities, and published and unpublished literature on organism response to experimental treatments using suspended sediments. Other useful references included reports of monitoring data and effects data prepared for port districts and the Los Angeles Contaminated Sediments Task Force (MBC 2000, Anchor Environmental 2003).

Appendix C provides supporting information for this report section. Monitoring requirements for several representative sediment management projects are summarized in Appendix C.1, and turbidity monitoring data for several different types of sediment management projects are summarized in Appendix C.2.

This summary section is organized in four subsections. Section 5.5.1 provides an overview of water quality impact issues. Section 5.5.2 identifies water quality criteria and monitoring requirements. Section 5.5.3 compares water quality during sediment management activities with natural conditions. Section 5.5.4 summarizes water quality impact concerns for habitats and species. The several CSMW questions related to turbidity effects on biota are addressed in Section 5.5.4.

5.5.1 Overview of Water Quality Impact Issues

This section presents a brief overview of factors associated with turbidity generation during sediment management activities. In addition, an overview is given of factors influential to sediment resuspension, transport, and deposition.

5.5.1.1 Overview of Turbidity Generating Activities

Suspended sediment concentrations and plumes associated with dredging and disposal will vary depending on the following types of environmental and operational related factors (Wright 1978, Herbich and Brahme 1991, LaSalle et al. 1991, Anchor Environmental 2003, USEPA and USACE 2004):

- Project location and/or waterway restrictions (beach, open ocean, embayment channels and/or obstructions).
- Project sediment volume.
- Type of dredge equipment and size (mechanical, hydraulic dredges).
- Dredge equipment operation (production rate, thickness of cut, overflow, etc.).
- Sediment placement method (hydraulic pipeline, mechanical discharge, earthmoving equipment).
- Sediment placement location (dune, beach, nearshore, embayment).
- Turbidity controls (e.g., operation, silt curtains, berms, settling ponds).
- Sediment characteristics (grain size distribution, density, specific gravity, water content, organic content, debris).
- Environmental conditions (hydrodynamics currents, tides, waves, water depth, salinity, temperature).

Project location and volume will influence the type of equipment selected. Location also will define the environmental conditions at the receiving site, including hydrodynamics influencing the transport and fate of the plume. Sediment volume will define how long it takes to remove or place sediment and relate to duration of plumes.

The selected equipment and how it is operated will define how much turbidity is generated during dredging and/or beach nourishment. Equipment also will define if turbidity is continuous or discontinuous. For example, cutterhead dredges involve a continuous operation of hydraulic removal and pumping of sediments between the dredge and discharge site. Mechanical dredging involves lowering a bucket that takes a ‘bite” out of the sediment, raising the bucket, and emptying the contents into a dredge scow for later discharge at an appropriate site. A hopper dredge is a discontinuous method involving dredging while underway at the dredge site and then transiting to the discharge site to unload the hopper bins of dredged sediment.

Sediment characteristics and environmental conditions will influence the physical aspects of sediment resuspension and deposition. Environmental conditions will affect where turbidity plumes go, deposition rates of suspended particles, and factors that may contribute to resuspension. Natural and anthropogenic factors may influence turbulence and suspension of particulates (e.g., waves, tides, vessel traffic). Salinity and particle characteristics may affect flocculation and settlement rates. Density differences in the water column (pycnocline) may affect the deposition and/or distribution of suspended sediment with depth. Ambient conditions also provide a comparative standard of background conditions at the time of project implementation.

5.5.1.2 Overview of Factors Affecting Turbidity and Particle Deposition

Several factors affect the concentration and behavior of suspended sediment plumes (Eisma 1993):

- Particle settling velocity.
- Concentration of particulates.
- Flocculation.
- Flow characteristics.
- Turbulence.

Basically, suspended sediment settles when the downward transfer from gravity overcomes flow characteristics and/or the upward diffusion from turbulence (Eisma 1993, Kineke and Sternberg 1989). Sediment fall rates affect the distance and duration of suspended sediment plumes. The fall rate of suspended sediment is largely controlled by particle size, shape, roughness, and density, which define the drag coefficients of particles (Eisma 1993). Generally, larger sandy particles settle more rapidly than smaller silt/clay particles according to Stokes' law of settling velocity (Eisma 1993, Davies-Colley and Smith 2001). The combination of increasing settling velocity as particle size increases means that small particles, silt size and smaller (e.g., clay minerals, phytoplankton cells), are the dominant contributors to overall light attenuation in natural waters (Davies-Colley and Smith 2001).

Factors such as concentration of particles and flocculation also affect settlement rates (Eisma 1993). For example, clouds of particles settle faster than single particles because particles in the cloud settle in the wake of others. However, as particle concentration increases, the fall velocity of an individual particle decreases because it is hindered by other particles; at concentrations of approximately 2 g/L hindered settling becomes marked and at > 100 g/L settling is negligible (*ibid.*).

Flocculation of suspended particles results in the formation of larger aggregated particles out of small ones, and may result in relatively faster settling rates than otherwise possible for fine particles, unless the larger flocs contain relatively more organic matter and/or enclose (trap) water (Eisma 1993, Davies-Colley and Smith 2001). Settling rates of flocs are highly variable (may vary over three orders of magnitude) based on constituent characteristics and variations in total fluid shear, concentration, and salinity (reviewed by Eisma 1993 and Kineke and Sternberg 1995). Suspended sediment settling experiments conducted in San Pablo Bay, California indicated that flocs (with aggregates as large as 450 μm) may have

settling velocities as high as those of sand-sized quartz spheres (> 0.2 cm/second) (Kineke and Sternberg 1995). Kineke and Sternberg (1995) found that use of *in situ* estimates of settling velocity (i.e., that measure flocs) substantially improved calculations of suspended sediment concentration profiles than possible from grain-size distribution of suspended sediment samples.

Suspended sediment transport takes place between two moments: (1) the initiation of particle motion (e.g., erosion, resuspension) and (2) deposition when turbulence is too week to keep the particle in suspension (Eisma 1993). While sand usually is usually transported along the bottom in the littoral zone as bed load, it may also be transported in suspension where currents and turbulence are sufficiently high (e.g., surf zone, sandy shelves during storms) (Eisma 1993). Settling velocities of sand are such that they do not remain in suspension very long unless conditions are very turbulent (e.g., large waves, storms).

Suspended matter usually is fine-grained/low density material. Finer silt/clays will transport to where turbulent mixing is sufficiently reduced to permit settling (e.g., outside the surf breaker zone, certain distance from source). Freshly deposited sediment may immediately resuspend and mix with the ambient suspended sediment field (Germano and Cary 2005). Storms and/or waves may facilitate resuspension, transport, and dissipation of settled silt/clays that may settle in the nearshore during beach nourishment (Parr et al. 1978). Conversely, low wave climate may contribute to their persistence. It is suspected that low wave climate may have influenced silt/clay persistence in the nearshore after beach nourishment at Perdido Key, Florida. The Florida panhandle in the vicinity of Perdido Key is characterized by gentle waves except during major storms and hurricanes (http://www.drbeach.org/drbeach/florida_golfcoast/beach_florida_golfcoast.htm).

5.5.2 Water Quality Criteria and Monitoring Requirements Associated with Sediment Management Projects

The following CSMW question is addressed in this section.

- *What water quality criteria have been used to regulate projects with beach and/or nearshore sand placement?*

Water quality may be monitored during sediment dredging and/or discharge to ensure compliance with water quality objectives of the California Ocean and Thermal Plans, regional Basin Plans, AB-411 bacteriology standards, and/or California Water Code (CWC) Section 13050, as appropriate. Water quality objectives address concerns related to public health/nuisance issues and protection of biological resources (Section 2.3.5).

Monitoring requirements and methods specificed in 401 water quality certification and/or waste discharge requirements (WDRs) are reviewed for several representative sediment management projects in this section. Generally, some combination of visual observations, receiving water limitations, effluent limitations, and/or water quality monitoring at dredge and/or discharge sites has been required. Additional monitoring requirements often have been required to address compliance with WDRs specified for turbidity and/or turbidity plumes. Because sediments involving beneficial use for beach nourishment are required to be free of substantial contamination, water quality objectives related to toxic effects, bioaccumulation, radioactivity, and/or impairments due to chemical contamination are met

with pre-project testing and/or evaluations of the suitability of sediments for that use and do not require additional monitoring of those constituents during project implementation.

Representative monitoring requirements and criteria are reviewed in the following subsection. Several methods may be used to monitor turbidity. The methods differ with respect to utility as operational compliance measures and/or biological relevance, which are reviewed in the second following subsection.

5.5.2.1 Monitoring Requirements and Criteria

A primary testing requirement before permit issuance is compatibility testing of sediment, which is used to confirm suitability for beneficial resuse for beach nourishment. Passing this initial screening test ensures sediments placed along the shore are "clean" and free of substantial contamination. Monitoring may be required during project implementation to comply with 401 Water Quality Certification and/or Waste Discharge Requirements (WDR) (Table 5.5-1, Appendix Table C.1).

Water Quality Certifications for maintenance dredge/fill projects generally address compliance with provisions of sections 301 (Effluent Limitations), 302 (Water Quality Related Effluent Limitations), 303 (Water Quality Standards and Implementation Plans), 306 (National Standards of Performance) and 307 (Toxic and Pretreatment Effluent Standards) of the Clean Water Act and with other applicable requirements of State law (e.g., USACE Permit 200401896-KW). The numerical criteria are reviewed in Section 2.3.5 for ocean receiving waters (Table 2.3-1), water contact bacteria standards (Table 2.3-2), ocean effluent limitations (Table 2.3-3), and for limitations associated with enclosed bays and estuaries (Tables 2.3-4 and 2.3-5). These water quality objectives address protection of aesthetics, human contact and consumption, and biological resource beneficial uses.

Effluent testing may be required during construction to verify compliance with WDR limitations. For example, maintenance dredging at Crescent City Harbor required discharges from settling ponds to not exceed specified thresholds for total suspended and settleable solids. Dredging projects in Dana Point Harbor, Oceanside Harbor, and Agua Hedionda Lagoon have required testing of barge supernatant to ensure acceptable levels of oil and grease (Appendix C.1). Moss Landing Harbor dredging required pre-discharge decant water turbidity to not exceed an instantaneous maximum of 225 NTU, daily average of 100 NTU, or 30-day average of 75 NTU (RWQCB WDR 01-007).

Receiving water monitoring may include visual observations to verify water quality objectives for the following parameters, which may not be visible, detected, and/or at levels that cause a nuisance or adversely affect beneficial uses (Table 5.5-1):

- Discoloration.
- Floating particulates, trash, debris, solids, foam, scum.
- Objectionable aquatic growths.
- Odors (not detected and/or no aesthetic nuisance).
- Oil, grease, waxes, petroleum substances, visible films, coatings on objects.

Visual observation requirements also may include documentation of the extent of the turbidity plume.

Table 5.5-1. Water quality monitoring conducted during representative California sediment management projects.

Project	Effluent Limitations[1]	Receiving Water Limitations		
		Observations	Turbidity	Bacteria
Crescent City Maintenance Dredging, 1998 WDR 92-103	TSS and settleable solids (mg/L) – weekly harbor	Discoloration, floatables, pH, objectionable aquatic growths, odors, oil and grease, temperature	Turbidity (NTU)), near surface - daily beach, weekly harbor	No
Moss Landing Harbor Dredging, 2002 WDR 01-007	Decant water	Discoloration, odors, debris/solids	Turbidity (NTU), near surface – weekly prior to and during dredging	No
Goleta Beach BEACON Project, 2003, 401 Water Quality Certification	No additional	Weather	Turbidity mapping – daily off beach, weather	No
USACE RGP 67 401 Water Quality Certification	No additional	Weather (temperature, wind speed, cloud cover, rain), surf conditions (wave height, swell), recreational beach use (number of people, distribution)	Turbidity plume (map of maximum plume, digital photographs), and turbidity level (murky, slightly murky, average, clear).	No
Marina Del Rey Maintenance Dredging, Nearshore Discharge, 1999-2000, WDR, as amended Nov. 1998	TSS, dissolved oxygen (mg/L), pH daily 7 days, then weekly - dredge and disposal sites; if excessive turbidity, sample for metals	Discoloration, odors, floatables, oil/grease, tide stage, current speed and direction, weather, wind velocity – daily for first 7 days, then twice/week	Secchi disk, Turbidity (NTU), mid-depth harbor, nearshore –daily for first 7 days, then twice/week	No
Dana Point Harbor Maintenance Dredging and Beach Discharge, 2000 WDR 96-32	TSS, hydrogen sulfide (mg/L) – monthly; polar & non polar oil and grease (mg/L) monthly or 3 times/week if beach disposal	Discoloration, floatables, odors, oil/petroleum, current speed/direction, tide stage - daily	Turbidity (NTU) or Secchi disk – daily dredging, weekly off beach	Weekly
Agua Hedionda Lagoon Maintenance Dredging, 1999 RWQCB General WDR 96-32	Supernatant- polar & non polar oil/grease – weekly; Lagoon and nearshore - hydrogen sulfide, oil and grease, TSS (mg/L) - monthly	Discoloration, floatables, odors, oil/petroleum, plume extent– daily	Turbidity (NTU) or Secchi disk – daily lagoon, weekly beach	Weekly
San Diego Regional Beach Sand Project, 2001, 401 Water Quality Certification File No. 00C-063	No additional	Discoloration, floatables/debris, odors, current speed/direction, tidal stage, conductivity, dissolved oxygen, pH, temperature – daily to weekly borrow sites	Turbidity (NTU), Secchi disk – daily then weekly borrow sites; Secchi disk – daily beach	Weekly

Note1: Discharge must pass Tier 1, Tier II, or Tier III testing criteria applicable to disposal method.

Monitoring may include use of *in situ* instruments to demonstrate compliance with the following receiving water quality objectives:

- Dissolved oxygen not depressed by more than 10% from ambient (ocean) or ≥ 5 to 7 mg/L (enclosed bays and estuaries, depending on RWQCB Basin Plan – see Table 2.3-4).
- pH not deviating from ambient by more than 0.2 units (ocean) or 0.2 to 0.5 units (enclosed bays and estuaries, depending on RWQCB Basin Plan – see Table 2.3-4).
- Temperature not deviating from ambient by more than 4°F (2.2^{o}C).

Sometimes other observations and/or instruments are used to further characterize environmental conditions at the time of monitoring, such as: current speed and direction, conductivity/salinity, tidal stage, and/or weather (Appendix Table C.1). In some cases, water samples have been analyzed for hydrogen sulfide and oil and grease (or hexane extracted material) to ensure compliance with receiving water objectives for enclosed bays and estuaries (e.g., Agua Hedionda Lagoon, Dana Point Harbor, Oceanside Harbor, San Diego Bay) (Table 5.5-1, Appendix Table C.1).

Additional monitoring criteria often are specified to address receiving water objectives associated with turbidity. Sometimes one or more methods are required to be used (Table 5.5-1, Appendix Table C.1). The following examples illustrate that monitoring requirements may differ with respect to monitoring frequency and where in the water column measurements are taken.

- Weekly measurement of suspended solids (mg/L), settleable solids (mg/L), and turbidity (NTU) near surface at dredge location, and daily turbidity (NTU) near surface at beach discharge location (Crescent City Harbor maintenance dredging, 1998).
- Pre-discharge and weekly near surface turbidity (NTU) during dredging (Moss Landing Harbor maintenance dredging, 2002).
- Daily near surface turbidity (NTU) during dredging and beach discharge (Santa Barbara Harbor maintenance dredging, 2004-2005).
- Weekly water transparency (Secchi disk) during dredging and beach discharge (Santa Barbara Harbor maintenance dredging, 1998-1999).
- Weekly total suspended solids (mg/L) and light transmittance (%) at 2-m intervals during dredging (Ventura Harbor maintenance dredging, 2004).
- Daily water transparency (Secchi disk), and daily to weekly near surface turbidity (NTU), light transmittance (ft), and suspended solids (mg/L) (Marina del Rey Harbor maintenance dredging, 1999-2000).
- Daily for first week, followed by weekly near surface turbidity (NTU) and water clarity (Secchi disk) during dredging, and daily water clarity (Secchi disk) during beach nourishment (San Diego Regional Beach Sand Project 2001).
- Daily visual turbidity plume mapping (Goleta Beach BEACON Demonstration Project 2003).

- Daily near surface and bottom light transmittance (%) during dredging and mid depth during nearshore placement, monthly TSS mid depth during dredging and nearshore placement (San Diego Harbor Deepening Project 2004-2005).

Compliance criteria may include monitoring of turbidity plumes. For small opportunistic sand programs, visual monitoring of turbidity plumes may be all that is required to satisfy Water Quality Certification requirements as long as plumes are localized. Water clarity associated with turbidity plumes may be required if construction is scheduled within seasonal occurrence periods and foraging range of sensitive visual foragers (e.g., least terns).

- The SCOUP project includes daily documentation of environmental conditions (e.g., waves, wind, weather) and the turbidity plume, including photographs and mapping the plume dimensions to ensure that it is not excessive (greater than ambient beyond one-half mile offshore at or downcoast of the placement site) for a prolonged period, assumed to be 5 days (Moffatt & Nichol 2006a). If turbidity is considered excessive, then placement should halted or be modified to reduce turbidity.
- RGP 67 (USACE 200401896 KW) for opportunistic beach nourishment projects requires daily monitoring of the turbidity plume (map of maximum plume, digital photographs), weather (temperature, wind speed, cloud cover, rain), surf conditions (wave height, swell), recreational beach use (number of people, distribution), and turbidity level (murky, slightly murky, average, clear) during construction to ensure that turbidity is not excessive (greater than ambient beyond one-half mile offshore at or downcoast of the placement site) for more than two consecutive days. If excessive turbidity persists on the third day, daily water clarity testing (using transmissometer) will be conducted at mid-depth at a minimum of four locations (close to discharge site, and one-half mile upcoast, downcoast, and offshore). If turbidity one-half mile away is greater than ambient, the discharge will be halted or modified.
- A turbidity plume threshold to minimize impacts to sensitive bird foraging was recommended by the USFWS during the Section 7 consultation under the Endangered Species Act for the 2001 San Diego Regional Beach Sand Project to protect sensitive visual feeders (California brown pelican, California least tern) and was included as a special condition of the Department of Army 404 permit (USACE 1999-15076-RLK, USFWS Biological Opinion FWS Log. No. 1-6-01-F-1046). The threshold criteria specified that water clarity of < 3 ft (1 m) (determined by Secchi disk) was not to exceed 2.47 acres (1 hectare) at offshore borrow site locations and in the nearshore off beach receiver sites.

Bacteria monitoring has been required by RWQCBs for some projects, presumably where water contact concerns have been raised and/or are of potential concern. Bacteria monitoring requirements may differ in monitoring frequency (e.g., weekly, beginning of dredge cycle) and sampling locations (e.g., offshore discharge, 100 ft (30 m) downcurrent from discharge) (Table 5.2-1, Appendix Table C.1).

Monitoring requirements often differ in distance of monitoring stations from dredging and/or discharge operations where observations, measurements, and/or water samples are collected. Representative examples of different sampling designs are provided below (also see Appendix Table C):

- *Dredge* monitoring stations A. 100 ft (30 m), B. 200 ft (60 m), C. 500 ft (150 m) downcurrentt, E. 500 ft (150 m) outside and south of harbor; *Beach Nourishment* stations 200 ft (60 m) downcurrent (Santa Barbara Harbor maintenance dredging, 2004-2005).
- *Dredge* monitoring stations: A. 100 ft (30 m) downdrift, B. 100 ft (30 m) upcurrent C. 300 ft (100 m) upcurrent, D. 1,000 ft (300 m) upcurrent, E. 1300 ft (400 m) upcurrent; *Beach Nourishment* monitoring stations: A1.100 ft (30 m) downcurernt, B1. 100 ft (30 m) upcurrent, C1. 300 ft (100 m) downcurrent, D1. 1,000 ft (300 m) away, E1.1300 ft (400 m) away (Los Angeles River Estuary Maintenance Dredging, 1999; Los Angeles Harbor maintenance dredging, 1998).
- *Dredge* monitoring stations: A. 500 ft (150 m) upcurrent, B. Within plume, C. Within 250 ft (75 m) downcurrent; *Beach Nourishment* monitoring stations: D. 3000 ft (900 m) upcurrent & 500 ft (150 m) offshore, E. 1500 ft (450 m) downcurrent & 500 ft (150 m) offshore, F. Discharge site inside any visible plume, if possible (RWQCB General WDR 96-32 for Maintenance Dredge/Fill Projects – San Diego Region).
- *Dredge* monitoring stations: A. 500 ft (150 m) upcurrent, B. 250 ft (75 m) upcurrent, C. within visible plume, D. far extent of plume no more than 250 ft (75 m) downcurrent, E. 500 ft (150 m) downcurrent; *Nearshore Placement* monitoring stations: F. 3,000 ft (900 m) upcurrent and minimum of 500 ft (150 m) offshore, G. 1,500 ft (450 m) downcurrent and within any visible plume and minimum of 500 ft (150 m) offshore (San Diego Bay Channel Deepening Project, 2004-2005).

Compliance threshold criteria for suspended sediment, turbidity, light transmittance, and water transparency measures often include not exceeding ambient conditions by 20%. Because of differences in station location distances, the spatial-scale associated with compliance determinations and distance from source that defines ambient are inconsistent among projects, as the following examples illustrate:

- Turbidity values at dredge stations: A. 250 ft (75 m) downdrift, B. 500 ft (150 m) downdrift, C. 250 ft (75 m) updrift, D. 500 ft (150 m) updrift, E. Control 1000-1500 ft (300-450 m) from dredge, F. 1000-1500 ft (300-450 m) from dredge and at least 500 ft (150 m) from first control (2001 San Diego Regional Beach Sand Project, RWQCB 401 Certification File No. 00C-063).
- Turbidity 250 ft from *dredge* perimeter no more than 20% over average ambient (Oceanside Harbor maintenance dredging 1994, RWQCB WDR 94-124).
- Turbidity values at *dredge* stations: A. 100 ft (30 m) updrift, B. 100 ft (30 m) downdrift, C. 300 ft (100 m) downdrift, D. outside affected area (Ventura Harbor maintenance dredging 2004, RWQCB WDR 76-59).
- Turbidity values at *dredge* Station C (within 250 ft, 75 m) no more than 20% over turbidity at Station A (500 ft, 150 m) upcurrent upcurrent. Turbidity values during *beach nourishment* at Station E (1500 ft, 450 m downcurrent and 500 ft, 150 m offshore) no more than 20% over turbidity at Station D (3000 ft, 914 m upcurrent and 500 ft, 150 m offshore) (RWQCB General WDR 96-32 for Maintenance Dredge/Fill Projects – San Diego Region).

- Turbidity during *beach discharge* at station (a) within plume and (b) in waters unaffected by discharge (Crescent City maintenance dredging and discharge 1998, RWQCB WDR 92-103).

The above review of monitoring requirements indicates lack of standardization of water quality compliance requirements in California (Appendix Table C.1). Differences exist in what parameters have been monitored, frequency of monitoring, locations of monitoring relative to distance from dredge and/or discharge sites, locations in water column where measurements are recorded, and compliance criteria.

Some of the inconsistencies in monitoring and compliance requirements may reflect differences in requirements among different regional RWQCB offices; however, there also are differences in monitoring requirements among projects conducted in the same geographic region and in some cases for the same project location over time. Inconsistencies in WDRs across the different California RWQCBs mean that the usefulness of resulting monitoring data beyond that for project specific compliance with water quality requirements is limited. Some of the limitations associated with lack of standardized monitoring include:

- Lack of standardized measured variables limit the ability to easily assemble a large and consistent data set for computing average measured values for different types of sediment management activities over a broad range of project and environmental conditions. Such information would be useful for future review and potential updates of Ocean and Basin Plan criteria for protection of beneficial uses of receiving waters.
- Lack of project-specific correlation between *in situ* measurements (turbidity, Secchi disk, light transmission) and TSS concentration limit the usefulness of monitoring data beyond that of project specific control during construction (see next subsection for additional discussion of this topic).
- Lack of standardized monitoring station distances from dredge and/or discharge locations limit the identification of distance gradients and/or near-field and far-field zones of influence for different types of sediment management activities. This limitation hampers identification of appropriate distance buffers for protection of sensitive resources from water quality impacts during sediment management operations. Such information would be useful for enhancing environmental sensitivity of project design, and simplifying environmental impact analysis of planned projects.
- Lack of requirements to record what measures are used to control turbidity at the time water quality monitoring data are collected limit the availability of monitoring data for evaluating the effectiveness of different control measures.

5.5.2.2 Comparison and Biological Relevance of Different Suspended Sediment/Turbidity Monitoring Methods

A variety of methods have been used to monitor and/or document sediment plumes associated with dredging and/or discharge operations (including beach and nearshore placement) (Puckette 1998, O'Connor 1991, MBC 2000, Thackston and Palermo 2000, Anchor Environmental 2003):

- Field collection and subsequent laboratory analysis of water samples for total suspended solids (TSS).
- *In situ* readings of turbidity, usually in Nephelometric Turbidity Units (NTU).
- *In situ* readings of light transmittance with transmissometers.
- *In situ* readings of water transparency with a Secchi disk.
- *In situ* acoustic monitoring.
- Visual observations.
- Remote sensing
- Modeling

These methods differ in biological relevance, usefulness for operational control during dredging and discharge operations, and expense. Differences among the methods with particular attention given to biological relevance are reviewed below.

Total suspended solids (TSS). This measure is of sediment concentration per unit volume of water, which is directly comparable to biological effects data based on experimental studies of organism response to different concentrations of suspended sediments (LaSalle et al. 1991, Clarke and Wilber 2000). TSS is more relevant to benthic effects of sedimentation than to optical effects (Davies-Colley and Smith 2001). TSS generally is reported in grams or milligrams of solids per liter of water (g/L or mg/L).

Determination of TSS concentrations requires collection of water samples and subsequent analysis in the laboratory (Davies-Colley and Smith 2001). TSS provides a direct measure of the mass of particles present in water and is comparable from site to site. Because of the time associated with collection and laboratory analysis of TSS (24 to 48 hours), this measure can not be used in real time as an operational strategy to control turbidity during construction. Therefore, TSS generally is not routinely used to monitor water quality compliance during sediment management projects (Appendic Table C.1); although it may be necessary to provide empirical values of suspended sediment concentrations associated with turbidity and/or acoustic monitoring (see below).

Turbidity. This measure is often included in water quality compliance monitoring programs because it can be readily measured in the field with minimal expense (Puckette 1988, Anchor Environmental 2003). Turbidity is often measured with a nephelometer, which produce NTU readings. Sometimes turbidity has been measured in Jackson (JTU) or formazin (FTU) units.

Turbidity is an expression of the optical property of a water sample that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample (APHA 1976 cited in O'Connor 1991). Nephelometers use a photomultiplier tube or silicon photodiode to measure light that has been scattered at a specific angle, usually 90 degrees, from the main light path. A value of zero NTU means no light is scattered; drinking water goals and standards typically range between 0.1 and 0.5 NTU. Thackston and Palermo (2000) refer to natural waters with 1-3 NTU as extremely clear, 10-15 NTU as having nominal turbidity, and 100-1,000 NTU as very turbid.

Turbidity is caused by the molecules of water itself, dissolved substances, and organic and inorganic suspended matter (Davies-Colley and Smith 2001). Turbidity may naturally vary depending upon factors such as proximity to river and other discharges, wave and storm conditions, and occurrence of plankton blooms. Turbidity measurements (NTUs) may exhibit considerable variability even among replicate samples when particle sizes vary in the water column (MBC 2000). There is no standard conversion between TSS and turbidity, and estimates of relationship are only accurate when turbidity is calibrated to a reference standard and suspended material from the area where the measurements are taken, particle size and composition do not change significantly during the measurement period, and all measurements are made with the same turbidity sensor (Pukette 1998, Davies-Colley and Smith 2001). Use of NTU as a surrogate indicator of environmental quality without establishing the NTU and TSS correlation is considered dubious (Henley et al. 2000). Therefore, turbidity only has indirect environmental relevance. Unless the project specific relationship between turbidity and TSS is determined during construction, the usefulness of turbidity information is limited to that of a qualitative measure to aid project operational control and not as a quantitative measure with environmental relevance.

Although some dredging and beach nourishment projects in California have required both turbidity and TSS measurements (Appendix Table C), the number of TSS samples (weekly, 1 or 2 per project) generally have been too few for establishing adequate turbidity TSS relationships. Thackston and Palermo (2000) recommend a systematic procedure for producing accurate TSS-turbidity correlation curves that consist of use of both methods to (1) calculate correlation curves from laboratory column settling tests using proposed project sediment, (2) measurement of both turbidity and TSS under field conditions to verify and/or refine the correlation curve early in the project and/or when project conditions change, and (3) routine use of turbidity on a daily basis as a project control strategy.

Light Transmission. This measure sometimes is taken in addition to or in place of turbidity. Light transmission provides the benefits of an *in situ* measurement and direct information on light penetration (water clarity), which is relevant to photosynthetic activity of aquatic vegetation and phytoplankton and has relevance for sighted aquatic animals (visual feeders). A transmissometer is commonly used and provides readings of percent light transmittance, which range from 100% for clear water and 0% when no light is transmitted through the water. Similar to turbidity, light transmission may be affected by properties of particulates in the water (e.g., shape, size, opacity, concentration) (Anchor Environmental 2003). Transmissometers have been found to be reliable at measuring low-particle concentrations; however, they become saturated at high-particle concentrations and are considered inadequate for measurements at TSS levels above approximately 150 mg/L (Puckette 1998). Therefore, light transmission values do not enable establishment of accurate correlation relationships with TSS.

Water Clarity (Transparency). This measure often is measured using a Secchi disk, which is a white or white and black disk that is lowered into the water to the depth (which is recorded) where the sharp outline of the disk disappears (Thackston and Palermo 2000). This method has been widely used to monitor water quality compliance during sediment management projects in California, sometimes alone or in addition to turbidity and/or TSS (Appendix Table C). The method is inexpensive, fairly reliable, has relevance to habitat for visual feeders, aesthetic quality of water for contact recreation (Davies-Colley and Smith 2001). Secchi disk readings of < 3 ft (0.9 m) were used to track turbidity plumes of potential consequence to sensitive visual feeders (e.g., California brown pelican, California least tern) during implementation of the 2001 San Diego Regional Beach Sand Project. Secchi disk

readings can be dependent on lighting conditions (Davies-Colley and Smith 2001), and correlations with TSS are considered imprecise (MBC 2000, Thackston and Palermo 2000).

Black disk visibility, which is measured horizontally in water, is not as subject to ambient lighting as a Sechhi disk, provides good estimation of light beam attenuation, and can be used in shallow waters (Davies-Colley and Smith 2001).

Acoustic Monitoring. This method sometimes is used to identify and track suspended sediment plumes associated with sediment management activities. An acoustic sensor projects a beam of acoustic energy into the water column, and the amount of energy reflected back to the transducer (backscatter) is related to the size distribution of the particulate matter relative to the wavelength of the acoustic energy and concentration of particulate matter (Puckette 1998). Acoustic-Doppler Current Profiler (ADCP) instruments have been used to record both backscatter intensity and currents for plume tracking, and when combined with collection and analysis of water samples for TSS analysis enable the calculation of an empirical backscatter-TSS correlation equation. Similar to TSS-turbidity correlations, backscatter-TSS correlations are site and sediment specific (Puckette 1998). ADCP and water sample TSS correlation has been used to track and characterize turbidity plumes in San Francisco Bay, Oakland Harbor, and bays and harbors elsewhere in the United States and internationally (SAIC 1987, O'Connor 1991, Puckette 1998, Hitchcock et al. 2002, MEC and USACE-ERDC 2004). This method provides an accurate image of plume dimensions and TSS when the backscatter-TSS correlation is adequately determined.

Visual Observations. Description of the extent and discoloration associated with turbidity plumes often are included as a monitoring requirement of sediment management projects in California (Appendix Table C.1). In some cases, visual estimation and/or mapping of the plume extent (with or without photography) has been implemented and/or recommended for small and/or opportunistic beach nourishment projects (e.g., 2003 Goleta Beach BEACON Demonstration Project, South Central Coast Enhancement Program, San Clemente Beach Replenishment Program, SANDAG Sand Compatibility and Opportunistic Use Program). In addition, the technically conditioned water quality certification for Regional General Permit (RGP)-67 for Beach Nourishment Projects in Southern California (Corps File No. 200401896-JLB) specifies visual mapping and photography as the method for monitoring turbidity during projects that qualify under this permit. It is the least expensive of the monitoring methods, provides a record of plume appearance, and may be used to assess whether the turbid plume extends outside the surf zone where visual feeders potentially could be affected or to rocky intertidal or nearshore reef habitats where sensitive marine resources may occur. However, it can be affected by weather, may be difficult to distinguish in areas of high ambient turbidity, and lacks empirical values relevant to biological effects (e.g., suspened sediment concentration, percent light reduction, and/or sufficient water clarity for surface feeders).

Remote Sensing. Aerial photography or multispectral imagery sometimes is used to monitor suspended sediment plumes, particularly associated with river discharges (Mertes 1987, Puckette 1998). While aerial photography may be useful for understanding the spatial extent and development of plumes, it can be difficult to distinguish plumes in areas with high ambient turbidity and photography surveys may be limited by weather (Puckette 1998.). Empirical measurements of TSS may be used to calibrate imagery (Mertes et al. 1987). Remote sensing is relatively expensive compared to other monitoring methods and has not been routinely used for sediment management projects in California.

Modeling

The USACE with consultant assistance has developed several models for predicting turbidity plume behavior. Some of these include (http://el.erdc.usace.army.mil/dots/doer).

- Automated Dredging and Disposal Alternataives Management System (ADDAMS), which evaluates behavior of sediment after discharge. The Short-Term Fate (STFATE) and Long-Term Fate (LTFATE) software enables examination of short-term behavior and long-term fate and stability of dredge material discharge (Schroeder and Palermo 1990, Scheffner et al. 1995).
- Suspended Sediment Fate (SSFATE) model, which permits ability to similulate suspended sediment plumes associated with multiple and different dredging project scenarios (Johnson et al. 2000, Swanson et al. 2000).
- Particle Tracking Model (PTM), which predicts fate of sediments and particulates by simulating sediment movement in a flow field, including erosion, transport, settling, and deposition, and produces maps of sediment processes such as sediment mobility (Davies et al. 2005).

Germano and Cary (2005) reviewed that several of the existing models (e.g., TASS, SSFATE, STFATE, and DREDGE) are fundamentally advection/diffusion models that address dispersion of sediments from a source based on local flow characteristics and then assume that after settling the deposits stay in place. These authors consider the later assumption a major deficiency since freshly deposited sediments are subject to nearly immediate resuspension and mixing with the ambient suspended material field. They recommend a need for a model that provides a means to quantify the extent and timing of mixing along the sediment-water interface to support efforts to quantify biological impacts of dredged-induced sedimentation. The PTM model, which was not reviewed by Germano and Cary, is the most recent advance in modeling sediment diffiusion and advection processes. Higgins (2004) reviewed that limited information is available on the success of these models as determined by field testing.

5.5.3 Comparison of Turbidity During Sediment Management Activites With Natural and/or Baseline Conditions

Turbidity-related measurements during monitoring of sediment management projects are reviewed in this section. Summary figures are presented for monitoring data collected during 11 beach nourishment, 9 nearshore placement, 6 offshore borrow site dredging, and 18 harbor dredging projects from California (Appendix C.2). The figures provide the range and average values measured at different distances from dredging and/or discharge locations. The distance scale was presented as a standardized range because of differences in monitoring requirements relative to distance of sampling locations from a source. The number of available surveys for each of the examined monitoring variables (TSS, turbidity, light transmittance, water clarity) varies according to available data.

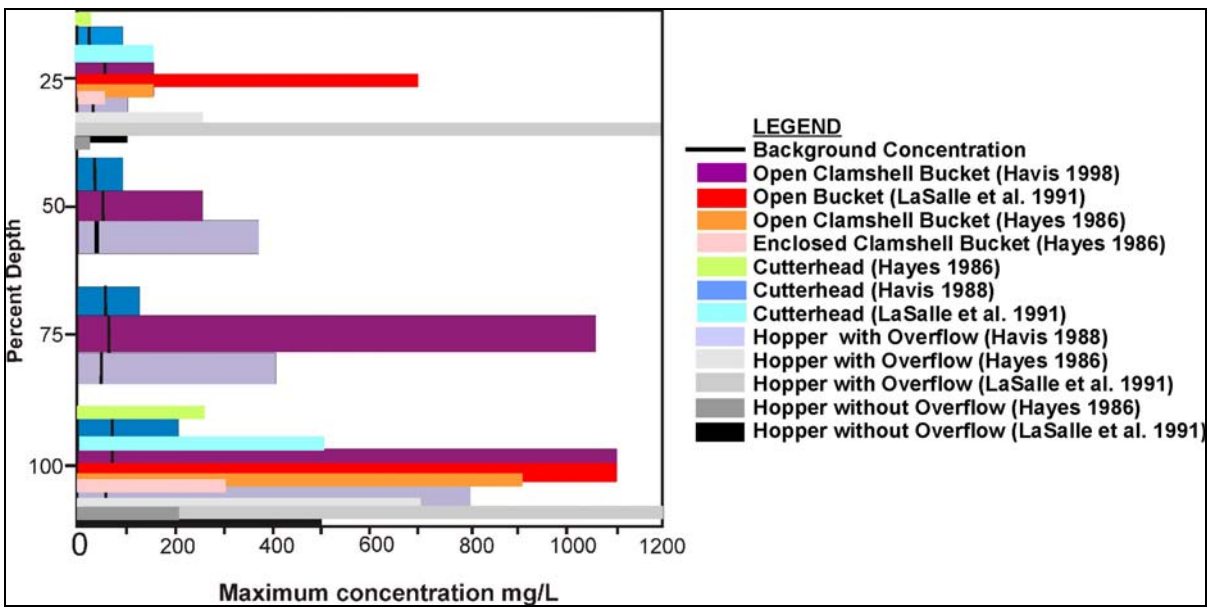
Monitoring data from California projects are compared with values reported from other geographic locations as available from documents obtained during the literature review.

5.5.3.1 Total Suspended Sediment

Dredging Operations

Figure 5.5-1 shows maximum total suspended sediment concentrations from conventional dredges studied under the Corps' IOMT program (Hayes 1986, Havis 1988, McClellan et al. 1989), and generalized maximum suspended sediment fields summarized from various studies (LaSalle et al. 1991). TSS concentrations were similarly low with cutterhead dredges, hopper dredges without overflow, and closed clamshell bucket dredges. Higher TSS concentrations resulted with hopper dredges with overflow and conventional open clamshell bucket dredges. The following ranges of TSS concentrations were reported within 100 ft (30 m) from the dredges:

- Closed bucket dredges – ≤50 mg/L near surface and ≤300 mg/L near bottom.
- Cutterhead dredges – ≤150 mg/L near surface and ≤500 mg/L near bottom.
- Hopper dredges without overflow – ≤100 mg/L near surface and ≤500 mg/L near bottom.
- Hopper dredges with overflow – 100 to >1,000 near surface and 700 to >1,000 mg/L near bottom.
- Open bucket dredges – ≤ 700 mg/L near surface to ≤ 1,100 mg/L near bottom.



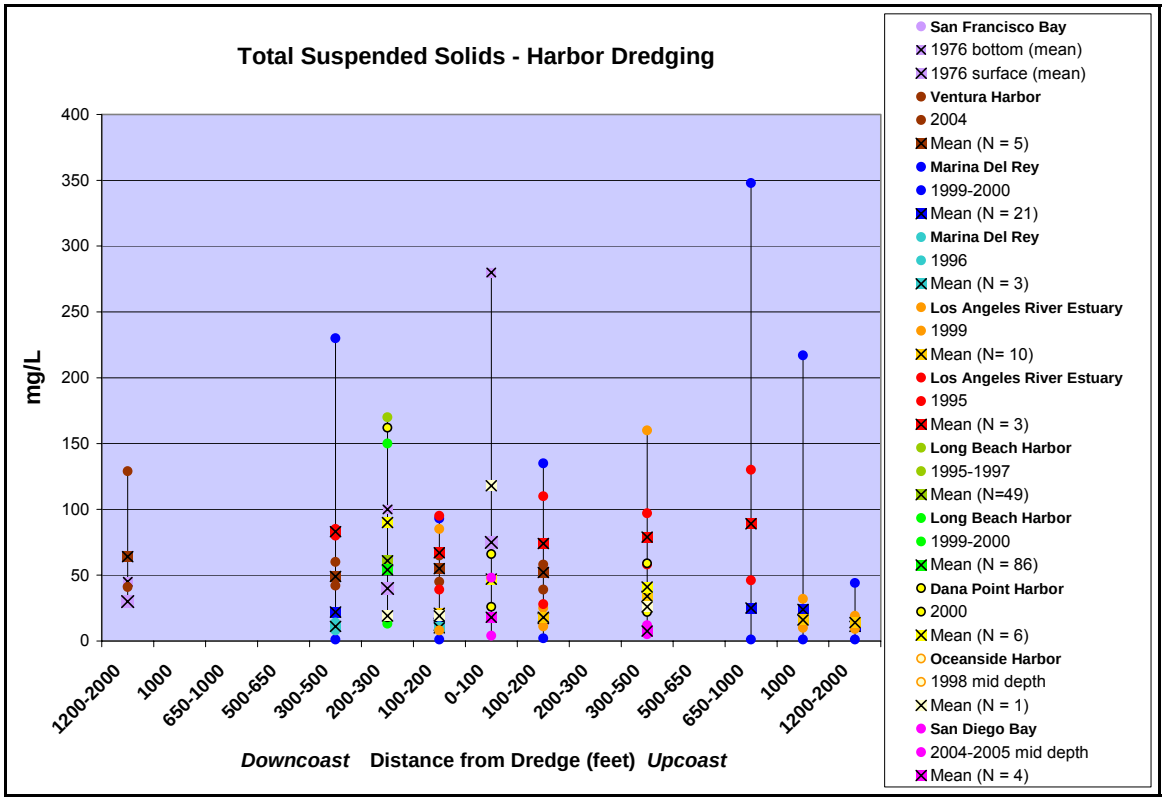
Sources: Redrawn from Havis 1988, with addition of data from Hayes 1986 and LaSalle et al. 1991.

Figure 5.5-1. Maximum total suspended sediment concentrations measured around commonly used mechanical and hydraulic dredges.

Generally, TSS concentrations are highest near the bottom in the vicinity of the dredge and decrease towards the surface. However, open bucket dredges and hopper dredges with

overflow may generate very high near surface turbidity from spillage of turbid water. Use of enclosed watertight buckets may reduce near surface TSS concentrations by 30 to 70%, although near-bottom concentrations may increase by 50 to 70% as the bucket descends through the water column (LaSalle et al. 1991). Operations using hopper dredges without overflow may reduce TSS concentrations by on order of magnitude (*ibid.*).

Figure 5.5-2 summarizes TSS concentrations from 11 representative California dredging projects that included nearly 200 surveys. The projects were in bays and estuaries and used mechanical or hydraulic dredges (Appendix Table C.2). Data for Long Beach Harbor are from MBC 2000. No reports of TSS monitoring data was found for offshore borrow site dredging off California, although other plume related measurements have been used during compliance monitoring (Section 5.5.3.2). The maximum TSS concentration was 350 mg/L (Marina del Rey Harbor maintenance dredging using an open bucket dredge, 1999-2000). Mean concentrations were <100 mg/L at distances >300 ft (> 91 m) for all reviewed projects. Often the depth of sampling was not specified in the monitoring reports.



Note: Circles depict range, square box with centered "x" depict mean value.

Figure 5.5-2. Representative total suspended solids concentrations during sediment dredging activities.

Relatively high mean concentrations (> 100 mg/L) were recorded at mid-depth and near bottom within 100 ft (30 m) for two projects. For example, a mean concentration of 110 mg/L was measured at mid-depth within 100 ft (30 m) of the clamshell dredge during maintenance dredging at Oceanside Harbor. Mean concentrations near the bottom ranged

from 280 mg/L within 100 ft (30 m) to 100 mg/L at 328 ft (100 m) from the dredge, but mean concentrations near the surface were ≤ 75 mg/L during a project in San Francisco Bay. In contrast, mean concentrations at mid-depth in San Diego Bay were <20 mg/L.

Anchor Environmental (2003) reported an average TSS value of 60 mg/L for 9 projects using mechanical dredging in Long Beach and Los Angeles Harbors. Values were recorded from 80 to 300 ft (24 to 91 m) from the dredge, with most recorded 300 ft (91 m) away. When they added data from nearly 30 other project locations from other geographic locations in the United States and internationally, they obtained an average value of 83 mg/L. In comparison, background concentrations ranged from 8 to 19 mg/L.

Concentrations during dredging may be similar to those during storms and/or high river runoff (Table 5.5-2). For example, elevated concentrations ranging from 58 to 350 mg/L have been reported for San Francisco Bay (O'Connor 1991, Wilber and Clarke 2001). Nearshore TSS concentrations of 56 to 100 mg/L have been measured or estimated during storm events offshore the Russian, Santa Clara, and Ventura Rivers (Mertes et al. 1987, Sherwood et al. 1994, Warrick et al. 2004). TSS concentrations of 1,000 to 2,000 mg/L at elevations of 6 to 11 in (15 to 27 cm) above the bottom were measured during high energy events off the Eel River, Northern California (Wright et al. 1999).

Concentrations during dredging also may be similar to those during other vessel activities. Weston and U.S. Army-ERDC (2006) reported TSS concentrations of > 30 to > 170 mg/L, compared to ambient conditions of 20 to 30 mg/L, during large vessel traffic and docking in San Francisco Bay. TSS concentrations up to 250 mg/L, which persisted 8 hours, were associated with vessel traffic in Hillsborough Bay, Florida (Schoellhamer 1996 cited in Wilber and Clarke 2001). Schubel et al. (1978) reported concentrations of 100 to 550 mg/L behind a shrimp trawler in Corpus Christie Bay, Texas.

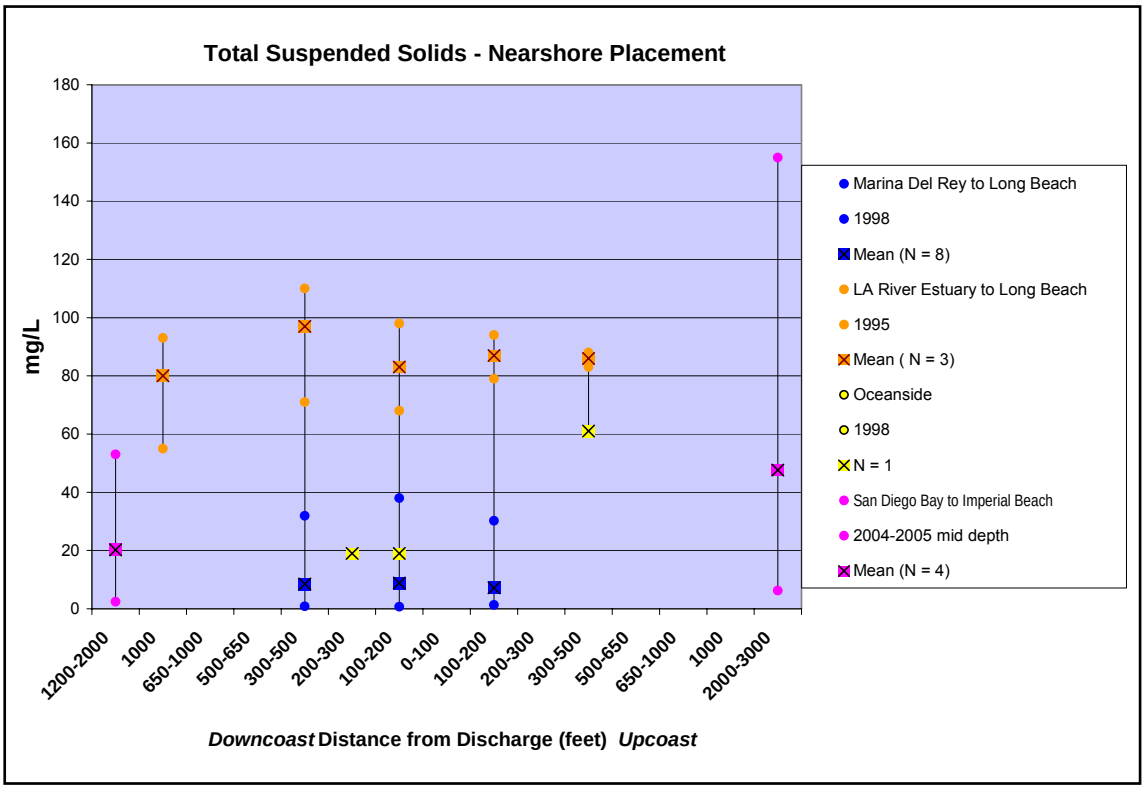
Table 5.5-2. Total suspended solids concentrations during storms and/or high river runoff in bays and the nearshore zone.

Location	TSS (mg/L)	Reference
Bays		
San Francisco Bay, CA	58-200	O'Connor 1991
San Francisco Bay, CA	250-350 5 days peak, background within 1 month	Buchanan and Schoellhamer 1996[1], Schoellhamer 1996[1]
Indian River Bay, DEL	570	Huntington and Miller 1989[1]
Chesapeake Bay,	600	Brownlee et al. 1988[1]
Offshore River Mouths		
Eel River, CA	1,000 to 2,000 (bottom)	Wright et al. 1999
Russian River, CA	56 to 100	Sherwood et al. 1994
Santa Clara and Ventura Rivers, CA	60	Warrick et al. 2004
Santa Clara and Ventura Rivers, CA	70 to 100	Mertes et al. 1998
Manasquan Inlet, NJ	225 mg/L (surface)	Wilber et al. 2006
Shark River, NJ	200 mg/L (bottom)	Wilber et al. 2006

In-Bay and Nearshore Placement

Several factors affect turbidity plumes and suspended sediment concentrations during sediment discharge, including: method of discharge (e.g., mechanical, hydraulic), sediment characteristics (e.g., grain size, solids, water content), discharge rate, discharge configuration (e.g., above, at, or below water), water depth, and hydrodynamic regime (LaSalle et al. 1991).

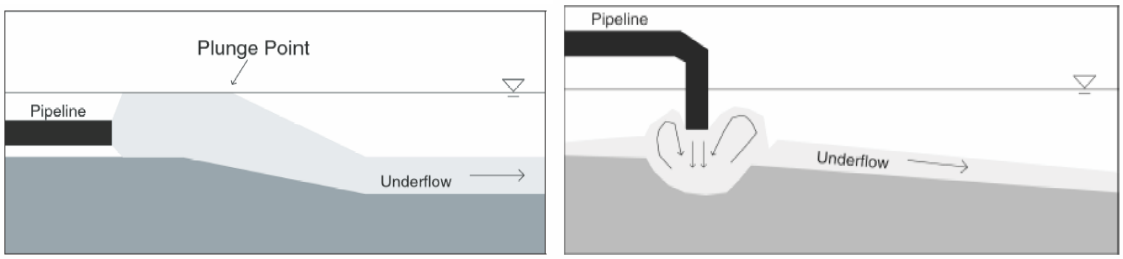
Figure 5.5-3 presents TSS concentrations during nearshore placement during four California sediment management projects consisting of 16 surveys. Mean values varied more by project than by distance from the discharge. Mean values during the nearshore placement off Long Beach ranged from 80 to nearly 100 mg/L when materials were dredged from Los Angeles River, and were < 20 mg/L when dredged from Marina del Rey. Values clearly outside the turbidity plume were not measured with those projects. During nearshore placement at Oceanside, mean values were higher 500 ft (152 m) upcoast than off the discharge location. During placement off Imperial Beach, mean concentrations ranged from 20 to nearly 50 mg/L outside the plume, no measurements were taken in the plume.



Note: Circles depict range, square box with centered "x" depict mean value.

Figure 5.5-3. Representative total suspended solids concentrations during nearshore placement activities.

TSS concentrations range higher during hydraulic discharge in shallow waters. During hydraulic discharge, sediments form layers of fluidized sediment at the bed, which flow away from the point of discharge. Teeter (2000, 2001, 2002) described and modeled processes associated with the movement, spreading, and water column entrainment of fluidized mud flows have been described for shallow and deep water discharges (Figure 5.5-4). With horizontal pipeline discharge in shallow waters, turbulent mixing may result in a visible surface plume behind the discharge; a localized turbulent mixing zone also occurs in the vicinity of downward directed vertical pipeline discharge, which in shallow waters also may result in a scour hole. Underwater, the fluid layer moves and spreads depending on bottom slope, ambient currents, and the initial discharge trajectory. The fluid layer near the bottom is referred to as the underflow, a portion of which forms the near-bed deposit and the remaining portion becomes entrained in the water column and is transported by currents away from the area.



Source Teeter 2001

Note: Horizontal pipeline - fluidized mud suspension with turbulent surface flow and transition to submerged underflow at plunge point with horizontal pipeline discharge; Vertical downward pipeline with localized turbulent zone and transition to underflow.

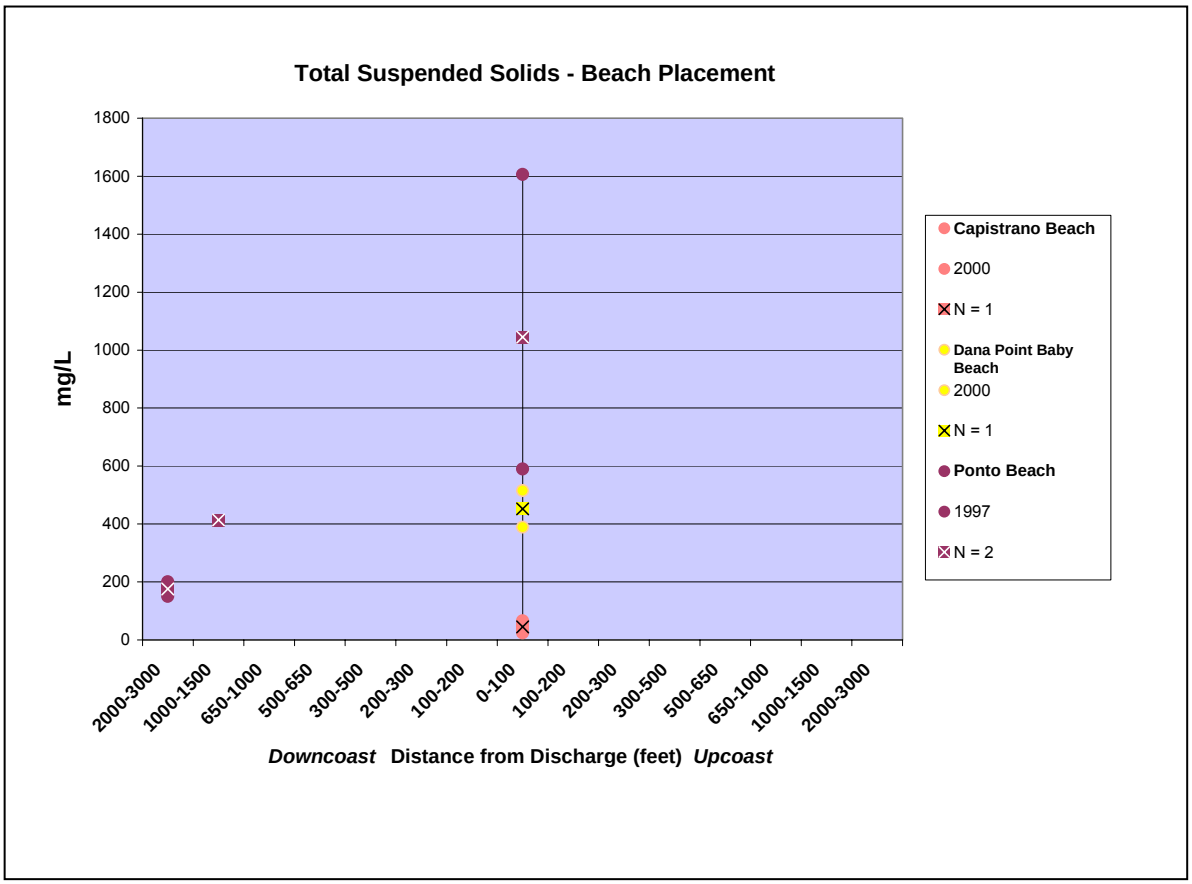
Figure 5.5-4. Schematic of hydraulic pipeline discharge.

The typical solids content of the slurry is 10 to 20%by weight (LaSalle et al. 1991). TSS concentrations in the underflow may be on the order of several thousand milligrams per liter (LaSalle et al. 1991). Elevated suspended sediment concentrations may occur above the underflow by a process referred to as entrainment, which may be enhanced by waves and/or wind wave advection. Generally, the quantity of material suspended in the upper water column is from 1 to 5% of that released, and range from tens to a few hundred milligrams per liter (LaSalle et al. 1991).

Teeter (2002) measured TSS concentrations above the fluidized underflow associated with hydraulic pipeline discharge of muddy sediments in shallow (≤ 6 ft, 2 m) waters of the Laguna Madre embayment in Texas. Measurements were made mainly within 1,640 ft (500 m) of the discharge; elevated TSS concentrations did not extend much beyond the underflow footprint due to limited water column advection (mainly from wind driven waves). Depth-averaged concentrations ranged from 168 to 1,053 mg/L. Concentrations considered as background ranged from 30 to 120 mg/L.

Beach Placement

Highly variable TSS concentrations may be measured during placement on the beach. Mean concentrations ranged from <100 mg/L to over 1,000 mg/L during 3 projects (Figure 5.5-5). Some of the variability may have related to where the measurements were taken. For example, a mean concentration of 45 mg/L was measured at mid depth approximately 500 ft (150 m) offshore a discharge location at Capistrano Beach. Placement of dredge materials from Dana Point Harbor on Baby Beach resulted in relatively high mean concentrations (452 mg/L) at the discharge location. During the Ponto Beach Project, a high mean concentration (1,045 mg/L) was measured directly offshore the discharge location and relatively high values (150 to 414 mg/L) were measured within approximately 0.6 mile (1 km) downcurrent, indicating rapid transport in the surf zone. The relatively high TSS concentrations were short-lived; TSS concentrations returned to background levels (approximately 21 to 25 mg/L) within approximately 1 hour after cessation of construction each day of the two-day project (Sherman et al. 1998). The Ponto Beach Project involved pushing sediments with 18% silt/clay directly into the surf zone using earth moving equipment.



Note: Circles depict range, square box with centered "x" depict mean value.

Figure 5.5-5. Representative total suspended solids concentrations during beach placement activities.

High TSS concentrations (1,760 to 4,700 mg/L) were measured in the surf zone during hydraulic beach nourishment of Fort Macon, North Carolina (Reilly and Bellis 1983). The spatial extent of elevated concentrations was not reported with that study.

Versar (2004) reported that TSS levels during beach nourishment were typically below 100 mg/L with occasional spikes near 1,000 mg/L, but spikes also were observed during other periods likely in response to off-shore storms, winds, tidal cycles, and high surf conditions. The turbidity plume associated with sand placement tended to remain close to shore, with its direction of displacement being associated with tide stage and currents. They concluded that turbidity plumes caused by the beach disposal operations were small and short-lived.

Wilber et al. (2006) measured TSS concentrations in the swash zone, surf zone, and nearshore during beach nourishment at two sites, constructed one year apart, as part of a several million cy beach nourishment project in New Jersey. Nourishment involved hydraulic placement on the beach, with slurry running in streams down the beach face. The projects differed in measured concentrations and plume extent (Table 5.5-3). Maximum TSS concentrations were <700 mg/L in the swash zone, 64 mg/L near the bottom in the surf zone, and 34 mg/L near the bottom in nearshore waters during placement at the two receiver sites. Background concentrations were less than 20 mg/L. Elevated turbidity mainly was confined to the surf zone within 984 ft (300 m) upcurrent and 1,640 ft (500 m) downcurrent depending on survey. In the nearshore, elevated concentrations extended farther downcurrent (up to 2,297 ft, 700 m).

TSS concentrations measured during two separate storm events withn a two-week period one year after the second nourishment project (i.e., two years after the first project) varied among the receiver sites and sites that had not received any nourishment. Results suggest that storm effects were greater off the nourished sites (Table 5.5-3). TSS concentrations after storms were higher in the swash and nearshore zones off the site that had been nourished the previous year (1998) than a site that was nourished two years previously (1997) or at beach sites that had not received any nourishment. In the surf zone, storm effects were less pronounced among all sites. The authors noted that sediments at the beach nourished in 1998 had become finer between pre- and post-nourishment; however, some of that change had started before nourishment and was widespread in the area.

Table 5.5-3. Comparison of total suspended solids concentrations during beach nourishment and storm conditions off New Jersey.

Site	1997	1998	1999 (storm 1)	1999 (storm 2)
Receiver Beach				
Swash	176	< 700	691	30,000
Surf Zone (bottom)	< 30	64	< 75	~ 150
Nearshore (bottom)	< 10	< 20	75	425
Unnourished Beach				
Swash	< 10	< 20	120	> 150
Surf zone (bottom)	< 10	< 20	< 50	> 150
Nearshore (bottom)	< 10	< 20	< 50	< 50
Offshore River Inlets				
Manasquan Inlet			> 200 (nearshore surface)	
Shark River				> 200 (surf zone , nearshore)

Source: Wilber et al. 2006

During storm conditions off California, TSS concentrations may range from 50 to >1,000 mg/L near river discharges (Sherwood et al. 1994, Nezlin and DiGiacomo 2004). During large river floods, near bottom (hypopyncnal) plumes of fluid mud with TSS concentrations >10,000 mg/L may extend offshore (Ogston et al. 2000, Warrick and Milliman 2005).

Measured concentrations during beach nourishment also can be within ranges that naturally occur during high wave conditions off California and Oregon. For example, TSS concentrations near the bottom averaged 340 mg/L during wave induced sediment suspension events with short-term (seconds) instantaneous maximum values >20,000 mg/L In the nearshore (39 ft, 12 m) off central California, (Storlazzi and Jaffe 2002). Surf zone TSS measurements during a period when significant offshore wave heights were 10 to 16 ft (3 to 5 m) ranged between 500 and 28,000 mg/L at an elevation of 1.5 in (4 cm) above the bottom, 600 to 2,900 mg/L at 7 in (20 cm) above the bottom, and 500 mg/L at 21 in (54 cm) above the bottom at a dissipative beach in Oregon (Beach and Sternberg 1992, Ogston and Sternberg 1995). Instantaneous peak concentrations over periods of 30 to 45 seconds can reach 20,000 to 40,000 mg/L at elevations of up to at least 10 in (26 cm) in the surf zone (Beach and Sternberg 1988).

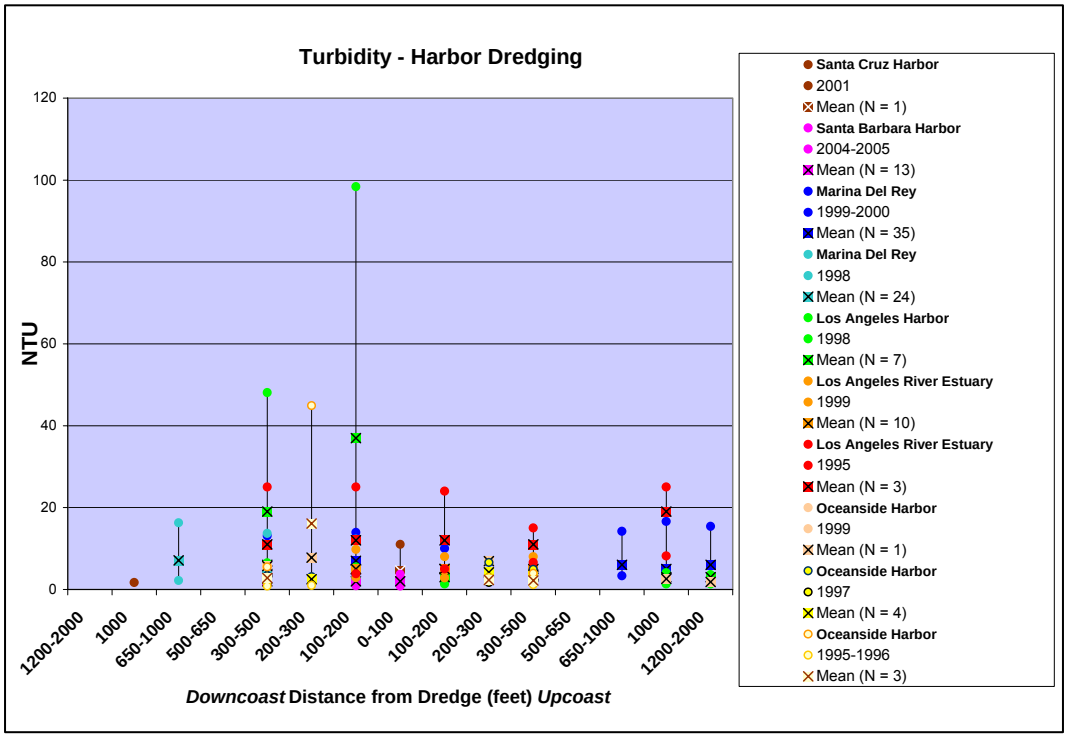
5.5.3.2 Turbidity Values

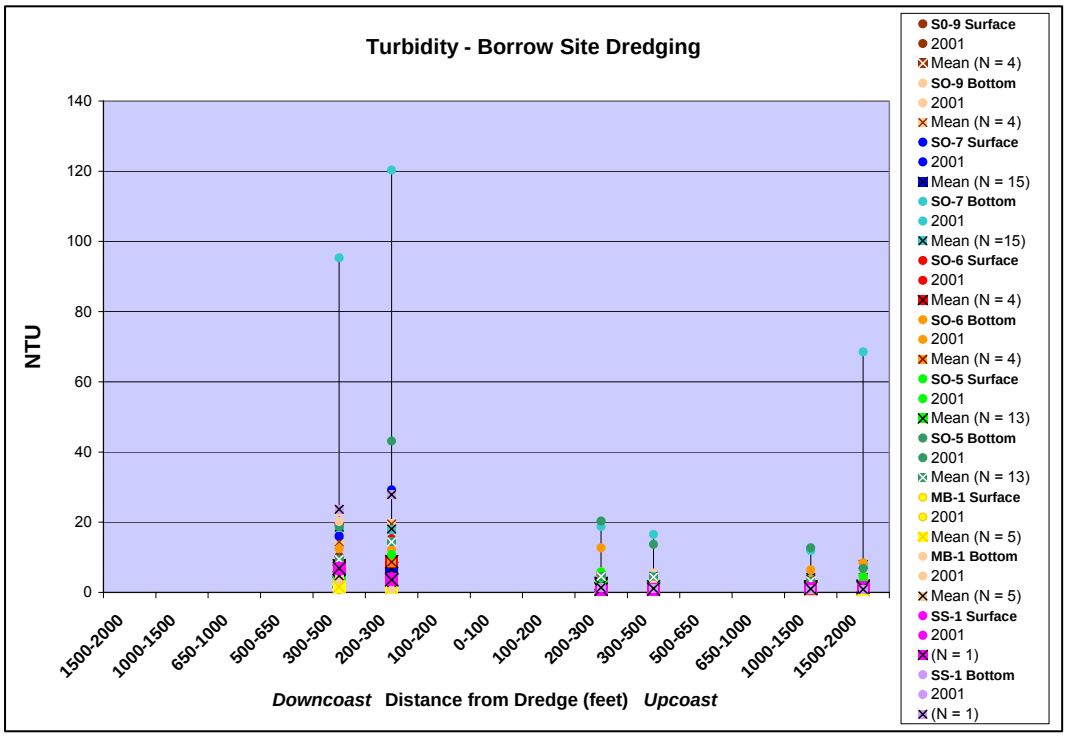
Figure 5.5-6 shows turbidity values measured during 175 surveys from 16 harbor, estuary and offshore borrow site dredging projects in California. Turbidity values ranged up to 98 NTU on one occasion; however, mean values were substantially lower. Most mean values were 20 NTU or less, although one project had a mean of 37 NTU that was measured within 200 ft (60 m) of the dredge (Los Angeles Harbor 1998).

Similarly, mean values were low (< 30 NTU) during offshore borrow site dredging (2001 San Diego Regional Beach Sand Project); higher values (28 to 120 NTU) were measured infrequently near the bottom. Elevated values were within 500 ft (150 m) downcurrent, measurements were not collected farther away downcurrent. Downcurrent values sometimes were > 20% from control values. Low concentrations were measured between 250 and 1,500 ft (75 to 450 m) upcurrent.

Figure 5.5-7 shows turbidity concentrations measured during 7 beach (49 surveys) and 4 nearshore (31 surveys) sand placement projects. Mean values were < 4 NTU at mid-depth during nearshore placement. The very low values suggest measurements were taken above the descending plume.

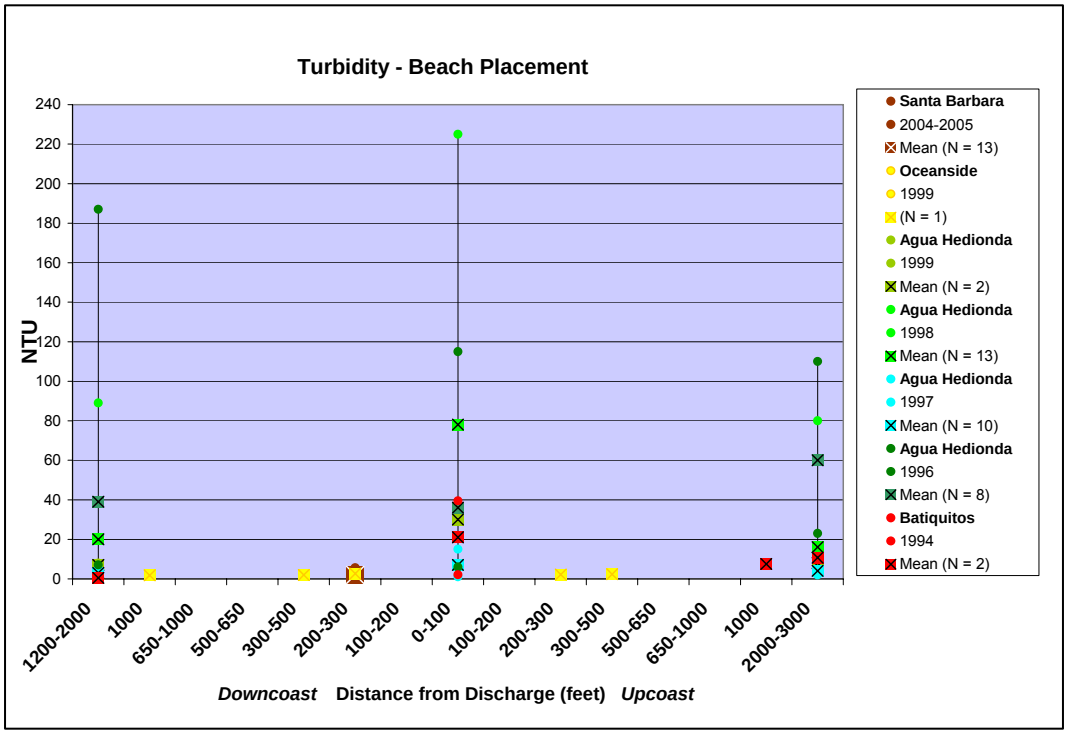
Mean values during beach placement projects were variable and ranged from < 3 NTU to 78 NTU. Tubidity during beach placement was measured from a boat outside the surf zone. On some surveys values were 2 to 3 times higher offshore the discharge location (7 to 78 NTU) than at distances 2,000 to 3,000 ft (450 to 500 m) away (3 to 20 NTU). During one project (Agua Hedionda Lagoon 1996 maintenance cycle), mean values were as high or higher (39 to 60 NTU) 2,000 to 3,000 ft (450 to 500 m) away as directly offshore the discharge location (36 NTU), suggesting operations were conducted during storm conditions.

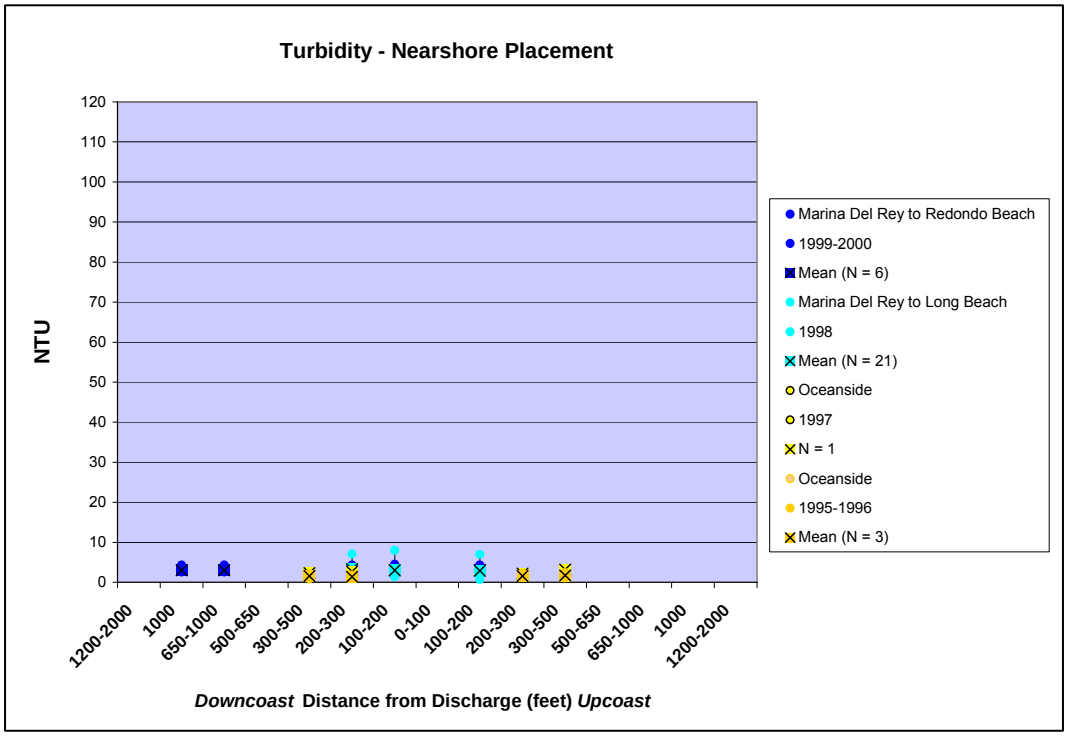




Note: Circles depict range, square box with centered "x" depict mean value.

Figure 5.5-6. Representative turbidity measurements during sediment dredging activities in California.





Note: Circles depict range, square box with centered "x" depict mean value.

Figure 5.5-7 . Representative turbidity measurements during sediment placement activities in California.

Studies on the East Coast have reported variable turbidity values during beach nourishment. Wilber et al. (2003) reported values from 9 to 70 NTU during beach nourishment compared to 2 to 60 NTU at reference stations; higher values at reference stations were near river inlets. After beach nourishment, turbidity values ranged from 2 to 87 NTU (median 9 NTU) one year later and <5 to 54 NTU (median 8 NTU) two years later. TSS concentrations associated with this project are reported in Section 5.5.3.2 (Wilber et al. 2006).

Ambient levels of NTU vary depending on water characteristics, including type of particulates. Generally, values of 1-3 NTU are considered very clear, 10-15 NTU as having nominal turbidity, and 100 to 1,000 NTU as very turbid (Thackston and Palermo 2000). NTU values > 50 typically are associated with storms and/or high wave conditions (MEC 2000a).

5.5.3.3 Water Clarity Values

Figure 5.5-8 illustrates Secchi disk depth measurements of water clarity during dredging of 11 harbor and estuary projects (137 surveys) and 6 offshore borrow site projects (44 surveys) in California. During harbor-estuary dredging, overall mean values were less within 500 ft (152 m) of the dredge compared to farther away. During borrow site dredging, mean values ranged from 3.2 to 18.4 ft (1 to 5.6 m) within 500 ft (150 m) downcurrent of the dredge compared to 11.1 to 32 ft (3.3 to 9.7 m) at distances 200 to 2,000 ft (60 to 450 m) upcurrent, representing 0 to 78% reductions in near-field, downcurrent water clarity (Appendix C.3). Water clarity reductions greater than 20% are outside compliance criteria.

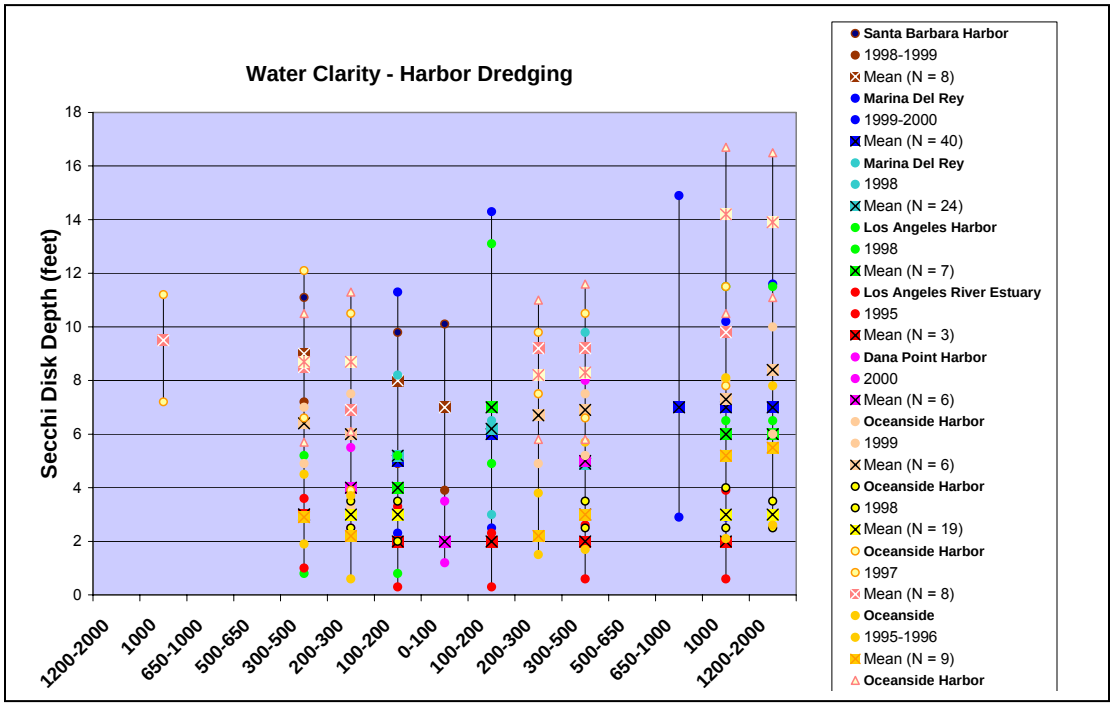
Figure 5.5-9 presents Secchi disk measurements of water clarity during four beach (12 surveys) and six nearshore (68 surveys) placement projects. During beach placement, mean values near the discharge location ranged from 1.2 to 4 ft (0.4 to 1.2 m) compared to 2 to 9 ft (0.6 to 3 m) at distances 200 to 3000 ft (approximately 60 to 900 m) away, representing 11 to 76% reductions in water clarity offshore the discharge location (Appendix C.3). Water clarity reductions greater than 20% are outside compliance criteria.

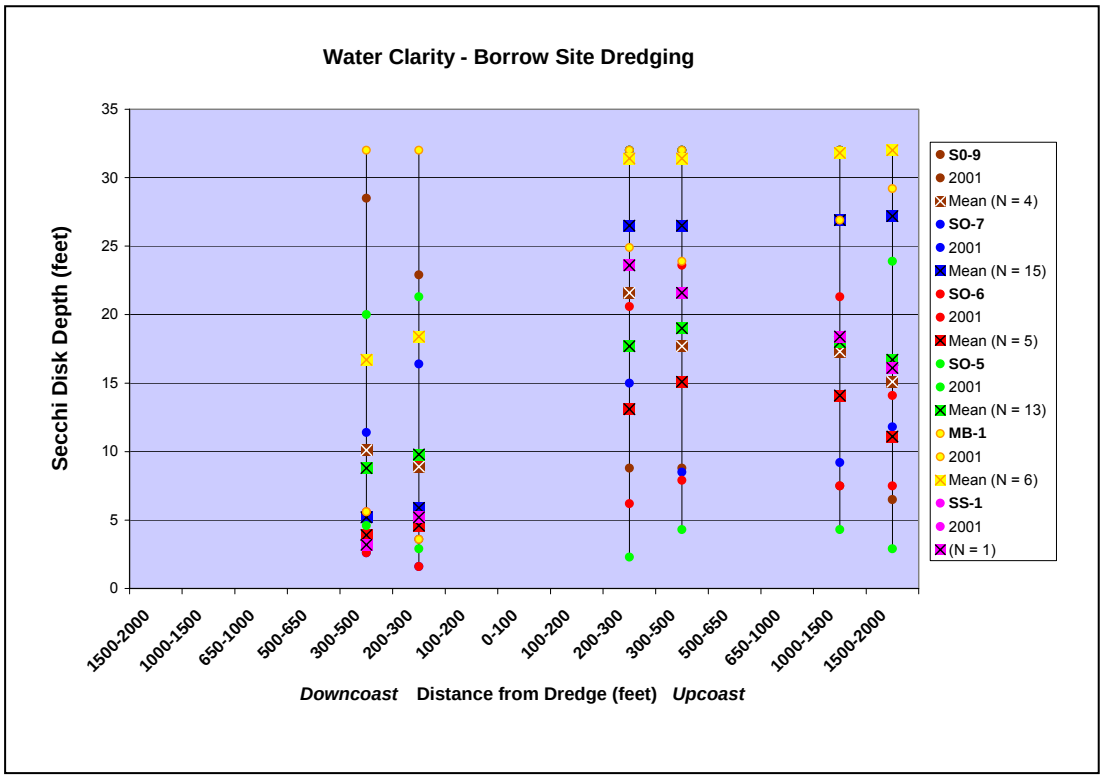
Less reduction was associated with nearshore placement; mean values within 200 ft (60 m) of the discharge ranged from 2.9 to 9.5 ft (0.9 to 3 m) compared to 8 to 13.7 ft (2.4 to 4 m) at distances 300 to 2,000 ft (100 to 450 m) away, representing 0 to 11% reductions in water clarity near the discharge location.

5.5.3.4 Light Transmission

Figure 5.5-10 shows light transmittance values measured during nearshore placement (56 surveys) and harbor dredging (169 surveys). Mean light transmittance values of 60 to 73 % were measured at distances 1,200 to 3,000 ft (365 to 450 m) away from the nearshore placement location during the 2004-2005 Imperial Beach Project; no measurements were taken closer to the discharge precluding near- and far-field comparisons for that project.

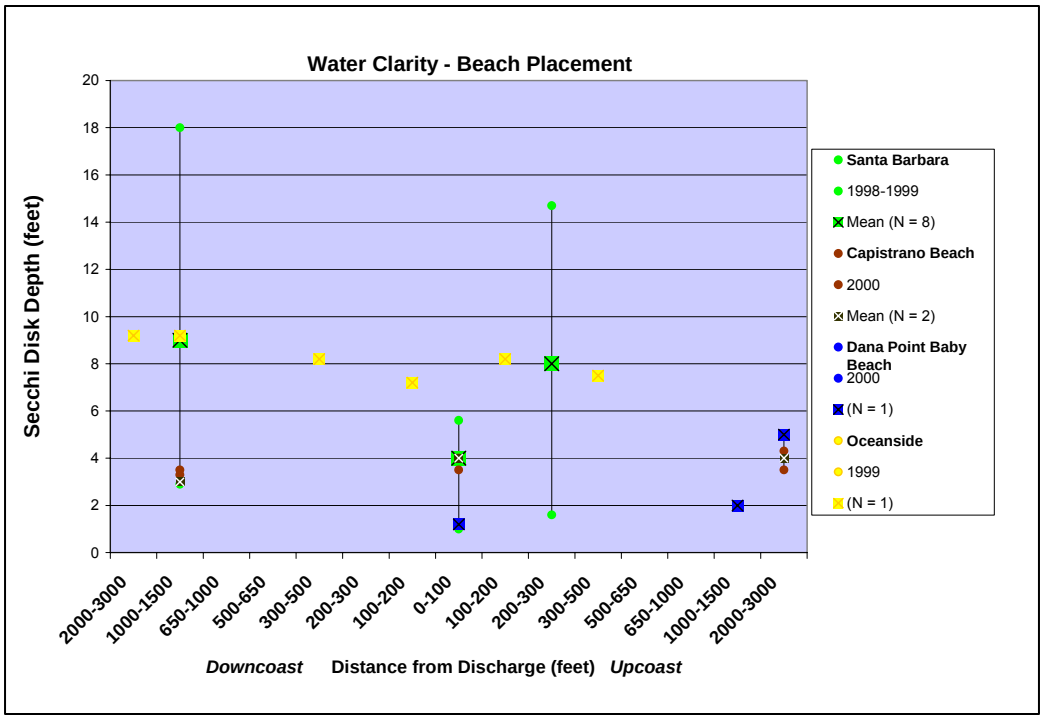
During harbor dredging mean light transmission values varied more by project location than with distance from the dredge. For example, mean transmission values during the 2004-2005 San Deigo Bay Deepening Project were slightly lower at 70% within 100 ft (30 m) of the dredge, but were near 80% farther away. In contrast, mean values in Ventura Harbor were below 40% near the bottom near the dredge and ranged from approximately 40 to 50% farther away. In Long Beach Harbor, a mean transmission value of 30% occurred within 300 ft (91 m) of the dredge; MBC (2000) reported that “control” values averaged 57%.

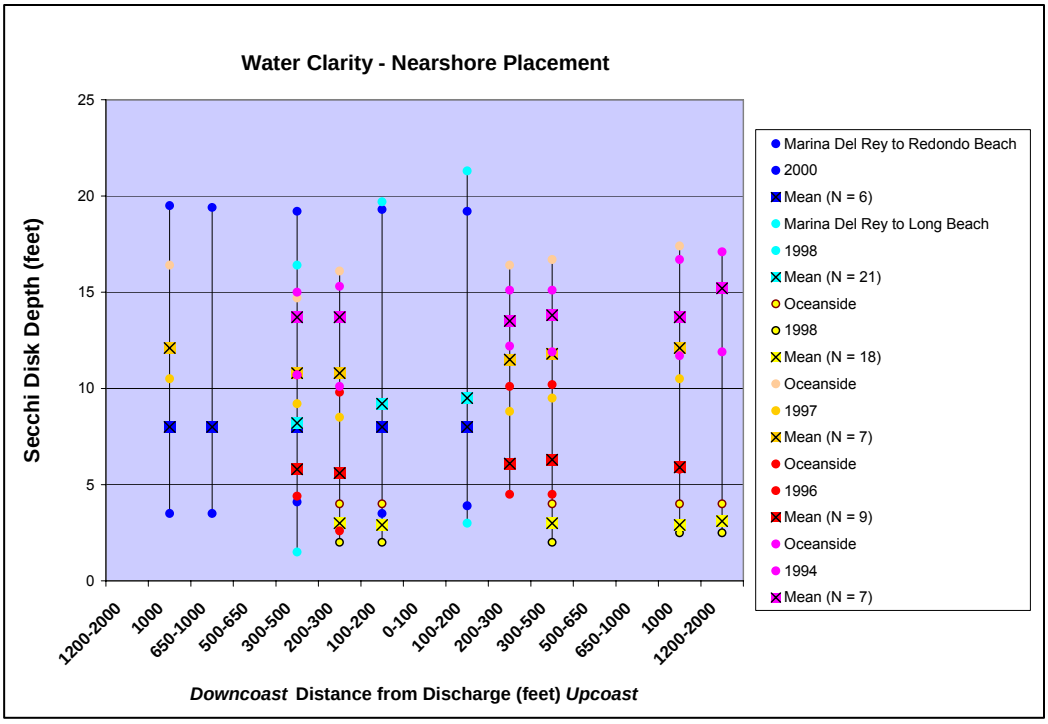




Note: Circles depict range, square box with centered "x" depict mean value.

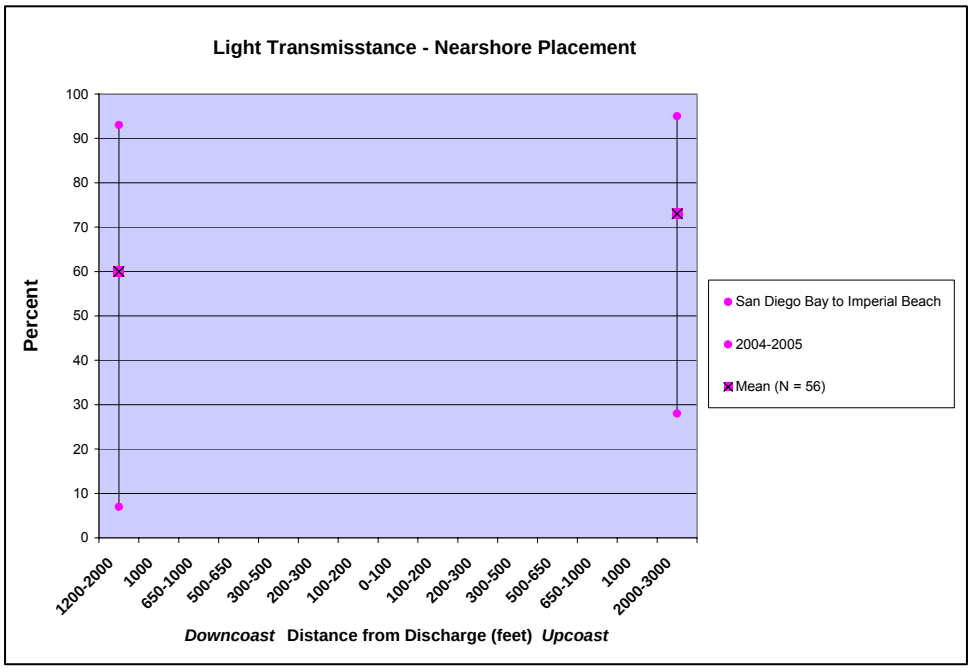
Figure 5.5-8 . Representative water clarity measurements during sediment dredging activities in California.

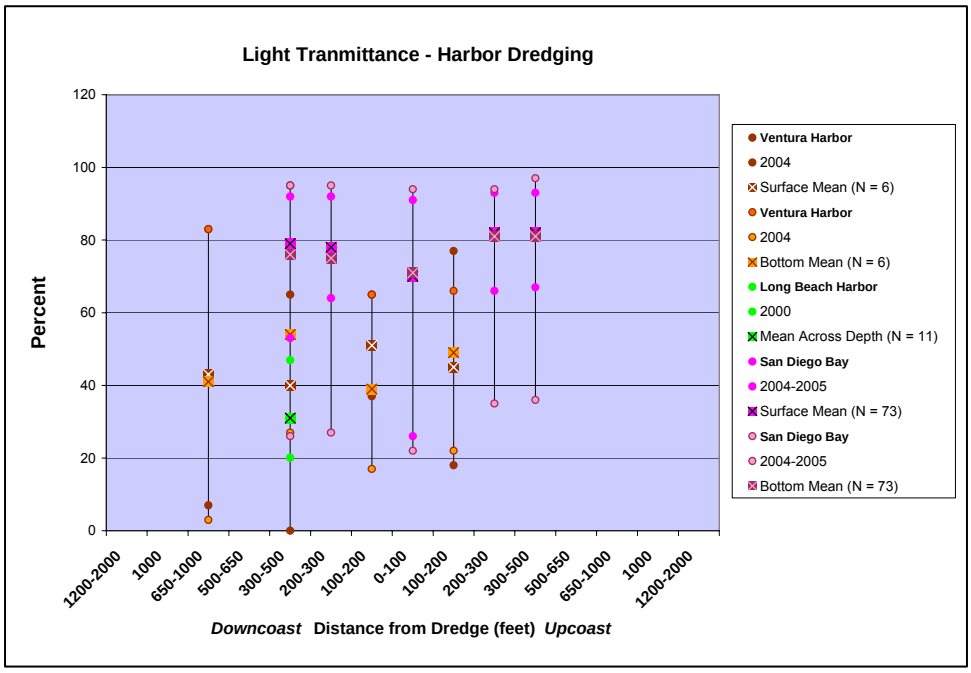




Note: Circles depict range, square box with centered "x" depict mean value.

Figure 5.5-9 . Representative water clarity measurements during sediment placement activities in California.





Note: Circles depict range, square box with centered "x" depict mean value.

Figure 5.5-10 . Representative light transmittance measurements during sediment management activities in California.

5.5.3.5 Turbidity Plumes

Sediment fall rate affects the distance and duration of suspended sediment plumes (Section 5.5.2.2). Generally, larger sandy particles settle more rapidly than smaller silt/clay particles; although, flocculation of fine particulates may increase fall rates. Suspended sediment plumes associated with dredging differ from those caused by disposal, although plume transport may be similar for both. Both are reviewed in this section.

Dredging

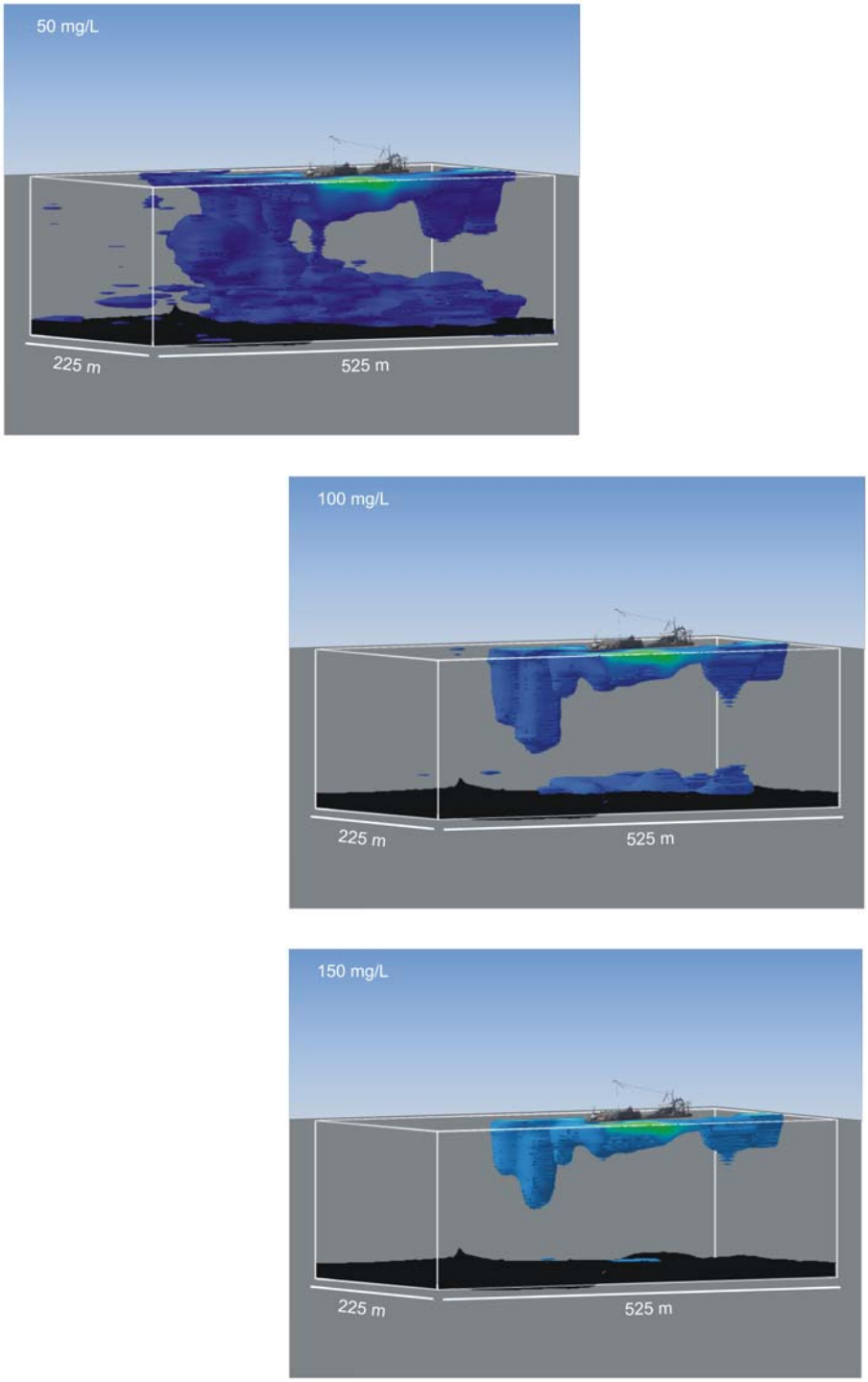
Dredging involves the removal of bottom sediment; consequently, resuspended sediment plumes have higher concentration near the bottom and typically decrease towards the surface unless there is overflow. The TSS concentration and spatial extent of plumes vary depending on type of dredge, operational controls, and environmental conditions at the time of dredging.

LaSalle et al. (1991) summarized that general suspended sediment plume lengths around three commonly used dredge types were as follows:

- Hydraulic suction cutterhead dredges – 0 to 328 ft (0 to 100 m) near surface, ≤ 1640 ft (≤ 500 m) near bottom.
- Hydraulic suction hopper dredges – 0 to 2,297 ft (0 to 700 m) near surface, ≤ 3,937 ft (≤ 1,200 m) near bottom without overflow.
- Mechanical bucket/clamshell dredges – 328 to 1,969 ft (100 to 600 m) near surface, ≤ 3,281 ft (≤ 1,000 m) near bottom.

Sedimentation during dredging results from the resuspension of sediment from equipment disturbance and transport and deposition, which are related to sediment grain size characteristics and hyrodynamics of the water body (see Section 5.5). Deposition may range over distances > 1 mile (> 1.6 km), but settlement occurs over near- to far-field gradients associated with physical and hydrodynammic processes. Generally, the majority of sediment deposits within 164 to 328 ft (50 to 100 m) of the dredge, and decrease with increasing distance from the source; a generalized worst-case plume ia considered ≤ 500 mg/L at distances ≤ 1,640 ft (≤ 500 m) (LaSalle et al. 1991).

A comparative study of laboratory measured TSS concentrations with estimates from acoustic ADCP surveys in Oakland Harbor during dredging with an 12-cy closed cable bucket showed distinct plume signatures with a TSS concentration of 50 mg/L up to 1,312 ft (400 m) from the source; whereas, concentrations of 100 mg/L occurred in localized pockets above the bottom and sometimes into mid-depth (MEC and USACE-ERDC 2004) (Figure 5.5-11). Concentrations >150 mg/L (maximum of 390 mg/L) were highly localized around the source, and mainly occurred in surface waters. Background concentrations generally were <50 mg/L, but sometimes ranged higher perhaps as a result of the onset of the plume and/or commercial vessel traffic. These values are similar to those reported from several dredging projects conducted in other California harbors, which were reviewed in Section 5.5.2.1 (Figure 5.5-2).



Source: MEC and U.S. Army ERDC 2004
Permission to use by MEC-Weston

Figure 5 5-11. Illustration of decay of TSS concentrations with increasing distance from clamshell dredging operations.

Turbidity measurements reviewed for offshore borrow sites in Section 5.5.2.2 (Figure 5.5-5) suggests that the majority of deposition was within 500 ft (152 m) downcurrent of the dredge. Similarly, sand deposition occurred within 500 ft (150 m) of hydraulic trailer dredge operations involving commercial aggregate extraction in the Baltic Sea (Gajewski and Uscinowicz 1993 cited in Newell et al. 1998).

Thinner-layer deposition may occur over greater distance. Total suspended sediment concentrations rapidly decayed within 829 ft (250 m) of four commercial aggregate dredges during normal operations off the United Kingdom (Hitchock and Drucker 1996 cited in Newell et al. 1998). Concentrations of suspended sand-sized material decayed to background levels over a distance of 650 to 1,640 ft (200 to 500 m) of a commercial aggregate dredger operating in Moreton Bay, Queensland, Australia; deposition of fines was estimated as 23 mm/m^2 at (1,640 ft) 500 m, 16 mm/m^2 at (0.6 mi) 1 km, 12 mm//m^2 at (1 mi) 1.5 km, 8 mm//m^2 at (1.5 mi) 2 km, and < 6 mm/m^2 at (1.5 mi) 2.5 km (Poiner and Kennedy 1984 cited in Newell et al. 1998). The zone of sand deposition was confined within 984 ft (300 m) of the area dredged by hydraulic suction without screening off the South Coast of Britain (Hitchcock et al. 2002).

In contrast, hydraulic dredging with overboard screening may result in deposition of well-sorted fine sands up to at least 1.2 mi (2,000 m) away from the site of discharge (Boyd et al. 2004).

Nearshore Placement

During open water disposal most of the material rapidly descends as a turbid cloud and forms a more dense cloud near the bottom after dynamic collapse as it reaches the bottom (SAIC 1987). The near bottom turbidity plume spreads horizontally until its momentum has dissipated, with migration in the direction of the current at the time of discharge. Vertical profiles of turbidity plumes during disposal at the Alcatraz site (San Francisco Bay) in 1976 showed TSS concentrations ranging from 25 mg/L (near surface) to 275 mg/L (near bottom) approximately 164 ft (50 m) from the release point and values declined to near background concentrations (25 mg/L) approximately 1,312 ft (400 m) downcurrent (USACE 1976 cited in LFR 2004).

Water clarity (Secchi disk) measurements reviewed in Section 5.5.3.3 (Figure 5.5-9) suggest that most sand deposition occurred within 500 ft (152 m) of the discharge location. Sampling design limitations preclude near-field and far-field gradient analysis of available TSS data (Figure 5.5-4). Mid-depth measurements of NTU during nearshore placement failed to detect any gradient with distance from the discharge (Figure 5.5-7), suggesting that measurements may have been taken above the descending plume.

Beach Nourishment

Turbidity plumes during beach nourishment vary depending on equipment used and operational controls. Generally, turbidity is most pronounced within the swash zone, but may extend farther offshore where there are rip currents (AMEC 2002). Turbidity also may be influenced by local weather-related conditions and/or proximity to river inlets (Wilber et al. 2003). Some projects have used temporary sand dikes and/or swales to minimize turbidity, which appears to be effective based on relatively small plumes. Representative plume measurements during beach nourishment projects are described below.

- Moffatt & Nichol (2003) provided results of turbidity mapping by lifeguards during the Goleta Beach Nourishment Project. Maps indicate lengths on the order of a few hundred feet that did not extend outside the surf zone. Pumped sediments were discharged in a swale to hasten settling of sands and minimize turbidity discharge.
- AMEC (2002) mapped turbidity plumes during placement at 12 beach sites during the 2001 San Diego Regional Beach Sand Project. Plumes were reported as primarily inside the surf zone except were there were rip currents. Sand was pumped behind temporary longitudinal dikes constructed of existing substrate and/or built after sufficient sand deposition. Longitudinal sand dikes and operational controls were used to control turbidity. Plume dimensions generally ranged from 100 to 328 ft long by 66 to 164 ft wide (30 to 100 m long by 20 to 50 m wide); on one occasion a plume of 984 ft long by 656 ft wide (300 by 200 m) was measured, but was short-lived after longitudinal dike was lengthened and water content of discharge was adjusted (AMEC 2002).
- MEC (1997) mapped plumes ranging from 100 to 10,560 ft long (30 by 3,218 m) by 50 to 1,000 ft (15 to 300 m) wide during the 1997 Surfside-Sunset Beach Nourishment Project. Generally, plumes were 200 to 300 ft long by 200 ft wide (61 to 91 m long by 61 m wide). Sands were dredged at an offshore borrow site and hydraulically pumped to the beach. Longitudinal sand dikes were used to control turbidity. Presence or absence of rip currents were not reported; however, based on extreme variation and reported greatest width, it is apparent that sampling covered both rip current and non-rip current periods.
- Plumes of approximately 700 to 2,500 ft long by 100 to 800 ft wide (213 to 762 m by 30 to 244 m) were reported during 4 different beach nourishment events off Aqua Hedionda Lagoon between 1993 and 1997; sands were dredged from the lagoon using a cutterhead dredge and hydraulically pumped to the beach. Upcurrent plumes ranged from 100 to 1,500 ft (30 to 457 m), whereas downcurrent plumes ranged from 700 to 2,500 ft (213 to 762 m). Dikes or movement of discharge location from swash to high on the beach were used to control turbidity (B. Dyson, 2000 personal communication). Presence or absence of rip currents were not reported; however, based on extreme variation and reported greatest width, it is apparent that sampling covered both rip current and non-rip current periods.
- Plumes of 200 to 900 ft long by 50 to 300 ft wide (61 to 274 m by 15 to 91 m) were reported during the 2000 Dana Point Harbor Beach Nourishment Project.
- Sherman et al. (1998) measured elevated suspended sediment plumes over a distance of 1.9 mi (3.1 km) during a small project (20,000 cy) involving pushing sediments (18% silt/clay) into the swash zone with bulldozers. High TSS values (700 to 1,500 mg/L) were measured off the discharge location, moderate TSS values of (201 to 561 mg/L) were measured within 0.8 mi (1.25 km) of the discharge, and lower, but detectable TSS values (96 to 127 mg/L) were measured from 0.9 to 1.9 mi (1.5 to 3.1 km) downcurrent. Background TSS concentrations ranged from 17 to 26 mg/L. The authors considered the probable zone of deposition on the order of 6 mi (10 km) long and 984 ft (300 m) wide based on review of aerial photographs. The authors reported that a large-scale, rip current contributed to plume expansion and mixing.
- Versar (2004) reported that TSS levels during beach nourishment were typically below 100 mg/L with occasional spikes near 1,000 mg/L, but spikes also were

observed during other periods likely in response to off-shore storms, winds, tidal cycles, and high surf conditions. The turbidity plume associated with sand placement tended to remain close to shore, with its direction of displacement being associated with tide stage and currents. They concluded that turbidity plumes caused by the beach disposal operations were small and short-lived.

- Wilber et al. (2006) reported that turbidity effects of beach fill operations associated with a several million cy project off New Jersery were short-term and limited to a relatively narrow swath of beach front with a lateral extent on the order of 1,312 ft (400 m) of the discharge pipe. Review of their figures showing gradient sampling indicated plumes sometimes extended up to 300 m upcurrent and 500 m downcurrent. Significantly higher TSS concentrations were measured in the swash zone at nourished than unnourished sites; however, values in the surf zone and nearshore were more variable and significant differences were not detected between nourished and unnourished sites. Maximum TSS values reported for surf zone (64 mg/L) and nearshore waters (34 mg/L) off the nourished sites were lower than values measured during storm conditions.

5.5.3.6 Summary of Turbidity Plume Characteristics During Sediment Management Activities

The above review of reports and field monitoring data of suspended sediment concentrations and turbidity plumes under a variety of dredge conditions generally indicate the following conditions with few exceptions (Hayes 1986, Havis 1988, Herbich and Brahme 1991, Anchor Environmental 2003):

- There is no standard conversion between TSS, turbidity, and water clarity which must be determined on a site specific basis and must consider differences in sediment characteristics if they vary across a proposed dredged project (Thackston and Palermo 2000).
- TSS concentrations are higher near the bottom compared to surface waters during dredging and discharge (Havis 1998, Hayes 1996, LaSalle et al. 1991).
- TSS concentrations, turbidity, and depressions in water clarity are greater when the particle distribution includes a higher percentage of silt/clays than sand/gravel (Herbich and Brahme 1991, LaSalle et al. 1991, Newell et al. 1998).
- Particle flocculation may increase fall rate and decrease duration of suspended sediment plumes associated with dredging fine sediments (Eisma 1993, Davies-Colley and Smith 2001).
- TSS concentrations, turbidity values, and water quality depressions decrease with increasing distance from the dredge or discharge location (USACE 1976, Hayes 1986, Herbich and Brahme 1991).
- TSS concentrations, turbidity values, and/or water quality depressions generally decrease within one hour after dredging operations or beach nourishment activities cease, with ambient conditions generally returning within one tide cycle (Wright 1978, Sherman et al. 1998, Anchor Environmental 2005).
- Visual observations indicate turbidity plumes during beach nourishment are confined to the surf zone unless carried offshore by rip currents. Measurements of turbidity

(NTU) and TSS appear to confirm the trend of higher concentrations in the surf zone than nearshore outside the breaker zone (Burlas et al. 2001, Wilber et al. 2006).

- o Monitoring data from 7 California beach nourishment projects indicate considerable variability in turbidity measured outside the breaker zone. Sometimes values were similar to background (e.g., 1 to 16 NTU) suggesting the plume did not extend beyond the breaker zone. Other times values were 2 to 7 times higher (e.g., > 20 to 225 NTU) offshore the discharge location than outside the plume (< 10 to 110 NTU). Values outside the plume indicate monitoring covered average through high wave and/or storm conditions. For example, a bckground values outside the breaker zone of < 16 NTU indicate low to nominal turbidity, whereas values ranging from > 20 to 110 NTU indicate moderate to very turbid conditions. Too few sampling locations were sampled with the reviewed projects to determine the primary, longshore extent of the plume under different environmental conditions.
- o TSS values of 24 to 66 mg/L were measured off the discharge location outside the breaker zone during the Capistrano Beach project; assuming a background concentration of approximately 20 mg/L, the measured values indicate the plume sometimes did not (24 mg/L) or did (66 mg/L) extend beyond the breaker zone.

- TSS values during beach nourishment are within ranges measured during substantial storm and/or high wave conditions.
  - o TSS values in the surf zone of 96 to 1,606 mg/L were measured when bulldozers pushed sediment into the swash zone during the Ponto, California project (Sherman et al. 1998).
  - o TSS values of 24 to 66 mg/L were measured outside the breaker zone during the Capistrano Beach, California project (monitoring data reviewed).
  - o TSS values in the surfzone of 1,760 to 4,700 mg/L were measured during hydraulic discharge into the swash zone during the Fort Macon, North Carolina project (Reilly and Bellis 1983).
  - o TSS values of 64 mg/L in the surf zone and 34 mg/L outside the breaker zone were measured during the Asbury Park to Manasquan Inlet, New Jersey project (Wilber et al. 2006).
  - o TSS values under high wave and substantial storm events may range from 400 to 2,900 mg/L near the bottom (< 1 ft, < 0.3 m) and 100 to 500 mg/L at elevations between 1 and 2 ft off the bottom (0.3 and 0,6 m) in the surf zone (Beach and Sternberg 1992, Ogston and Sternberg 1995, Wilber et al. 2006). Instantaneous (< 1 minute) maximum concentrations of 20,000 to 40,000 mg/L may be measured up to 10 in (26 cm) above the bottom during high wave conditions (Beach and Sternberg 1988) or during large, river floods (Ogston et al. 2000, Warrick and Milliman 2005).

- Secchi disk and turbidity readings within 500 ft (150 m) of the dredge sometimes deviated by more than 20% from ambient. However, mean values of turbidity (< 40 and often < 20 NTU) were less than values associated with storms and high-wave conditions (> 50 NTU). Occassionally, higher levels were recorded both near- and outside the plume indicating surveys being conducted during storm or high wave conditions. Similar findings were noted with beach placement.

- Sampling designs used to monitor sediment management project often are deficient with respect to measuring the primary near-field deposition zone versus far-field effects. Mid-depth measurements during dredging or nearshore placement projects may fail to detect the plume either because the plume is localized near the bottom during dredging or rapidly descends during placement.
- Limited turbidity data are available from beach nourishment projects. Turbidity plume descriptions and mapping indicate that plumes are localized within the surf zone unless carried outside the breaker zone by rip currents (AMEC 2002, Moffatt & Nichol 2003, Versar 2004, Wilber et al. 2006). Available measurements indicate suspended sediment concentrations may be significantly elevated in the surf zone during unconfined hydraulic placement and when sands are mechanically pushed into the swash zone. Longitudinal dikes or swales may be used during construction to limit length of turbidity plumes and presumably TSS concentration (AMEC 2002, Moffatt & Nichol 2003); however, comparisons to demonstrate effectiveness are lacking.

5.5.4 Suspended Sediment and/or Turbidity Impacts on Habitats and Species

The following questions of interest to the CSMW are addressed in this section:

- *Are there critical levels of turbidity that cause adverse impacts?*
- *What have studies investigating the flocculation of clays within turbidity plumes determined with respect to how this phenomenon may have affected biota, ecosystems, and/or habitats?*
- *Are impacts affected by seasonality?*
- *Are anecdotal observations indicating increased and concentrated fish (and subsequent bird) feeding along the edge of and within turbidity plumes scientifically supportable?*
- *Can the effects of turbidity on the foraging capabilities of fish and birds be scientifically quantified?*
- *How do turbidity plumes affect herring eggs, salmon runs, and other similar critical species?*

Suspended particulate plumes often comprise both inorganic sediment and organic matter. While organic particulates may constitute an important food source for suspension and detritus feeding animals, suspended and settling inorganic particles generally are considered a stress disturbance for aquatic vegetation and animals (LaSalle et al. 1991, Airoldi 2003). Organisms living in nearshore and/or estuarine environments often are exposed to variable turbid conditions associated with wave and/or wind re-suspension and periodic storm runoff, and species display a variety of behavioral and/or physiological adaptations and varying tolerance levels to suspended sediment (Sections 3, 4).

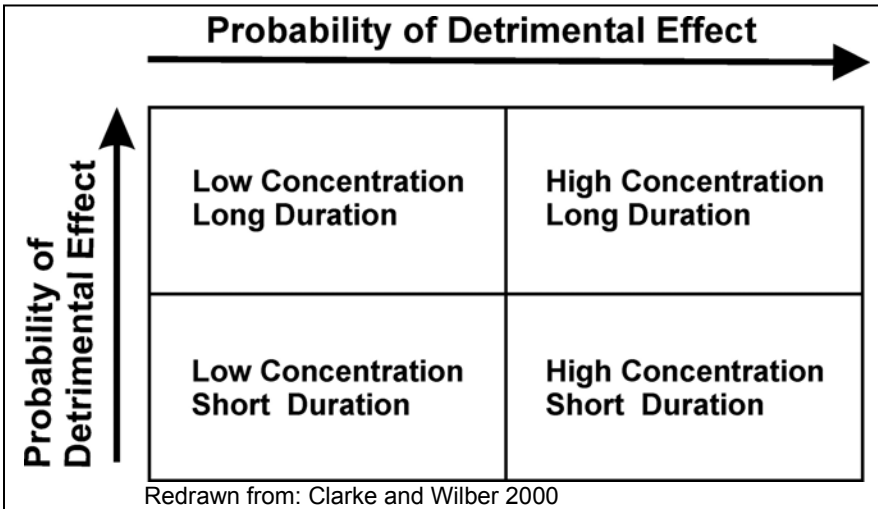
While natural adaptations may make it possible for many species to tolerate elevated suspended sediment concentrations, prolonged exposure and/or excessive suspended sediment concentrations may exceed defensive mechanisms and/or tolerance levels. Substantial reductions in water clarity may affect photosynthesis, growth, and/or

reproduction of aquatic plants (e.g., Zimmerman et al. 1991, Pondella et al. 1996, Cabello-Pasini et al. 2002). Elevated concentrations of suspended sediments may result in reduced foraging, growth, and/or respiration, and at very high concentrations may be lethal to aquatic animals (LaSalle et al. 1991, Newcombe and MacDonald 1991, Newcombe and Jensen 1996, Clarke and Wilber 2000, Wilber and Clarke 2001, Berry et al. 2003).

Several laboratory experiments of response of fish and invertebrates to elevated suspended sediment concentrations have been conducted. Many of the experiments have been of freshwater species; fewer data are available for marine species (LaSalle et al. 1991, Clarke and Wilber 2000, Wilber and Clarke 2001, Berry et al. 2003). Experiments have been conducted on different life stages, egg and/or larvae to adult (Appendix C.3). Generally, early life stages are more sensitive to suspended sediment concentration than adults (LaSalle et al. 1991, Wilber and Clarke 2001).

Laboratory studies of organism response to TSS have not been standard, varying in test sediment, duration, and recorded endpoint. Test sediments have included natural fine sediments and a range of artificial substrates (e.g., kaolin clay, Fuller's earth, chalk) (LaSalle et al. 1991, Clarke and Wilber 2000, Wilber and Clarke 2001, Berry et al. 2003). Few studies cross reference effects between different source sediments. Generally, effects occur at lower concentrations with artificial sediments than natural sediments (Appendix C.3).

Reviews of suspended solids effects on biological resources emphasize that impact assessments must consider both concentration and duration of exposure to more accurately predict the potential for impact (Figure 5.5-12). Short-term exposures generally are considered within the range of natural exposure to high suspended concentrations that may result during storms and/or high wave activity (Germano and Cary 2005).



Redrawn from: Clarke and Wilber 2000

Figure 5.5-12. Categories of potential impact risk from turbidity.

Exposure to suspended sediment plumes varies depending on equipment, placement technique, grain size characteristics, hydrodynamics, and type of organism. Spatial scales associated with turbidity plumes generally are < 1,640 ft (500 m) during dredging (Section 5.5.3.5). Beach nourishment plume lengths also may vary substantially depending on placement method and occurrence of rip currents.

Temporal scales of exposure to dredge plumes depend on equipment, weather, hydrodynamic conditions, and advance rates of dredge (Clarke and Wilber 2000). With mechanical bucket dredges, pulsed tubidity clouds result from impact of the bucket on the bottom (Moore, 2007 personal communication). Cutterhead dredge advance rates depend on pipeline size and sediment type, but generally range from 20 ft/hr (6 m/hr) when sandy sediments are pumped with 20- to 24-in (0.5- to 0.6-m) pipelines, and 59 ft/hr (18m/hr) when pipeline dredges pump silty material (Clarke and Wilber 2000). Cutterhead dredges may operate nearly continuously and produce a similarly near continuous turbidity plume. Hopper dredges may maintain speeds up to 7 kn (3.6 m/sec) while dredging (Morton 1977 cited in Clarke and Wilber 2000). Consequently, hopper dredge turbidity will decay relatively rapidly associated with advance rate, and will dissipate during the period when the dredge moves from the dredging site to the discharge site.

Wilber and Clarke (2000) estimated that turbidity exposure durations of sesslle organisms may be on the order of 2.8 to 4.3 days with use of a bucket dredge and 1 to 3.5 days with a cutterhead dredge. They considered it unlikely that durations of exposure would exceed 5 days with a cutterhead dredge in most situations (Figure 5.5-13).

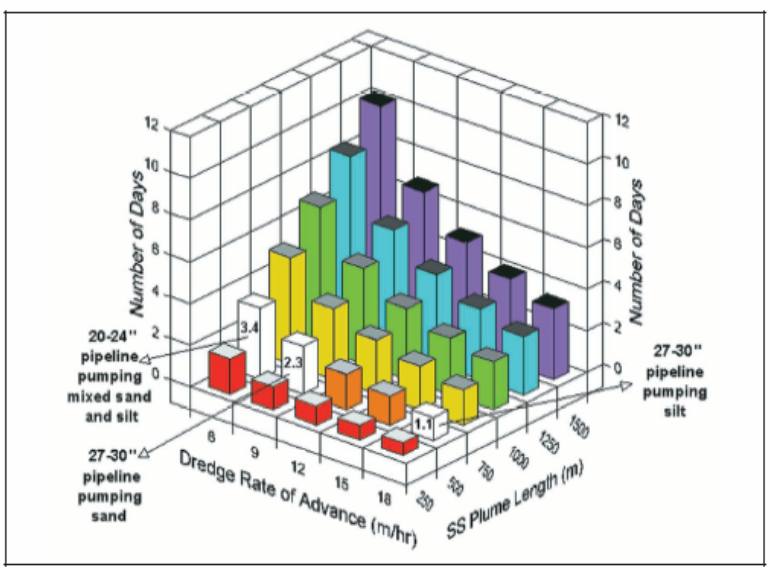


Figure 2. Range of exposure durations that may be experienced by sessile organisms as a suspended-sediment plume passes in association with a hypothetical hydraulic cutterhead dredging project. The white bars depict estimated exposure durations based on selected pipeline diameters and in situ sediment types

Source: Clarke and Wilber 2000; reproduced with permission of the authors

Figure 5.5-13. Estimated range of turbidity exposure of sessile organism during cutterhead dredging.

The potential for prolonged turbidity effects during dredging may occur in areas where sediments are relatively fine and turbidity becomes confined within a basin (e.g., Sabol et al. 2005). Prolonged turbidity also may be a concern in shallow water bodies where mixing and dilution may be impeded (e.g., Onuf 1994).

During beach nourishment, turbidity exposure durations of sessile organisms would likely depend on project volume, placement method, sediment characteristics, and hydrodynamics (Section 5.2.3.3). Placement with trucks or hopper dredge is discontinuous with intervening periods between obtaining source sands and placement at the beach. During the intervals between sand loads, turbidity plumes will have some time to dissipate. Hydraulic pumping with a cutterhead dredge is a nearly continuous operation; therefore, exposure duration will relate to project schedule. Differences in type of equipment and placement method are important considerations with respect to exposure durations to turbidity during beach nourishment.

Based on the above considerations, detrimental effects would not be expected with sediment management projects of short duration. While large sediment management projects do not represent a chronic source of turbidity, the potential for detrimental effects increases with project duration and/or suspended sediment concentration (Clarke and Wilber 2000).

Table 5.5-4 summarizes turbidity impact factors by habitat and species. Water quality impacts during sediment management activites do not have the potential to remove or alter habitat type, but rather affect associated species based on their specific tolerances and/or adaptations to the temporarily changed condition. Therefore, this section is organized differently than previous review sections by not including separate habitat and species sections; instead the following review is organized by type of species. Vegetated habitats treated in previous report sections are reviewed below according to dominant plant species.

5.5.4.1 Coastal Dune and/or Strand

Dune placement will not generate turbidity during construction.

5.5.4.2 Submerged Aquatic Vegetation

The amount of PAR reaching the bottom is an important determinant of distribution and extent of algae and seagrasses in coastal waters. Suspended sediment and/or turbidity may reduce water clarity resulting in increased light attenuation (reduction) through the water column. Light attenuation and/or a deposit of silt on leaf blades may result in reduced photosynthetic activity (North 1986, LaSalle et al. 1991, Airoldi 2003). Several studies have documented adverse impacts to SAV in areas with a prolonged increase in turbidity and reduction in PAR. Short-term increases in turbidity appear to have little effect.

Table 5.5-4. Potential turbidity impacts to habitats and species from sediment management activities.

	Mortality	Reduce Recruitment	Feeding Interference	Reduce Growth	Displace Attract
Habitats					
Coastal Dune and/or Strand					
Sandy Beach		X			
Sandy Subtidal		X			
Rocky Intertidal		X			
Rocky Subtidal		X			
Kelp Forest and/or Bed	X	X		X	
Surfgrass Bed		X		X	
Eelgrass Meadow	X	X		X	
Shallow Inlet Embayment		X			
Deepwater Inlet Embayment		X			
Species					
Abalone					
California Lobster					X
Dungeness Crab		X			
Pismo Clam		X	X	X	
Soft substrate Invertebrates	X	X	X	X	X
Hard bottom Invertebrates	X	X	X		X
California Grunion		X	X		X
Pacific Herring		X	X		X
Salmonids	X	X			X
Demersal Fish		X			X
Pelagic Fish		X	X		X
Reef Fish	X	X			X
Tidepool Fish	X				X
California Brown Pelican			X		
California Least Tern			X		X
Western Snowy Plover					
Shorebirds					
Gulls and Terns			X		
Wading Birds, Waterfowl					
Cetaceans					X
Pinnipeds			X		X
Sea Otters			X		X
Potential impact Factors of Concern					
Habitat Suitability					
Beach Morphodynamics					
T&E Species			X	X	X
Fisheries	X	X	X		
Season			X	X	X
Proximity to Nesting Site			X		X
Proximity to Spawning Ground		X			X
Migration Route					X

Note: Blank entries indicate no turbidty impact concerns

Kelp Forests and Beds

Canopy forming kelp are more vulnerable to near bottom than surface light reduction. Giant kelp and bull kelp form canopies extending to the sea surface, therefore, adult plants are fairly tolerant to changes in light levels; however, early life stages near the bottom are sensitive to changes in irradiance (Foster and Schiel 1985).

- Giant kelp recruitment (successful production of sporophytes from gametophytes) as well as growth of juvenile kelp respond to changes in light levels. Low light thresholds for these functions include PAR values of 0.4 E m^{-2} d^{-1} for sporophyte production and 0.7 E m^{-2} d^{-1} for growth (Neushul and Haxo 1963, Dean and Dyscher 1983, Dean and Jacobsen 1984, Deysher and Dean 1984, Dean 1985).

Algae differ in their capacity to store reserves that enable growth during periods of low irradiance.

- Dean and Jacobsen (1984) reviewed that giant kelp adults probably have a two-week reserve, and juveniles may have less.
- *Laminaria* have reserves that enable continued growth during extended periods of low irradiance or nitrogen availability (cited Chapman and Craigie 1978, Luning 1979, Wheeler and North 1981, Gerard 1982).

Sedimentary deposits may adversely impact adult and early life stages of Kelp (North 1986, DeVinny and Volse 1978) and other species of algae.

- North (1986) reported that light sedimentary deposits are detrimental to giant kelp blades, which may disintegrate after a few weeks of coverage, such as may occur in quiet waters of bays and inlets where scrubbing action by wave surge is lacking.
- Experimental studies involving exposure of *Laminaria saccharina* to sediment suspensions demonstrated that deposition of fine-grained sediment on thalli resulted in plant damage and reduced growth, nitrogen uptake, and chlorophyll *a* concentrations, although no effects were observed for photosynthetic capabilities or phosphorus uptake (Lyngby and Mortensen 1996 cited in Airoldi 2003).
- Settling of zoospores of *Ecklonia cava* and *Undaria pinnatifida* decreased to 0.023% at levels of turbidity greater than 2 mg/L of kaolinite (Arakawaa and Morinaga 1994 cited in Airoldi 2003).

There is some evidence suggesting that kelp beds on mixed sand/cobble (and perhaps sand) substrates may be more sensitive to effects of elevated suspended sediments than beds on consolidated outcroppings (Dean 1985, Bence et al. 1989).

Chronic turbidity may result in reduced kelp density, altered and reduced species composition of understory species, and/or complete reduction in algae depending on magnitude of impact.

- Reduced numbers of species of algae have been reported in areas affected by chronic turbidity associated with runoff (CRM 1997).
- Reduced numbers of species of algae have been reported in areas affected by chronic suspended sediment plumes in areas influenced by landslides and point-source discharges (Bence et al. 1989, Murray and Bray 1993, Konar and Roberts 1996, Pondella et al. 1996, CDFG 2001).

- Evaluation of data from Ponella et al. (1996) and Konar and Roberts (1996) suggests that understory species such as feather boa kelp, bladder chain kelp, and winged kelp appear to be more tolerant of chronic turbidity and/or sedimentation than giant kelp and bull kelp.

Seagrasses

Seagrasses have morphological and physical adaptations that provide some tolerance to turbidity. Long, buoyant leaves facilitates photosynthesis under naturally varying light conditions, and storage of carbohydrate reserves in rhizomes and leaves during periods of active growth may support metabolism during periods of light limitation and/or disturbance (Stewart 1989, Zimmerman et al. 1995, Burke et al. 1996). For some species (e.g., eelgrass), reduction of above-ground biomass in response to light limitation reduces metabolic demand over winter (Phillips 1984).

Surfgrass

- Leaves of surfgrass have morphological adaptations for turbid nearshore waters associated with reduced lacunae and thickened leaf epidermal layers where gas exchange and photosynthesis occur (Cooper and McRoy 1988, Marin-Spiotta 1996).

Eelgrass

Relevant reports demonstrate that eelgrass is relatively tolerant of short-term reductions in light levels. Widespread losses of eelgrass have been reported in areas of chronic light limitation (turbidity) due to eutrophication (Cardoso et al. 2004, Hauxwell et al. 2006) and/or eutrophication and dredging activities (Giesen et al. 1990). Eelgrass has been impacted in estuaries and along the open coast when substantial turbidity lasted 3 to 4 weeks and stored carbohydrate reserves apparently were expended (Burke et al. 1996, Moore et al. 1997, Zimmerman et al. 1991, Cabello-Pasini et al. 2002). Shorter-term light limitation may have little consequence provided that sufficient carbohydrate reserves are available for eelgrass to draw upon (Zimmerman et al. 1991).

- Eelgrass response to turbidity depends on daily pattern of light levels. Eelgrass survival depends on the amount of time in a day that light levels are above a critical intensity, or the photosaturation period (Dennison 1987, Zimmerman et al. 1990). Zimmerman et al. (1990) estimated that the period of irradiance-saturated photosynthesis required to balance respiration may vary from 3 to 12 hours per day.
- Zimmerman et al. (1991) showed that extremes in turbidity were more influential on the depth distribution of eelgrass than mean turbidity level. In addition, the authors stated that eelgrass plants in favorable light environments may have adequate carbon reserves to withstand at least 30 days of light limitation, but it was doubtful that plants growing near the edge of depth distributions were capable of accumulating large carbon reserves.
- Timing of light limitation appears to be important. Burke et al. (1996) found that seasonal peaks in rhizome carbohydrate reserves paralleled growth patterns of eelgrass in Chincoteague Bay, Maryland/Virginia, and suggested that light limitation during spring could affect subsequent survival. Experimental shading of eelgrass by 80% of incident irradiance for 3 weeks was found to reduce growth and survival

rates. Burke et al. (1996) suggested that turbidity during the springtime "window of opportunity" may jeopardize subsequent survival as a result of inadequate carbohydrate reserves to maintain a positive carbon balance during the rest of the year.

- Cabello-Pasini et al. (2002) found 3 weeks of light limitation (near zero) a critical threshold for open coast populations in Baja California, Mexico. Open coast populations started experiencing leaf damage after 2 weeks and mortality after 3 weeks of light limitation (approximately 1% of surface irradiance); laboratory experiments confirmed that carbohydrate reserves were only sufficient to maintain metabolic activity for 3 weeks.
- Eelgrass transplants in the York River tributary of Chesapeake Bay did not survive a one-month period of light limitation (<10% of solar PAR or < 15% as scalar PAR) associated with a season turbidity pulse (up to 56 mg/L TSS) (Moore et al. 1996, 1997). Mean scalar irradiance of 9% of solar PAR was verified as limiting during experimental shading experiments (Moore and Wetzel. 1999).
- Merkel (personal communication 2005) noted eelgrass was able to tolerate 3 months of variable light reduction from a red tide (plankton bloom) before widespread loss was observed in Agua Hedionda Lagoon, San Diego County. It was suspected that variability in light levels contributed to tolerance of prolonged turbidity.
- The 2003 Goleta Beach Nourishment Demonstration Project resulted in limited turbidity that was confined to the surf zone; the sand slurry was pumped over a 25-day period behind a temporary swale on the beach where sands settled and water was discharged via three pipes to the ocean (Moffatt & Nichol 2004). No adverse impact to eelgrass habitat was observed at distances ranging from approximately 1,642 to 3,284 ft (500 to 1,000 m) from the discharge location (Chambers Group 2004).
- Sabol et al. (2005) reported substantial loss (65 percent) of eelgrass in an undredged anchorage basin adjacent to a dredged basin but not in undredged portions of the entrance channel of a small harbor in Massachusetts. Dredging spanned 5 months and removed 260,292 cy of sediment. Sabol et al. (2005) suggested that the different responses of eelgrass in these two areas may have been sediment related; the entrance channel dredged materials were primarily coarse sands and small cobble that likely settled rapidly; whereas the anchorage basin dredged sediments were predominantly silt that were more likely to have increased turbidity. Turbidity and light levels were not monitored during the study.

Other Seagrass Species

- Exposure to pulsed turbidity events lasting a month or more resulted in adverse impacts to *Halodule* spp. (Moore et al. 1977, Longstaff and Dennison 1999; both cited in Wilber et al. 2005).
- Turbidity associated with hydraulic placement and resuspension of dredged sediment in a shallow water embayment (Laguna Madre) in Texas is suspected as the most likely cause of loss of shoalgrass (*Halodule wrightii*) (Onuf 1994). Subsequent monitoring of shoalgrass, benthic invertebrate, and fish in areas of prior placement and minimum impact areas indicated slow recovery of habitat and community functions trends in impact areas (4 to 8 years) (Sheridan 2004).

- Long et al. (1995) documented that dredging of access channel in Deception Bay, Australia had no effect on a different species of eelgrass (*Zostera capricorni*) when tested with a Before/After, Control/Impact Repeated measures (BACIR) sampling design. Sampling both before and at a control area documented a high degree of background variability that was not statistically different from that observed after dredging.
- Analysis of impact of a beach replenishment made with terrigenous sediments on *Posidonia oceanica* showed a 20% reduction in leaf production immediately after the project, but was considered a pulse disturbance since leaf production appeared to recover over a time scale of approximately 2 to 3 years and no change in rhizome growth rates was detected (Guidetti 2001).

5.5.4.3 Invertebrates

Reviews indicate that marine and estuarine invertebrates are generally tolerant of high suspended solids concentrations over reasonably short durations (Stern and Stickle 1978, NRC 1995, LaSalle et al. 1991, O'Connor 1991, Clarke and Wilbur 2002). However, prolonged exposure to high concentrations may be lethal and/or substantially reduce habitat quality.

Turbidity may affect recruitment of invertebrate populations. Reilly and Bellis (1983) surmised that turbidity interfered with recruitment of invertebrates during beach nourishment based on observations that a substantial number of juvenile *Emerita* mole crabs were collected three days after nourishment operations ceased.

Invertebrates display a variety of feeding modes, some of which are more vulnerable than others to the effects of turbidity from dredging and/or beach nourishment. Species that filter and/or feed directly on microscopic food from the water column (i.e., filter-feeders, suspension-feeders) generally are more sensitive to turbidity than species that feed on sediments. Turbidity also may indirectly affect invertebrates by reducing vegetation forage. For example, in the Portuguese Bend landslide influenced area, invertebrates included opportunistic (e.g., barnacles), sand stress tolerant species (e.g., sea anemone, mossy chiton), and scavengers (e.g., shore crab); whereas, a nearby unaffected site also had a variety of herbivores (e.g., limpets, littorine and turban snails, sea urchins), herbivore-scavengers (hermit crabs), and suspension feeders (e.g., spirorbid worms) (based on author's review of species list in Pondella et al. (1996).

Mobility is an important factor relative to vulnerability to turbidity and sedimentation, with mobile species (e.g., shrimps) able to move away and lessen their exposure; whereas, sessile animals (e.g., clams, mussels) must wait for turbidity to dissipate. Some sessile species such as mollusks may close shell valves, retract siphons, and/or reduce pumping rates to compensate for elevated suspended sediment levels (LaSalle et al. 1991, Clarke and Wilber 2000). Eggs laid and/or attached to the bottom (demersal eggs) may be more vulnerable to turbidity/sedimentation impacts than eggs brooded by mobile crustaceans or that are planktonic and carried by currents.

Several laboratory studies have been conducted examining the effects of suspended sediments on marine and estuarine invertebrates (Appendix C.3). Very high suspended concentrations over several days generally have been required to induce lethal response in a variety of invertebrates.

Crustaceans

- Sublethal abnormalities occurred in juvenile Dungeness crabs at 1,800 to 4,000 mg/L (natural sediment) over a 25-day exposure period. Exposure to concentrations ranging from 3,500 to 35,000 mg/L over durations of 8 to 21 days resulted in 10 to 50% mortality in adult Dungeness crabs (Peddicord and McFarland 1978 cited in LaSalle et al. 1991).
- Exposure to concentrations ranging between 9,000 (natural sediment) and 50,000 (artificial sediment) mg/L over durations ranging from 8 to 25 days (1 to 3 weeks) resulted in 38 to 50% mortality in several types of crustaceans, including amphipod (*Anisogammarus confervicolus*), shrimps (*Crangon nigricauda, Palaemon macrodactylus*), and American lobster (*Homarus americanus*) (Appendix C.3).
- Mole crabs suffer impaired feeding with increased turbidity (Turner 1990).
- Long-term exposure to concentrations of 1,000 mg/L or more could reduce planktonic and/or nektonic organisms based on laboratory response of the mysid shrimp *Mysidopsis bahia* (Nimmo et al. 1982 cited in LaSalle et al. 1991).
- No apparent response to concentrations of 360 mg/L (natural sediment) was observed for rock lobster (*Jasus edwardsii*) (Perry 1999).

Mollusks

- Microcosm experiments lasting two weeks showed that growth of *Donax variabilis* was the same as controls when turbidity was 9 NTU, but growth was statistically lower (approximately 0.15 mm) lower when turbidity was 96 NTU; no significant difference in the condition of the clams were observed over this range of turbidity (Peterson et al. 2001).
- Exposure over 8 to 11 days to concentrations of 96,000 to 100,000 mg/L (artificial sediment) resulted in 10 to 50% mortality in California mussel (*Mytilus californianus*) and blue mussel (*Mytilus edulis*), but did not result in mortality Japanese littleneck clam (*Tapes japonica*). Shorter duration exposures (e.g., < 1 week) may not result in any apparent effects.
- Exposure for over a week duration to concentrations ranging from 750 to 2,000 mg/L (natural silt) produced 20 to 31% mortality in larval American oysters (*Crassostrea virginica*). Normal egg development of American oysters was reduced 22 to 27% from exposure to 188 to 250 mg/L (natural silt).
- Normal egg development of quahog clams (*Mercenaria mercenaria*) was reduced by 8 to 35% from exposure to 125 to 4,000 mg/L (natural to artificial sediment). Enhanced growth rates of oyster and quahog clam larvae have been reported for concentrations up to 500 mg/L (LaSalle et al. 1991).
- Sublethal siphon response (retraction, prolongation) was observed for soft-shelled clams (*Mya arenaria*) after exposure to 100-200 mg/L for periods ranging from 7 to 30 days (Grant and Thorpe 1991 cited in Clarke and Wilbur 2000).

- The introduced Japanese littleneck clam (*Tapes japonica*) tolerated exposure to 100,000 mg/L of kaolin clay for 10 days without mortality (Peddicord et al.. 1975 cited in LaSalle et al. 1991).
- Laboratory experiments of 3 and 21 days whereby surf clams (*Spisula solidissima*) were dosed with clay suspensions of 100, 500, and 1,000 mg/L showed decreased chlorophyll consumption and increased pseudofecal production over all tested concentrations during the 3-day experiments (Robinson et al.. 1984). Clams were unable to acclimate to clay suspensions of 100 to 500 mg/L over 21-day experiments showing higher chlorophyll consumption relative to 3-day experiments, but were unable to acclimate to the 1,000 mg/L concentration.
- Lassuy and Simons (1989) reported that razor clams are susceptible to suffocation from silt, and recommended that silt-generating activities in the vicinity of razor clam beds should be avoided.
- Germano and Cary (2005) speculated that estuarine clam larvae are not likely to be affected by sedimentation prior to larval settlement (except for potential effects on "selection" of settlement sites by larvae), but at earliest life stages may not tolerate rapid deposition of fine sediments if deposition exceeds burrowing rates. They noted that suspended loads can adversely affect feeding and growth and frequent and/or sustained exposure to high concentrations can be detrimental

<u>Worms</u>

- Concentrations of 2,000 to 6,000 mg/L (artificial sediment) did not affect adult reef building worms (*Phragmatopoma lapidosa*) over a four day exposure period (Main and Nelson 1988).

5.5.4.4 Fishes

There are several available reviews of the effects of suspended sediment on fishes (e.g., La Salle et al. 1991, Newcombe and MacDonald 1991, Newcombe and Jensen 1996, Clarke and Wilber 2000, Bash et al. 2001, O'Conner 1991, Berry et al. 2003, Wilber et al. 2005). A subset of fish effects data for species relevant to California sediment management activities is provided in Appendix C.3.3.

Reviews indicate fish exhibit different tolerances and/or behaviors relative to turbidity. Wilber and Clarke (2001) noted that available laboratory studies indicate a general trend in tolerance with the most tolerant species found near the sediment-water interface and decreasing tolerance as association with the bottom decreases. Cyrus and Blaber (1987a,b) distinguished distributional patterns of juvenile fish associations in estuaries in southeastern Africa that were characterized as clear water species (< 10 NTU), clear to partially turbid species (<50 NTU), intermediate turbidity species (10 to 80 NTU), turbid species (> 50 NTU), and species indifferent to turbidity.

Turbidity may affect fishes by abrasion of egg and larval surface membranes, delayed development, physiological stress, interference with feeding, interference with migration, and/or mortality (LaSalle et al. 1991, Berry et al. 2003, Wilber et al. 2005). Estuarine and coastal fishes are relatively tolerant of suspended sediments (La Salle et al. 1991).

Few studies have examined the effects of mechanical abrasion on fish. LaSalle et al. (1991) reviewed two relevant studies that indicate that grain size and shape may influence mechanical effects.

- Rogers (1969) demonstrated that coarse sediments and angular processed sediments exerted greater detrimental effects on fish survival than equal concentrations of fine sediments.
- Boehlert (1984) found angular volcanic ash resulted in puncture damage of yoslk-sac larvae of Pacific herring at concentrations of 1,000 mg/L; whereas, 4,000 mg/L was required to induce similar effects using natural sediments.

Laboratory studies have used both natural and artifical substrate for effects tests, usually effects are induced at lower concentrations of artificial substrate than natural substrate. The lowest TSS concentrations using natural sediment resulting in lethal effects for 50% or more of the test organisms generally range from 500 to 1,000 mg/L for early life stages, depending on species. Few data are available across life stages. A notable exception is salmonids, which show increasing tolerance to TSS concentrations across larvae, juvenile, to adult stages.

Some species show enhanced feeding at low to moderate TSS concentration and inhibition at higher concentration, but information is limited across life stages. For example, Pacific herring larvae display enhanced foraging at 500 mg/L, but reduced foraging at 1,000 mg/L. No information is available on response of juveniles or adults to TSS concentration.

Short-term (30-minute) feeding experiments by Colby and Hoss (2004) demonstrate that prey and suspended sediment concentrations affect estuarine fish foraging success differently depending on species. Flounders fed when TSS concentrations were low and prey concentrations were high, but not with the reversed condition. Menhaden exhibited a similar response, but consumed prey at higher TSS levels. Croaker, pinfish, and spot were most tolerant and were able to feed at the highest test concentration (20,000 mg/L) when prey concentrations also were high. Tests were conducted on larval and juvenile fish with kaolin clay at test concentrations of 20, 200, 2,000, and 20,000 mg/L and brine shrimp and natural plankton as prey.

A number of studies have documented attraction and/or avoidance of turbid plumes by fish. Decreased foraging efficiency may occur at relatively low turbidity levels for piscivorous fish (De Robertis et al. 2003, Wilber and Clarke 2001). Studies also have suggested that turbidity may protect some fishes from predation by visual predators (De Robertis et al. 2003, Gregory and Levings 1998). Available information information regarding the behaviror of fish in response to turbidity plumes is limited. Reports identified during the literature review are summarized below according to type of fish.

Wilber and Clarke (2001) summarize that much of the available laboratory effects data has been based on determining acute mortality reponse, often requiring much higher concentrations than commonly associated with dredging projects. This is particularly so for juvenile and salmonids (Appendix C.3) and several estuarine species. Clarke and Wilber (2000) recommend integration of best available knowledge and consideration of both concentration and realistic estimates of likely duration of exposure until more adequate data are available.

LaSalle et al. (1991) reported that previous investigators suggested that conservative "safe" concentration at which no impact would be anticipated would be at 500 mg/L, and based on their review a strong case could be made for 1,000 mg/L. The case for 1,000 mg/L over short exposure times appears stronger based on review of available information and considering response of the more sensitive species and life stage responses. In areas where fish are adapted to more tubid conditions, this value may be overly conservative. With the exception of salmonids, available laboratory data are inadequate for estimating "safe" levels with prolonged exposures to turbidity. This data gap may not be critical for many fish that may limit exposure by moving from unacceptable turbid plume. However, the data limitation hampers impact assessments for habitats of more concern where fish may exhibit limited movement (e.g.,SAV nursery habitat, reef).

California Grunion

Grunion may be sensitive to turbidity based on laboratory studies conducted on other species of silversides. Responses include reduced feeding efficiency and mortality, when confined. Observations suggest that grunion may spawn after storms and during beach nourishment.

- Feeding efficiencies of Atlantic silverside were affected at turbidity levels ranging from 28 to 120 NTU concentrations (Wilber and Clarke 2001).
- Laboratory studies on response of Atlantic silversides to suspensions of Fuller's earth over a 24-hour period found mortality rates increased with increasing concentration, as follows: 10% at 58 mg//L, 50% at 250 mg/L, and 90% at 1,000 mg/L (Sherk et al. 1975 cited in Berry et al. 2003). Atlantic silversides were classified by Sherk et al. (1975) as highly sensitive to turbidity (Wilber and Clarke 2001).
- Monitoring has documented grunion spawning during surf zone discharge at Santa Barbara and Ventura beaches (USACE 1998a). Low densities of fish were observed during the March-April time period of the sediment management operations.
- Monitoring documented grunion spawning during elevated turbidity levels caused by storm runoff from Mission Creek, Santa Barbara (USACE 1993).

Pacific Herring

Ogle (2005) reviewed available experimental studies of Pacific and Atlantic herring and summarized the effects of suspended sediments in an effort to address data gaps in support of the San Francisco LTMS. Conclusions of his review were that typical peak TSS concentrations (200-225 mg/L) associated with dredging in San Francisco Bay were below effects thresholds on embryo development and hatching, most reported thresholds for larval survival, potentially could enhance larval feeding, and would not be expected to affect migration or spawning. Laboratory data suggest that early life stages of Pacific herring may be sensitive to turbidity, with reduced larval survival reported between 500 and 1,000 mg/L. At Concentrations at or below 500 mg/L, larval feeding may be enhanced or reduced However, Ogle (2005) expressed uncertainty with establishing effects thresholds for larval feeding and/or survival based on data limitations and/or contradictory results from different studies. Key findings of reviewed studies are summarized below.

- Experiments in which adults were prevented from spawning over different time intervals up to two weeks, and then allowed to spawn showed that delays in spawning of up to two weeks had no affect on fertilization, embryo survival, or hatching success (Hays 1986).
- 9-day experiments demonstrated reduced hatching and larval survival at 1,000 to 2,000 mg/L and complete hatching failure at ≥ 4,000 mg/L using estuarine sediments or volcanic ash with pulsed-static (suspensions renewed every 72 hours) tests. A second experiment in which the sediments were kept in suspension did not produce significant results (Boehlert et al. 1985).
- 4-day experiments demonstrated delayed and reduced hatching at 10,000 mg/L and reduced survival at 500 mg/L using contaminated sediments (Morgan and Levings 1989).
- Larvae experienced epidermal damage with pulsed (every 2 hour) exposures of ≥ 4,000 mg/L over 24 hours (Boehlert 1984).
- Experiments with Atlantic herring showed no apparent effect on egg hatching and larval survival at several concentrations from 3 to 700 mg/L, but reduced survival at > 6,000 mg/L over 11 to 15 day tests (Kiorboe et al. 1981, Messieh et al. 1981). Post-hatch larval feeding was enhanced up to 35 JTU and reduced at 80 JTU (Utne-Palm 2004). However, Johnston and Wildish (1982) reported reduced feeding at 20 mg/L.

Laboratory studies suggest that herring larvae may experience enhanced or reduced foraging efficiency depending on TSS concentration.

- Laboratory studies of 10- and 22-day old Pacific herring larvae showed enhanced feeding rates and prey consumption from 2-hour exposures of 500 mg/L, and gradual declines in organisms consumed at concentrations ranging from 1,000 to 8,000 mg/L (Boehlert and Morgan 1985 cited in Ogle 2005). Reduced larval feeding was reported at high suspended sediment loads of > 500 mg/L over 2 hours and > 1,000 mg/L over 12 hours.
- Concentrations of 4 and 8 mg/L did not result in reduced feeding, but larval herring did consume significantly less prey than controls at 20 mg/L (Johnston and Wildish 1982). The herring larvae appeared to avoid areas of the tank where TSS was > 9 mg/L. Adult Atlantic herring exhibited avoidance response at threshold of 9 to 12 mg/L (Johnson and Wildish 1981).
- Feeding rates increased with increasing turbidity up to 2,000 mg/L, which inhibited feeding (Boehlert and Morgan cited in Germano and Cary 2005).

<u>Salmonids</u>

The most comprehensive information on salmonid responses to suspended sediment are by Newcombe and Jensen (1996), Bash et al. (2001), and Berry et al. (2003). Desired salmonid freshwater habitat conditions for sediment-related indices were recently released for the North Coast Basin of California (NCRWQCB 2006). Although the turbidity criterion remains the same as in the Basin Plan (i.e., no more than a 20% increase over background levels), several sources of information were reviewed that NCRWQCB staff indicated may lead to future development of a turbidity water quality objective for salmonid habitat.

One potential consideration was expressions of chronic turbidity - such as number of days exceeding 27 NTUs or the 10% exceedence NTU (based on work by Klein 2001, 2003 cited in NCRWQCB 2006). Another possibility was a suspended sediment dose index developed

by Newcombe and Jensen (1996) (see below). NCRWQCB (2006) indicated interest in a index value of < 4, corresponding to a threshold below which there were no adverse impacts to juvenile feeding to avoid potential long term reductions in growth and population sustainability. This application was for protection of beneficial uses in streams.
The Dose Index is calculated from taking the natural log of the product of total suspended sediment (mg/L) and hours of exposure, as follows:

Suspended Sediment Dose Index = $\log_n$ (SSC x Hours Exposed), where
SSC = suspended sediment concentration

During sediment management activities relevant to beach nourishment, the primary concern would be protection of water quality of migratory salmon during embayment maintenance dredging and/or beach nourishment. According to the Newcombe and Jensen (1996) scale, a Severity Index of 7 identifies a response of impaired homing.

Other concerns relate to response to increased TSS concentration and turbidity. Studies indicate variable response of salmonids depending on concentration and life stage. Responses may include increased suspended sediment load, including changed behavior, physiological stress, reduced growth, increased predation risk, and mortality. Siltation associated with turbid conditions also may be detrimental to incubating eggs and adversely affect larval, juvenile and adult behavior, migration, or spawning (NMFS 1996). Laboratory studies indicate a range of responses (Appendix C.3).

- Sublethal alarm and avoidance have been reported for juvenile Coho salmon at TSS concentrations of 88 to 100 mg/L (cited in Berry et al. 2003).
- Reduced feeding of juvenile Coho has been reported at concentrations of 100 to 250 mg/L over short duration exposures of one hour, reduced growth has been demonstrated for both Coho and Chinook salmon with exposures with concentrations ranging from 6 to 102 mg/L over 6 to 14 days (cited in Berry et al. 2003).
- Mortality of juveniles occurred at moderate concentrations (488 to 1400 mg/L) over four days (96 hours) (Bash et al. 2001), shorter term exposures (36 hours) to very high concentrations >10,000 resulted in mortality of juvenile Coho and Chinook salmon (Berry et al. 2003).
- Adult Chinook salmon tolerated short term exposures to very high concentrations (39,000 mg/L) over a 24 hour period, but most died when exposed to concentrations of ≥ 82,400 mg/L.

Turbidity may decrease foraging efficiency. However, juvenile salmonids display some preference for foraging in moderately turbid waters, despite lower efficiency, that has been interpreted as a protective behavior against predation.

- Salmonids are often associated with river plumes during their first few months in the ocean, which may not be sufficient to affect planktivorous feeding but may reduce vulnerability to predation (Gregory and Levings 1998 cited in DeRobertis et al. 2003).
- Juvenile Coho salmon, steelhead and Chinook salmon appear to prefer moderately turbid water for foraging (Sigler et al. 1984).

- The effectiveness of salmonids in obtaining food may be reduced by turbidity levels as low as 20 NTU (Bash et al. 2001).
- Turbidity may decrease feeding efficiency in salmonids (Bash et al. 2001, Madej 2004, Barrett et al. 1992, Vogel and Beauchamp 1998).
- The effects of moderate turbidity on salmonids may represent a trade-off between feeding efficiency and predation risk (Bash et al. 2001, Gregory and Northcote 1993).

Demersal Fish

- Bottom fishes may be more tolerant of suspended sediment than water column fishes (Wilber and Clarke 2001).
- Greene (2002) cited a study in which winter flounders were observed leaving shallow coastal waters during storms, perhaps to avoid turbulence and associated turbidity.

Reef Fish

Reef fishes are site tenacious and therefore may be more vulnerable to impacts from displacement as a result of turbidity than water column and soft bottom fishes.

- Reef fish become skittish under turbid conditions (Ebeling personal communication to N. Davis, July 2005).
- Courtenay et al. (1972) observed temporary displacement of fish from coral reefs in Florida due to turbidity.

Water Column Fish

Limited information is available on California fish species response to turbidity. Some nearshore coastal fish (e.g., white croaker) are noted for their association with cloudy water (Love 1996). Other fish have been observed to avoid turbid areas around dredge operations. Sensitivity of water column fish may depend on feeding strategy. DeRobertis et al. (2003) generalized that planktivorous fish may be less sensitive to moderate turbidity because less reaction time is necessary to obtain prey; they also suggested that turbid environments may be advantageous due to a decreased vulnerability to predation. They indicated that the primary effect of turbidity may be reduced illumination affecting the depth at which planktivores forage in all but the most turbid waters. In contrast, predatory fish may be the most sensitive to turbidity because of their reliance on optical properties of water to see prey.

Planktivores

- Fishes were observed to move away from the discharge area in response to sediment disposal at the Alcatraz Dredged Material Disposal Site in San Francisco Bay, but returned to the site within an hour or two after the disposal event (O'Conner 1991).
- Chason (1993) documented increased activity of rainbow smelts at suspended sediment concentrations greater than 10 mg/L. He interpreted this increased swimming behavior as an alarm response.

- Wilber et al. (2003) reported there was no significant difference in food habitats of Atlantic silverside (*Menidia menidia*) before and after beach nourishment.
- Ambient lighting may affect fish response to turbidity. The planktivore walleye pollock (*Theragra chalcogramma*) feeding rate was not affected at turbidity up to 40 NTU under low light intensity, but was affected at high light intensity.
- Reaction distance to food decreases with increased turbidity. Utne (1997) found that reaction distance of a marine planktivore (*Gobiusculus flavescens*) decreased significantly with increased turbidity. Feeding rate of silverside (*Atherina breviceps*) was significantly reduced at a high turbidity level (120 NTU); decrease in reactive distance to prey occurred at turbidities as low as 28 NTU (Hecht and van der Lingen 1992 cited in Clarke and Wilber 2000).

Demersal Feeders

- Some coastal fish are considered tolerant of turbidity. White croaker is known to favor cloudy water (Love 1996).
- Wilber et al. (2003) reported that northern kingfish (*Menticirrhus saxatilis*) were attracted to locations undergoing active beach nourishment, probably due to prey availability; turbidity was not substantially elevated (Wilber et al. 2003).
- Petersen et al. (2001) studied feeding efficiency of Florida pompano exposed to different turbidity levels and prey in wave tank mesocosms; i.e., coquina clams (*Donax variabilis*) (101 versus 9 NTU) and mole crabs (*Emerita talpoida*) (74 versus 7 NTU). Results suggest some lowering of prey consumption by pompano under higher turbidity, but the results were not statistically significant.

Piscivores

- The sablefish (*Anoplopoma fimbria*) feeding rate was decreased between 5 and 10 NTU (DeRobertis et al. 2003).
- Wilber et al. (2003) reported reduced abundance of bluefish (*Pomatomus slatatrix*) during beach nourishment; turbidity averaging (70 NTU) was suggested as possibly having reduced habitat suitability for this visual forager.

<u>Ichthyoplankton</u>

Limited information is available regarding sediment management impacts on early life stages of fish and/or recruitment under field conditions. Burlas et al. (2001) conducted the first examination of ichthyoplankton in the surf zone with respect to beach nourishment. Results of surf zone surveys during and up to two years after a several million cy beach nourishment project off New Jersey did not detect any obvious differences between reference and nourished beaches in ichthyoplankton abundance, size and species composition. Although dramatic changes in ichthyoplankton were not observed, the authors acknowledged that results did not preclude the possibility that that effects occurred on smaller temporal and spatial scales not captured by the study design, which would have only detected large shifts in density and/or taxonomic composition given the physical attributes of high energy ocean beaches, coupled with the highly dynamic spatial and temporal distributions of larvae.

5.5.4.5 Birds

Turbidity from sediment management activities has the potential to affect foraging of piscivorous birds, including the endangered California least tern and endangered California brown pelican. Only a few studies have documented bird foraging response during sediment management activities.

- Least tern foraging activity was monitored during beach nourishment activities between Seal Beach Pier and Warner Avenue in Orange County (MEC 1997). The observations did not provide any evidence that the activities adversely affected least tern foraging. Over the 11-week study, more foraging behaviors were observed offshore the beach noursihemnt site than other locations father downcoast or directly offshore the harbor entrance to Anaheim Bay.
- During a Navy dredging project in San Diego Bay, Forster's terns and royal terns were observed foraging within visible turbidity plumes (USFWS 2000).
- Collins et al. (1979) noted that least terns foraged much less in the chronically turbid Talbert flood control channel than in clearer water bodies in the vicinity of Huntington Beach colony. No sediment management activity was associated with that turbidity.

5.5.4.6 Marine Mammals

Turbidity has the potential to affect marine mammals, which are visual predators, but little information is available. Capture efficiency of salmonids was lower for seals in turbid water compared to waters shallow and clear (Seligson 1998).

6.0 REVIEW OF IMPLEMENTED IMPACT SIGNIFICANCE THRESHOLDS AND MITIGATION MEASURES

Sediment management projects require environmental assessment and review pursuant to CEQA and/or NEPA. Impact assessment requirements generally vary depending on complexity, significance, and/or uncertainty associated with impacts and may range from a simpler MND/FONSI to comprehensive EIRs/EISs (Section 2.2.1). Mitigation measures are used to reduce adverse impacts below a level of significance.

Section Topics:

6.1 Impact Thresholds of Significance

6.2 Overview of Mitigation Measures

6.3 Pre-Construction Phase Mitigation Measures

6.4 Construction Phase Mitigation Measures

6.5 Post-Construction Mitigation Measures

6.6 Summary of Mitigation Measures by Habitat and Species

Environmental documents prepared for sediment management projects have varied with respect to impact criteria and significance thresholds, and types of recommended mitigation measures. The CSMW desires better understanding of these differences to assist future environmental review and project implementation. This report section provides a review and evaluation to address the following questions of interest to the CSMW:

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- *What are the biological thresholds of significance established by various cities and counties as guidelines to identify when mitigation under CEQA and NEPA may be required?*
- *What mitigation measures have been implemented to avoid adverse impacts to biota during beach nourishment and related sediment management activities?*
- *What types of methods have been used to minimize impacts associated with different beach nourishment methods? Has the effectiveness of any of these mitigation measures been demonstrated?*
- *Can an appropriate level of impact/mitigation measure be recommended for the species/habitat/ecosystem of concern?*

Section 6.1 reviews impact significance criteria and thresholds used during representative California sediment management projects. Section 6.2 provides an overview of mitigation measures. The next three sections review in greater detail the types of mitigation measures that may be implemented prior to construction (Section 6.3), during construction (Section 6.4), and after construction (Section 6.5). Section 6.6 summarizes mitigation measures by habitat and species.

6.1 Review of CEQA/NEPA Thresholds of Significance

Section 15065(a) of the CEQA Guidelines states that a project may have a significant effect if it has the potential to:

> (1) The project has the potential to*:* substantially degrade the quality of the environment*;* substantially reduce the habitat of a fish or wildlife species*,* cause a fish or wildlife population to drop below self-sustaining levels*,* threaten to eliminate a plant or animal community, or substantially reduce the number or restrict the range of an endangered, rare or threatened species.
>
> (2) The project has the potential to achieve short-term environmental goals to the disadvantage of long-term environmental goals.
>
> (3) The project has possible environmental effects that are individually limited but cumulatively considerable. "Cumulatively considerable" means that the incremental effects of an individual project are significant when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects.

The CEQA implementing guidelines (Cal. Code Regs., Title 14, § 15000 et seq) encourage public agencies to develop and publish thresholds of significance that the agency uses in the determination of the significance of environmental effects. To be adopted for general use, the thresholds of significance must be developed through a public review process and be adopted by ordinance, resolution, rule, or regulation (http://ceres.ca.gov/topic/env_law/ceqa/guidelines/art5.html). A threshold of significance is defined in the CEQA implementing guidelines as:

> An identifiable quantitative, qualitative or performance level of a particular environmental effect, non-compliance with which means the effect will normally be determined to be significant by the agency and compliance with which means the effect normally will be determined to be less than significant (§15064.7).

CEQ regulations for implementing NEPA (40 CFR Section 1508.27) specify that significance requires consideration of both context and intensity of the action. Context refers to analysis of several different contexts, as appropriate, such as the affected region, locality, and site-specific area including both short- and long-term effects. Intensity refers to the severity of impact, which includes consideration of beneficial and adverse impacts, unique characteristics and/or resources, degree to which the action may adversely affect an endangered or threatened species or its habitat, degree to which the effects are uncertain and/or likely to be controversial, whether it is anticipated that the action may contribute to a cumulatively significant impact on the environment, and/or threatens a violation of environmental protection laws.

Thresholds of significance are considered a proven method of streamlining the CEQA process; however, few agencies have formally adopted them (http://www.jonesandstokes.com/resource/rsrc_crs.htm#Thresh). Furthermore, adopted significance thresholds mainly focus on terrestrial and wetland resources with limited attention given to coastal marine habitats and resources.

Useful Online References for Thresholds of Significance in California

State website - http://www.ceres.ca.gov/planning/ceqa/thresholds.html

Counties with Adopted Thresholds of Significance

- San Diego - http://www.sandiego.gov/development-services/news/pdf/sdtceqa.pdf
- Ventura - http://www.ventura.org/planning/pdf/ordinanes_regs/Initial_Study_Assessment_Guidelines2_06.pdf
- Santa Barbara http://www.sbcountyplanning.org/

Results of the review indicate that criteria have become more explicit in definition of significance thresholds over time. However, there also has been a lack of consistency in the approach used to judge significance of sediment management projects in California.

A total of twenty-seven CEQA and/or NEPA documents prepared for representative sediment management projects in northern, central, and southern California were reviewed. Biological resource evaluations in those documents included significance criteria for one or more of the following resource categories, which are reviewed in greater detail in the subsections below:

- Federal- and/or State-Listed Sensitive Species.
- Essential Fish Habitat (EFH).
- Native Species and/or Other Sensitive Resources.
- Wildlife Movement.
- Commercial Fishing.
- Environmental policies.

Example significance thresholds for each of the above-listed criteria are reviewed in the following sections. Criteria are listed for all reviewed projects in Appendix D.1.

6.1.1 Federal-listed, State-listed, and/or Other Special Status Species

Impact assessments generally include separate evaluations for species covered under the federal Endangered Species Act (ESA) and California Endangered Species Act (CESA). Separate evaluations also may include candidate or proposed species for listing (Chambers 1992, 2001c, USACE 1994, 1995, 2000, 2002c), fully protected species (CRM 2000, MEC 2000), species of concern (Chambers 2000), or other sensitive species (USDN 1997a,b, USACE 2002d).

Criteria for evaluating federal-listed, state-listed, and/or other sensitive species include the potential to affect individuals, their habitat, and/or populations. Recent documents also consider disturbance, although criteria have not been standard among documents.

The County of Ventura (2006) considers the following impacts to endangered, threatened, or rare species as significant if:

- The project would directly or indirectly reduce species population, reduce species habitat, and/or restrict reproductive capacity.

The County of San Diego (2006) considers the following types of impacts as significant if the project would:

- Impact one or more individuals of a federal or state-listed endangered or threatened species.
- Impact 5 percent or more of a population of a state Species of Special Concern or County listed sensitive species unless a biologically-based determination can be made that the project would not have a substantial adverse effect on the regional long-term survival of the species.
- Impact the regional long-term survival of a County-listed species considered regionally less common.
- Increase noise and/or nighttime lighting to a level above ambient proven to adversely affect sensitive species.

Example significance thresholds that have been used to evaluate impacts to sensitive species from California sediment management projects are listed below in order of increasing detail (also see Appendix D.1):

- Potential for direct impact (USACE 1993, 1994b, 1995b, 1998a, 1998b, 1999a, 2001; USDN 1997a, b).
- Substantial adverse effects to individuals or its habitat (Chambers Group 2000, Chambers Group 2001, USACE 2002d).
- Degrade habitat for, or reduce, the population size (USACE 2000b).
- Population directly affected or habitat lost or disturbed (USACE 1994a, 1995a, 2000a).
- Population directly affected, breeding impaired, or critical foraging or breeding habitat lost or substantially affected (Chambers Group 1992, CRM 2000, MEC 2000a, USACE 2002c).
- Loss or disturbance or reduction in the numbers of or a restriction in the range of, or any other impact to any unique, rare, threatened, or endangered species of animals or plants or their critical habitat (Chambers Group 2002, City of Buenaventura 2002).

The above criteria illustrate that documents prepared a decade ago focused on direct impacts (i.e., loss); whereas, more recent documents have recognized the significance of indirect means by which sensitive species may be impacted from an action; e.g., through degradation of habitat and/or impairment of critical functions (e.g., breeding, foraging).

Federal agency actions with the potential to adversely affect federal-listed species and/or designated critical habitat require federal resource agency coordination or consultation (e.g., NMFS, USFWS) per Section 7 of the ESA. Candidate and/or proposed species are addressed by resource agencies during conferencing and considered when making natural

resource decisions (USFWS and NMFS 1998). Similarly, the CESA requires that state lead agencies coordinate or consult with CDFG to ensure that state agency actions are not likely to jeopardize the continued existence of any species that is state listed as endangered, threatened, or rare. The CDFG also may make a Consistency Determination of whether conditions specified in a federal incidental take statement pursuant to a federal Section 7 consultation or a federal Section 10(a) incidental take permit are consistent with the CESA (Fish and Game Code Section 2080.1).

Federal and state resource agencies both recommend informal early coordination to avoid potential impacts to rare, endangered, and threatened species. Advantages of early consultation include appropriate mitigation planning to offset impacts to listed species and their essential habitats and a streamlined consultation process (USFWS and NMFS 1998).

Useful Online References Regarding Federal and State Endangered Species Consultation

http://www.fws.gov/endangered/consultations /s7hndbk/s7hndbk.htm

http://www.CDFG.ca.gov/hcpb/cegacesa/cesa/ cesa.shtml

6.1.2 Essential Fish Habitat

Essential Fish Habitat (EFH) is managed under the Magnuson-Stephens Fishery Conservation and Management Act (refer to Section 2.5.1). This act protects waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity. Federal agencies and permit applicants must consult with NMFS on actions that may adversely affect EFH, which is identified and described for managed species in Fishery Management Plans (FMPs). FMPs for Federal waters off the coasts of California, Oregon, and Washington address Pacific coast groundfish, commercial and recreational west coast salmon fisheries, and northern anchovy/coastal pelagics (http://www.nmfs.noaa.gov/habitat/habitatprotection/profile/pacificcouncil.htm).

NMFS (2004) EFH guidance provides the following definitions of adverse and substantial adverse effects:

- Adverse effect means any impact that reduces quality and/or quantity of EFH, including direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality and/or quantity of EFH. Adverse effects to EFH may result from actions occurring within EFH or outside of EFH and may include site-specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810(a)).
- Substantial adverse effects are defined as effects that may pose a relatively serious threat to EFH and typically could not be alleviated through minor modifications to a proposed action; e.g., major harbor development with significant dredging and filling, channel realignments, or shoreline stabilization near EFH.

NMFS (2004) guidance notes that it is difficult to conceive of situations involving active construction in EFH without crossing the "may adversely affect" threshold. However, NMFS (2004) stated that incorporation of avoidance and minimization measures into the proposed action may eliminate or lessen the need for additional conservation measures. Types of appropriate avoidance and minimization measures may include careful alternatives analysis, design stipulations, "best management practices", time-of-year restrictions; avoidance of submerged aquatic vegetation and shellfish beds, and/or monitoring (NMFS 2004).

Examples of criteria and significance thresholds that have been applied to California sediment management projects include (also see Appendix D.1):

- Adversely affect fisheries protected under essential fish habitat designation (SANDAG and USDN 2000).
- Potential to impact essential fish habitat (USACE 2001).
- Substantial adverse effects would occur to fish species or habitat listed in the Fishery Management Plans (USACE 2002d).

The last of the above three examples provides a more explicit description that the EFH assessment considers both habitat and species compared to the first two examples. However, all three lack clear definition of criteria used to assess adverse effects. NMFS guidance states assessments should address both a reduction in quality and/or quantity of EFH.

6.1.3 Native Habitats and/or Other Sensitive Resources

Criteria for evaluating native habitats and/or species, other than those covered under the Endangered Species Act, have varied in CEQA and/or NEPA documents. Some documents leave the description general; e.g., biologically important habitats, environmentally sensitive habitat, or habitat of any fish, wildlife, vegetation (Chambers Group 1992, USACE 1994a, 2000b,d).

Other documents are more specific in description of habitats and/or populations of concern (e.g., kelp beds, surfgrass, eelgrass, reefs with perennial biota, marine mammal haul out areas, Areas of Special Biological significance) (e.g., USACE 1994a, USDN 1997a,b, CRM 1997, 2000, MEC 2000a, Chambers Group 2001c, 2002, City of Buenaventura 2002).

Significance thresholds for non-covered native species generally address direct effects to populations and loss and/or degradation of habitats.

The County of Santa Barbara (2006) uses the following guidance criteria to assess whether disturbance to habitat or species may be significant:

a. Substantially reduce or eliminate species diversity or abundance.

b. Substantially reduce or eliminate quantity or quality of nesting areas.

c. Substantially limit reproductive capacity through losses of individuals or habitat.

d. Substantially fragment, eliminate, or otherwise disrupt foraging areas and/or access to food sources.

e. Substantially limit or fragment range and movement (geographic distribution or animals and/or seed dispersal routes).

f. Substantially interfere with natural processes, such as fire or flooding, upon which the habitat depends.

The County of San Diego (2006) guidelines consider the following types of impacts as significant if the project would:

- Prevent wildlife access to foraging habitat, breeding habitat, water sources, or other areas necessary for their reproduction.
- Substantially interfere with connectivity between blocks of habitat, or would potentially block or substantially interfere with a local or regional wildlife corridor or linkage.
- Create artificial wildlife corridors that do not follow natural movement patterns.
- Increase noise and/or nighttime lighting in a wildlife corridor or linkage to levels proven to affect the behavior of the animals identified in a site-specific analysis of wildlife movement.

Examples of criteria and significance thresholds that have been applied to California sediment management projects include (also see Appendix D.1):

- Potential impacts to plankton, invertebrates, fish, eelgrass, marine mammals (USACE 1993, 1994b, 1995b, 1998a, 1998b, 1999a, 1999b, Tekmarine and Analytic Planning Service 1990).
- Burial of 10 percent or more of a shoreline or subtidal habitat and associated biological communities for a period > 1 year and which are directly attributable to the sediment placement site program; (2) The loss of 10 percent or more of surfgrass habitat which does not recover over a period of one year following shoreline sediment placement activities (CRM 1997).
- If there is substantial loss in the population or habitat of any native fish, wildlife or vegetation (substantial loss defined as any change in a population which is detectible over natural variability for a period of 5 years or longer); and/or If there is a net loss in the habitat value of a sensitive biological habitat including marine mammal haul-out site or breeding area, seabird rookery, or Area of Special Biological Significance (USACE 1994a).
- Substantial loss of a population or habitat where long-term loss (greater than one year) was projected and/or sensitive resources such as reefs, surfgrass beds, and kelp beds were affected for a period of time that would substantially reduce the ability of the resource to recover (e.g., surfgrass criteria of > 2/3 cover for > 6 months was used to limit long-term damage) (CRM 2000).
- Degradation of biologically important habitats and/or areas of high biological activity, create a long-term (over 10 years) measurable change in species composition and/or abundance beyond that of normal variability, and/or creation of a long term (over 10 years) measurable change in ecological function within a localized area (USACE 2000b).

The above examples illustrate that biological criteria have varied with respect to duration and/or extent of loss and/or habitat modification considered significant. For example,

significance thresholds have been defined as substantial degradation for > 1 year (CRM 2000, Chambers Group 2001c), substantial loss for ≥ 5 years (Chambers Group 1992, USACE 1994a, USACE 2002c), or measurable change in species composition and/or abundance for > 10 years (USACE 2000b). Significance thresholds also have varied in definition based on extent of impact; e.g., beyond the immediate vicinity of the study site (USACE 2002c), > 10 percent of habitat or shoreline (Chambers group 1992, CRM 1997), or substantial (USACE 1994a, CRM 2000, MEC 2000a, Chambers Group 2001c).

An issue of importance with respect to impact is the time period over which the impact occurs. For example, impact determinations based on a period of one year may be sufficient for short-term construction-related effects, but may be insufficient to account for press disturbances associated with sand migration transport. Time scales for beach profile equilibration and alongshore spreading occur over different time scales depending on project length and volume, grain size, and wave environment, but generally range from few to several years (NRC 1995). Recovery rates after dredging and/or beach nourishment may range from < 1 to several years depending on existing conditions (Section 5.2.3.6). Therefore, duration thresholds for sediment management projects should exceed one year to distinguish short- from long-term impacts.

A concern with significance thresholds based on prolonged periods of disturbance (e.g., 5 to 10 years), besides reduction in ecosystem productivity, is potential reduction in habitat resiliency. Available scientific information indicates populations and habitats differ in tolerance and resiliency (e.g., recovery) to environmental variability and impacts (Section 5.2.3.6). For example, kelp beds and reefs may require several years to recover from natural environmental extremes that occur on decadal scales or less (e.g., ENSO, PDO) (Section 3.3.5, 3.3.6). Therefore, significance thresholds based on 5- to 10-year time frames may substantially reduce or eliminate available recovery periods between natural environmental extremes and, as a consequence, may not be sufficiently protective to prevent irreversible habitat loss.

A numerical threshold of ≥10% loss has been used to distinguish impacts greater than what may be attributed to natural variability. A potential concern with a set numeric limit is that natural environmental variability may substantially exceed that level. A BACI (before-after-control-impact) sampling design generally is recommended so that impact can be judged within the context of natural variability (Section 7.2.3). This approach minimizes conclusions based on Type 1 sampling errors (e.g., concluding an impact which did not actually happen (Green 1993, Underwood and Chapman 2003).

In the case of surfgrass, which may naturally experience seasonal sand accretion and erosion, significance thresholds have been defined as > 2/3 cover for > 6 months to limit long-term damage (CRM 2000) or burial that results in loss (MEC 2000a). The criteria based on persistent sedimentation of > 2/3 length of surfgass blades (CRM 2000) is supported by available information that indicates that prolonged partial burial of seagrass blades results in mortality (Fonseca et al. 1988, deWit et al. 1997, Reed and Hollbrook 2003); however, scientific data are lacking to understand what depth of blade burial and for how long leads to irreversible habitat loss of surfgrass. Therefore, use of a numerical threshold for depth of burial is arbitrary until this data gap is filled.
The above examples illustrate that criteria have varied from being vaguely defined (e.g., substantial in area) to more specific with respect to definition of spatial and/or temporal extent of impact. An advantage of defining significance thresholds with greater specificity is the potential to use them as a feedback loop during project design so that projects may be

designed below a level of significance. However, limited scientific data are available to support specific quantitative criteria. Underwood (2000) provides a relevant argument that experimental designs of sampling programs would be greatly improved if decision-makers and managers accepted the challenge to be clearer about what sorts, frequencies, and sizes of impacts they need to detect and manage resources. Development of standardized biological significance criteria for marine habitats in coordination with resource agencies would help address this issue by ensuring greater consistency of impact evaluations in CEQA and/or NEPA documents that could be refined over time based on results of permit required monitoring programs to yield consistent standards for resource protection.

6.1.4 Wildlife Movement

Significance thresholds for wildlife movement generally consider interference and/or introduction of barriers to movement. Sometimes factors that may affect normal activities of wildlife also are considered. Examples of criteria and significance thresholds applied to California sediment management projects include (also see Appendix D.1):

- Interferes (or impedes) substantially with the movement of any resident or migratory fish or wildlife species (Chambers Group 1992, 2000, 2001, 2002; CRM 2000, MEC 2000a, USACE 1994a, 2002c, 2002d).
- Cause the introduction of any factors that could hinder the normal activities of wildlife or cause a deterioration of their habitat (City of Buenaventura 2002).
- Introduction of barriers to movement of any resident or migratory fish or wildlife species and/or introduction of any factors (e.g., light, fencing, noise, human presence, and/or domestic animals) which could hinder the normal activities of wildlife (Chambers Group 2002).

Reported concerns of sediment management projects include interference with grunion spawning, migration of Pacific herring and salmonids, movement of fish between coastal habitats and estuarine nursery habitats, movement of plovers, movement patterns of whales, displacement of sea otters, and/or nesting of sea turtles (NRC 1995, Greene 2002). Available reports indicate that interference with movement, migration, and/or displacement may be associated with physical alteration of habitat (e.g., berms, scarps), barriers (e.g., pipelines), shoaling (e.g., inlet closure), noise, artificial lighting, and/or increased human activities (Sections 3, 4, 5.). Therefore, impact criteria that include specific reference to potential factors that may affect wildlife movement may help ensure that potentially important factors are not overlooked during impact assessment.

6.1.5 Commercial Fishing

Potential impacts to commercial and/or recreational fishing may be an important consideration for some California sediment management projects; e.g., those implemented in the vicinity of commercial aquaculture, oyster, lobster, sea urchin, and/or trap fisheries (e.g., SANDAG and USDN 2000, USACE 2000b). Commercial fishing conflicts also are a concern with offshore sand mining (Cooper 2005, Murray). Examples of criteria and significance thresholds that have been applied to California sediment management projects include:

- Potential for impacts to commercial oyster beds (USACE 1999a, 2001).
- If the project reduced or precluded fishing activity by 10% or more during the peak season, if the project permanently excluded 10% or more of a local fishing area, if any fish/shellfish population of commercial or recreational importance has the potential to be reduced by 10% or more in the local area, and/or if the project resulted in increased losses or damage to traps and nets (MEC 2000a, SANDAG and USDN 2000).
- Create a measurable change in commercial fishing opportunities, such that: (a) 10% or greater loss of, or preclusion from, current productive fishing grounds in the project area for more than 10% of the open or peak season, and/or (b) 10% or more of the fishermen regularly using fishing grounds in the project area are precluded from fishing for 10% or more of the open or peak season (USACE 2000b).

The above criteria include two different approaches to impact assessment. One approach addresses factors that may interfere with fishing activities (e.g., exclusion from fishing areas, preclusion of fishing activity, gear damage and/or loss). The other approach addresses the potential to impact populations of important fisheries species or mariculture areas. Generally, potential impacts to managed species populations are evaluated with the EFH impact assessment.

Generally, insufficient data are available to support impact evaluations with significance thresholds of 10% for fishery populations. Available data for commercial and/or recreational landings are recorded by port of landing and large geographical areas (fish blocks), which may display annual fluctuations in excess of 10% from a complex variety of reasons such as inaccuracies in reporting, El Niño and La Niña events, and export market demand (CDFG 2001). Some of the challenges associated with impact assessments of managed fisheries at a project-specific level may benefit from a process that includes coordination with local fishing organizations and resource agencies to review fishery impact areas of concern, significance thresholds, and measures to minimize interference and resource protection.

6.1.6 Environmental Policies

Generally, CEQA/NEPA documents specify the regulatory background relevant to the existing conditions and impact evaluations for each environmental issue area, including biological resources. The potential for possible conflicts between the proposed action and federal, state, and local plans, policies, and controls for the area of concern is part of the required assessment of environmental consequences of an action under CEQA (Section 15063) and NEPA (Section 1506.2(d)). Compliance issues relevant to biological resources may be found on the CEQA Initial Study Checklist (http://ceres.ca.gov/ceqa/):

- Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or State habitat conservation plan.
- Conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance.

6.2 Overview of Mitigation Measures

Mitigation is the process used to avoid and/or minimize impacts to the environment and may include (40 CFR Section 1508.20):

(a) Avoiding the impact altogether by not taking a certain action or parts of an action.

(b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation.

(c) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.

(d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.

(e) Compensating for the impact by replacing or providing substitute resources or environments.

Mitigation measures may occur throughout all project phases ranging from pre-construction to post-construction. Pre-construction phase mitigation measures generally focus on project design, buffer distance between impact source and sensitive resources, sediment compatibility, and/or refinement of construction plans to avoid and/or minimize potential impacts. Construction phase mitigation measures may include discharge location controls, buffers, prohibition zones, schedule restrictions (environmental windows), equipment operational controls, best management practices (BMPs), and/or monitoring. Post-construction measures generally include impact verification monitoring and compensatory mitigation, if necessary.

This report section reviews mitigation measures identified in CEQA/NEPA documents and/or permit requirements for several California sediment management projects (Appendix D.2). In addition, recommendations for minimizing impacts to biological resources are identified from the literature review and results of the reviews conducted in previous report sections. The review addresses the following general and specific questions of interest to the CSMW:

- *What mitigation measures have been implemented to avoid adverse impacts to biota during beach nourishment and related sediment management activities? Has the effectiveness of these mitigation measures ever been demonstrated?*
- *What types of prohibition zones have been permit-required surrounding various sensitive bird nesting and nearshore foraging areas? What are the reported bases for these zones? Have the dimensions been based on scientific data, do they relate to potential foraging ranges or nesting territories, do they reflect measured impact ranges, are they based on professional judgment or uncertainty-based conservatism*
- *Do typical bird breeding season limitations reflect the actual time the area is used for breeding and nesting? Can historic lengths of time or areas under limitation be safely revised? What types of information and process are needed to objectively review and establish appropriate sediment management permit conditions associated with breeding season restrictions?*

- *What are the types of methods that have been used to minimize impacts associated with different beach nourishment methods?*

Mitigation measures are reviewed by project phase in which they would be implemented. In addition, mitigation measures are organized into categories based on identified similarities in methods of implementation and/or type of impact the measures address. Monitoring activities that represent mitigation measures to avoid and/or minimize impacts are identified according to project phase in this report section; however, more detailed discussions of monitoring are given in Section 7.

A standardized format is used to review mitigation measures, which includes description of the measure, reference to relevant reports, and consideration of effectiveness. Relevant reports include examples of sediment management projects that recommended and/or implemented the referenced mitigation measure.

No reviews of mitigation effectiveness were identified from the literature review. For those measures that do not involve avoidance of impact; i.e., minimization measures, the general lack of information on effectiveness represents an important data gap that if filled could help streamline environmental review and permitting.

The approach taken in this document is to consider potential effectiveness of mitigation measures based on review the rationale and technical basis of the measure with respect to potential spatial and/or temporal scales of impact, biological response, and/or environmental factors. For example, the effectiveness of prohibition zones (buffers) relates to spatial factors such as noise attenuation, suspended sediment plumes and deposition rates, sediment transport rates, and differences in tolerance levels of sensitive resources. Most buffers, including those used for breeding birds, generally are determined during the pre-construction phase of project planning, and are reviewed in detail in Section 6.3.5. Some buffers are applied during construction and are reviewed along with other location controls in Section 6.4.1.

Seasonal limitations (environmental windows), including those that apply to birds, are based on the rationale that avoidance of the breeding season is the most effective means for protecting sensitive species populations. Schedule and/or seasonal restriction mitigation measures are applied during construction. Those that have been applied to California sediment management projects are reviewed in detail in Section 6.4.2.

Mitigation measures are reviewed in Sections 6.3 through 6.5 according to project phase. Summaries of mitigation measures are given in Section 6.6 according to type of sediment management activity and beach nourishment placement location, habitats, species, and ecological functions the measures address. For projects with sensitive resource constraints and/or potential fisheries management concerns, the process used to identify mitigation measures is one of the most important activities that can be conducted with respect to streamlining environmental review and permitting. A recommended coordination process and mitigation considerations specifically for essential fish habitat and sensitive species are presented in Section 6.6. The specific questions of the CSMW regarding buffers, seasonal restrictions, and mitigation measures associated with different placement methods also are addressed in Section 6.6.

6.3 Pre-Construction Phase Mitigation Measures

Several activities and/or measures may be taken during the pre-construction phase to avoid direct and minimize indirect impacts to biological resources during project implementation (Table 6.3-1). Measures may address sediment compatibility issues, optimizing project design and implementation strategies, environmental coordination, and monitoring surveys to support final design and permit requirements. Each of these topics is addressed in the following subsections. Types of monitoring that may be required during pre-construction are identified in this section; description and review of pre-construction monitoring are presented in Section 7.3

6.3.1 Sediment Compatibility and Quality

Sediment testing is required prior to any sediment management activity involving dredging and/or discharge of materials into marine and estuarine waters. Sediment testing of the physical and chemical properties of the substrate provides the initial step (or screen) for determining suitability of material for beach nourishment and/or identification of other alternative disposal options.

Potential source sediments for beach nourishment must be free of substantial contamination and of suitable grain size characteristics as part of the permitting process (Section 5.2.3.2). Sediment compatibility criteria for California beach nourishment projects have been defined with respect to percent content of fine sediments (silt/clays), percent content of coarse particles, particle shape, color, and compaction.

Mitigation measures address minimizing the differences of source sediments from those of the receiver site. In the case of beach nourishment, the compatibility criteria apply throughout the entire sand placement profile since erosion will expose different layers of the fill over time. For dredging, the issue is retaining compatibility of the surface substrate characteristics with that of surrounding sediment. These compatibility considerations generally apply unless the sediment management project represents an enhancement or restoration effort.

Relevant Reports:

- RPG 67 (USACE 2006) specifies beach nourishment material must be at least 80% sand and have less than 10% sand difference from the receiving beach. Permit requirements also specify preparation of an Aesthetic Qualities Report that includes a qualitative comparison of proposed discharge material with the qualities of the receiving beach.
- Sediment compatibility requirements for several opportunistic sand programs specify that source sands must match color of existing beach after natural color change, should not include particles larger than cobble sized and not constitute greater than 10% of beach fill volume, particle shape must not be substantially angular or jagged shaped and not constitute greater than 10% of beach fill volume, and must not form a hardpan crust after repeated wetting (Moffatt & Nichol 2000a, 2000b, 2005a, 2006a).

- The SCOUP project defines optimum sands as having a fines fraction within 10% of that of the existing dry beach sediments (Moffatt & Nichol 2006a). Less than optimum sands are defined as being within 10% of that of the existing nearshore sediments that exist along a beach profile.

Table 6.3-1. Types of pre-construction phase mitigation measures to avoid and minimize impacts during sediment management projects.

Pre-Construction Mitigation Measures	**Equipment**	**Burial**	**Sedimen -tation**	**Turbidity /Water Quality**
Maintain Sediment Compatibility and Quality				
Minimize difference in sediment characteristics unless enhancement is conducted		X	X	X
Minimize change in surface substrate unless enhancement is conducted		X	X	X
Environmental Design				
Avoid direct impacts to sensitive habitats	X	X	X	X
Match project volume to environmental constraints	X	X	X	X
Maintain hydrodynamics unless enhancement is conducted			X	X
Avoid steep scarps and slopes			X	
Environmental Implementation Strategy				
Avoid repetitive disturbance in same year[1]	X	X		
Use multiple small sites instead of one large site[1]		X	X	
Incorporate refuge areas[1]	X	X		
Reduce Maintenance Frequency Over Time				
Incorporate dune restoration[1]			X	
Use sedimentation basins and source control	X		X	
Habitat Buffers				
Buffer to minimize turbidity impacts	X	X	X	X
Buffer to minimize sedimentation impacts				
Sensitive Species Buffers				
Buffer to protect fishery spawning grounds	X	X	X	X
Buffer to minimize impacts to sensitive birds	X			X
Buffer to minimize impacts to marine mammals	X			
Environmental Coordination and Notifications				
Prepare hazardous materials management plan	X			X
Prepare inlet monitoring and response plan			X	
Conduct U.S. Coast Guard notification to minimize hazards and interference with other uses	X			
Conduct environmental training program	X	X	X	X
Mitigation and Monitoring Program				
Finalize mitigation and monitoring plan	X	X	X	X
Pre-construction surveys and monitoring	X	X	X	X

Note[1]: Measures to promote recovery rates and/or to minimize frequency of sediment management activity are listed under equipment if associated with dredging or burial if associated with beach nourishment.

The following two mitigation measures address compatibility issues and considerations of effectiveness with respect to minimizing impacts to biological resources. Construction

monitoring to ensure compatibility of sediments with permit requirements and to ensure no substantial adverse characteristics over time are addressed in Sections 6.4.5.1 and 6.5.1.1.

6.3.1.1 Minimize Difference in Sediment Characteristics Unless Enhancement is Conducted

This measure addresses minimizing differences in sediment grain size characteristics between source and receiver sites unless change represents an enhancement of beach habitat quality.

Consideration of Effectiveness:

Matching sediment characteristics between source and existing sediments is considered an effective precautionary measure for minimizing impacts to biological resources. A substantial body of literature describes the interrelationship between beach morphology, slope, and grain size (Hesp and Short 1982, McLachlan 1983, Wright and Short 1984). These interacting environmental influences, and in particular grain size have been related to invertebrate community structure and habitat quality (Straughan 1982, McLachlan 1990, Dexter 1992, Thompson et al. 1993, McLachlan 1996, Brown and McLachlan 2002, Defeo and McLachlan 2005). Alteration of benthic community structure may result when sediment grain size distribution becomes substantially coarser (McLachlan 1996) or finer (Rakocinski et al. 1996, 2001).

Several references emphasize the importance of sediment compatibility of source sands for beach nourishment to facilitate benthic recovery and minimize impacts to biological resources (e.g., Parr et al. 1978, Gorzelany and Nelson 1987, VanDolah et al. 1994, NRC 1995, Peterson et al. 2000a,b, Burlas et al. 2001, Greene 2002, Boyd et al. 2004, Versar 2004, Speybroeck et al. 2006). Use of compatible sediments also has been reported as being necessary for providing suitable nesting substrate for endangered piping plovers (Melvin et al. 1991, Melvin 2005) and sea turtles (Crain et al. 1995, Steinitz et al. 1998). Peterson (2000b) stated that to minimize habitat degradation associated with beach nourishment, sand grain size should not be smaller than natural beach, shell content should be low, mud ball content should be low, and toxic chemicals should be absent.

Burrowing capabilities of several bivalves and crustaceans inhabiting sandy beaches are related to grain size characteristics (Dugan et al. 2000b, Nel et al. 2001, de la Huz et al. 2002, Yannicelli 2002). Species also show preferences for sediment grain size that is reflected in their distribution patterns (Dugan and Hubbard 1996, Dugan et al. 200b, Speybroeck et al. 2006). Therefore, substantial changes in substrate conditions have the potential to alter habitat suitability for resident fauna.

Turbidity plumes relate to silt/clay content of dredged and/or placed sediments. Therefore, sediment characteristics will influence temporal and spatial effects of turbidity during construction and sedimentation during and after construction.

Sediment management activities may include enhancement and/or restoration actions that address rehabilitation of sediments to reduce contaminant loadings and/or removal of excess sedimentation that contributes to habitat degradation. In those cases, post-

project substrate characteristics may represent a beneficial change from existing conditions.

In erosional "hot spots" substrate characteristics may vary from cobble to sand or bedrock to sand across seasons. The sand scoured rocky substrate may support few biological resources (e.g., MEC 2000a). Beach nourishment that changes scoured rocky substrate with little to no biological resource use to persistent sandy beach habitat represents a beneficial change in substrate characteristics (e.g., SAIC 2006).

Critical impact thresholds with respect to substrate compatibility have not been established. A precautionary mitigation measure that minimizes change of sediment characteristics from existing conditions, unless the change represents enhancement, is considered prudent based on ecological considerations and the substantial body of literature recommending this measure.

6.3.1.2 Minimize Change in Surface Substrate Characteristics of Beach and/or Dredge Areas Unless Enhancement is Conducted

This measure addresses minimizing changes to the substrate surface after beach nourishment or dredging to facilitate recovery and/or foraging by resident fauna.

C*onsideration of Effectiveness:*

Beach nourishment materials consisting of sand or a combination of sand, gravel, or shells is considered acceptable as nesting substrate for sensitive bird species such as piping plovers (Melvin et al. 1991). A change of substrate characteristics from cobble to sand can improve primary habitat for invertebrates, foraging habitat for shorebirds, and spawning habitat suitability for California grunion (SAIC 2006).

Surface beach substrate characteristics may influence shorebird distribution and foraging capabilities (Quammen 1982). Sediment too coarse or high in shell content can inhibit a bird's ability to extract food from the substrate (Baird 1993, Greene 2002, Peterson et al. 2002). If the fill material contains a high proportion of shells, a solid floor of shells may form through a process termed cementation, in which chemical precipitates (in the form of new crystals) form in the pores of a sediment or rock, binding the grains together (Speybroeck et al. 2006).

Color, density, and grain size shape may influence heat retention capacity of sands (USACE 1989), although the ecological consequences of such changes are unknown (Speybroek et al. 2006). Sediment color, compaction, density, shear resistance, moisture content, and gas exchange influence the environmental suitability of beach sands as nesting habitat for turtles (NRC 1995).

Beach sand grains generally are rounded and smooth as a result of sand transport movement. Ecological consequences of introducing sediment with angular grains are unknown. Impact concerns could include interference with burrowing capabilities of benthic invertebrates, decrease in habitat suitability for grunion spawning, increase in scour effects on vegetated habitats, and/or interference with foraging of secondary consumers (fish, birds). Although coastal processes would round the grains over time, potential adverse impacts could last for several years until the beach fill was fully reworked.

A similarity of surface substrate characteristics after dredging is considered an important factor with respect to benthic community recovery rates (Hurme and Pullen 1988, Kenny and Rees 1996, Newell et al. 1998, Boyd et al. 2004).

6.3.2 Environmental Design

This measure involves incorporation of protective measures in the design of the project to avoid and/or minimize impacts to sensitive biological resources. Modeling and/or other analytical methods may be used to optimize design based on predicted performance and/or environmental considerations.

Generally, optimizing project design to minimize environmental impacts is considered to be the most effective measure from the perspective of environmental review, permitting, and resource protection. Because of limited understanding of critical impact thresholds, the success of this measure has the potential to improve with appropriate monitoring feedback loops and application of lessons learned to future project designs.

6.3.2.1 Avoid Direct Impacts to Sensitive Habitats

This measure considers existing conditions to select receiver and/or borrow site locations to avoid direct impacts to sensitive habitats such as:

- Coastal strand.
- Productive intermediate to dissipative beach types.
- Perennial rocky intertidal and subtidal reefs.
- SAV habitats.
- Critical habitat of sensitive species unless enhancement.
- Substantial spawning grounds of fishery species.

Relevant Reports:

- The 2001 San Diego Regional Beach Sand Project avoided direct placement on perennial rocky intertidal, surfgrass areas, and at locations with sensitive inshore reefs directly offshore SANDAG and USDN 2000, MEC 2000a).
- The 2003 Goleta Beach Nourishment Demonstration Project avoided direct placement on rocky intertidal and surfgrass areas (Moffatt & Nichol 2003).
- The impact of beach nourishment will be less on beaches dominated by organisms recruited from pelagic larvae than ones where organisms also include species whose entire life history is within the beach system (Reilly and Bellis 1983).

Consideration of Effectiveness:

Avoidance of sensitive resource areas is the most protective of mitigation measures.

Project areas with critical habitat for snowy plovers in the vicinity should be carefully evaluated with respect to beach erosion concerns. Sandy beach provides important foraging, resting, and/or nesting habitat for snowy plovers. However, these functions have the potential to be diminished for wintering populations under erosive beach conditions. Beach nourishment may enhance habitat functions for snowy plover by increasing sand persistence and width. However, disturbance of plovers may occur from the activity. Determination of whether beach nourishment in critical habitat should be avoided or implemented outside the breeding season should be determined on a project-specific basis in consultation with USFWS and (see Section 6).

Beach type is a relevant consideration for harbor maintenance dredging projects that include beach placement as a beneficial use alternative for suitable sediments. It also is a consideration for beach nourishment projects. Seasonally and/or persistent erosive beaches appear to support fewer biological resources than beaches with persistent sand (Section 3.3.2). In contrast, dissipative and productive intermediate beaches with persistent sand depth across seasons support the highest diversity of biological resources (Section 4.2.6). Impacts may be less when sand is placed on erosive and/or urbanized beaches than on less disturbed, dissipative, or productive intermediate beaches. Selection of erosive and/or disturbed beaches as beach nourishment receiver sites is environmentally preferred to minimize impacts to California sandy beach resources. However, human use patterns also should be considered. High levels of human disturbance may degrade habitat function on urbanized beaches. Therefore, potential benefits to biological resources from beach nourishment may be minimal at urbanized beaches.

6.3.2.2 Match Project Size to Environmental Constraints

This measure involves selection of appropriate project size to meet shoreline protection needs in balance with environmental impacts. In this context, an appropriate-sized project is one that provides shoreline protection benefits without loss or substantial degradation of native habitats.

Relevant Reports:

- The 2001 San Diego Regional Beach Sand Project included modeling and existing condition surveys to refine project design with respect to beach receiver site project lengths, volumes, and schedules to avoid and/or minimize impacts to sensitive reefs, SAV, California grunion, and California least tern. The project was modified from 3 million to 2 million cy and receiver site footprints were modified to minimize potential impacts to reefs based on modeling results. Pre-construction habitat suitability and nesting surveys were conducted to refine project schedules (MEC 2000a, Moffatt & Nichol 2000, SANDAG and USDN 2000).
- The BEACON South Central Coast Beach Enhancement Program included use of an analytical model to predict the depth of sand cover over the beach profile offshore the fill and comparing that to locations of sensitive biological resources to “back into” the sand quantity that would not cause biological impacts as determined by the project biologist (Moffatt & Nichol 2005a).
- The SCOUP project design for the cities of Encinitas, Solana Beach, Coronado, and Imperial Beach, California include volume, placement, and schedule

restrictions to avoid and/or minimize impacts to biological resources (Moffatt & Nichol 2006b).

- The National Institute of Coastal and Marine Management of the Netherlands (2004) recommends the following key management principle for coastal erosion management: When taking measures, try to work with natural processes or leave natural processes as undisturbed as possible.

Consideration of Effectiveness:

Burial and/or sedimentation may result in habitat loss and/or degradation of sensitive hard bottom and/or SAV habitats, if present, depending on depth of cover and duration of effect. Therefore, project size (volume) is an important consideration with respect to potential for and/or extent of impact. However, whether the volume results in impact will depend on site-specific factors such as reef heights, local physical conditions, coastal processes and rates, and wave characteristics.

Models have been developed to predict sand persistence and transport after beach nourishment (e.g., GENESIS). However, predicting sand increase along beach profiles when there are nearshore reefs is a deficiency of existing models, which do not include valid assumptions for shorefaces with different geologic characteristics than sand (Pilkey et al. 1993, 1994). Pilkey (1994) recommends an iterative, empirical approach that includes monitoring as a feedback loop to improve project design over time.

One strategy is to avoid sand placement in areas with reefs offshore. This rationale is supported by studies that have reported burial of hard bottom reefs resulting from implementation of several beach nourishment projects in Florida (Navqi and Pullen 1982, Lindeman and Synder 1998, Goreau 2001, Coastal Planning & Engineering 2004a, b). Other studies indicate that beach nourishment may be accomplished without significant impacts to nearshore reefs and/or SAV when project size is kept relatively small to avoid overtopping and/or substantial sedimentation of reefs (SANDAG and USDN 2000, MEC 2000a, Moffatt & Nichol 2000c).

Based on the above considerations, a precautionary approach is warranted for beach nourishment projects in areas where sensitive habitats are within the area of potential effect. Because of gaps in knowledge with respect to significance thresholds, the success of this measure has the potential to improve with appropriate monitoring feedback loops and application of lessons learned to future project designs.

6.3.2.3 Maintain Hydrodynamics Unless Enhancement is Conducted

This measure addresses maintaining hydrodynamics during sediment management projects to extent practicable.

Relevant Reports:

- Reduced water quality (anoxia) associated with changed hydrodynamics and deposition of fine particulates and organics has been reported for deep, offshore borrow pits (NRC 1995, Newell et al. 1998, Brynes et al. 2004b).

- Restoration dredging to increase tidal flushing and improve water quality and habitat for marine and estuarine resources has been permitted at several lagoons in California (e.g., Batiquitos, Bolsa Chica, San Dieguito).

Consideration of Effectiveness:

Measures have been recommended to reduce changed hydrodynamics during offshore sand mining, such as:

- Conduct shallow dredging over a larger area rather than creation of deep pits covering a limited area.
- Use modeling and pre-borrow assessments to avoid areas where fine sediment may be trapped in the borrow site.
- Limit overdredge depths to two feet to minimize changed hydrodynamics.

Newell et al. (1998) reviewed that infill rates of sand extraction areas depend on currents and sediment mobility. Deep pits may be slow to fill (> 5 years). Shallow dredge furrows may infill over tidal cycles in areas with high sand mobility, but commonly take 1 to 4 years under a variety of environmental conditions.

Development of anoxic conditions and sedimentation of fines and particulates in deep pits may occur (NRC 1995, Newell et al. 1998). However, Hitchcock and Bell (2002) noted little evidence of this with deployment of an underwater camera in aggregate extraction pits based on little visual difference in turbidity. Fisheries concerns with deep pits include risks of snagging towed gear within the depression, and general unsuitability for beam trawling.

Removal of as little as 1.6 ft (0.5 m) of the sediment surface will eliminate the benthos (Newell et al. 1998); therefore, the primary consideration with offshore borrow site dredging is recovery rates. Generally, less change to hydrodynamics and substrate conditions are expected with shallow rather than deeper dredged depths. Less change to hydrodynamics and substrate conditions favors more rapid invertebrate recovery (Section 5.3.2.2).

Maintenance of tidal flushing is essential to healthy embayments and support of nursery functions for marine fishery species. Maintenance of good water quality also is critical to health of nearshore spawning grounds and ecosystem. Use of dredging methods that maintain and/or enhance water quality is ecologically sound management.

6.3.2.4 Avoid Steep Scarps and Slopes

This measure addresses minimizing impacts to habitat suitability and/or use patterns by sensitive resources.

Relevant Reports:

- Changes in beach profile (linked to grain-size distribution of nourishment sands) can lead to changes in the hydrodynamics of the intertidal zone; an increase in slope resulting in an increase in wave energy, leads to a more stressful

environment and less diverse and abundant fauna (Speybroeck et al. 2006 based on consideration of Kaufman and Pilkey 1983 and McLachlan 1983).

- Low beach slope (10:1, horizontal: vertical) is a recommended design criteria for beach nourishment in areas with endangered piping plovers (Melvin 2005).
- NMFS (2002) recommended that discharge of dredged material on erosive river shorelines be contoured so that beach slopes have a minimum steepness of 10 to 15% to prevent stranding of salmonids (NMFS 2002).

Consideration of Effectiveness:

Beach nourishment sand placement on the beach results in a steeper slope until the beach equilibrates and reaches a more stable profile (NRC 1995). This may result in a shorebreak at the beach rather than a nearshore bar (Moffatt and Nichol 2006a). Speybroeck et al. (2006) state that significant changes of beach profile can give rise to a changed morphodynamic beach state, causing a slow recovery and maybe a permanent shift in ecological community structure.

Beach slope is an important factor associated with benthic resource development, habitat suitability for grunion spawning, and habitat suitability for sensitive plovers. Benthic invertebrate development is greater on gentle than steep slope sandy beaches (Short and Hesp 1982, McArdle and McLachlan 1992, Defeo and McLachlan 2005). This is an important consideration with respect to forage prey for shorebirds, including sensitive plovers. Melvin (2005) reviewed that design criteria for beach nourishment should include 10:1 beach slopes for endangered piping plover; however, it was noted that a 6:1 slope was okay for chick access to feeding habitat.

Beach slope also is an important consideration for fish spawning. Grunion eggs are deposited high in the intertidal for better drainage and oxygen availability (Martin and Swiderski 2001). Therefore, beach slope may be influential factor to habitat suitability for grunion. No definitive information on beach slope relationships with grunion habitat suitability was identified from the literature survey. Straughan (1982) noted grunion occurrence on beaches was associated with gentler slopes. Martin (2007 personal communication) noted that grunion do not use steep beaches for spawning. This is understandable based on consideration of the swash zone, which is narrow at beaches with steep slopes and wide at beaches of low slope (McArdle and McLachlan 1992).

As-built beach slopes for the 2001 San Diego Regional Beach Sand project ranged between 10:1 and 20:1 (horizontal:vertical) (SANDAG and USDN 2000). Grunion eggs were observed during monitoring surveys two to four years later on the Moonlight Beach receiver site (SAIC 2006), which was built with a 20:1 slope (SANDAG and USDN 2000).

NMFS (2002) recommended a minimum steepness of 10 to 15% to prevent stranding of salmonids associated with slope repair in erosion areas along the Columbia River.

Because as-built beach slopes of beach nourishment projects will change as a beach equilibrates under natural erosion and accretion processes (NRC 1995), consideration of beach slope during the construction phase is mainly relevant to the first year after sand placement. Based on the above considerations, beach slopes of 10:1 or greater may minimize short-term impacts to biological resource habitat suitability than steeper as-built slopes.

6.3.3 Environmental Implementation Strategies

6.3.3.1 Avoid Repetitive Disturbance in Same Year

This measure involves minimizing disturbance at a beach nourishment location from multiple project activities that may be conducted in the same year to minimize recovery rates and impacts to sandy beach resources.

Relevant Reports:

- Small, opportunistic sand placement projects in San Diego County that are conducted between March 1 and May 31 are required to not exceed 25,000 cy per month, be scheduled no less than two weeks apart, spaced at least 150 ft (46 m) apart, and not involve disturbance of previous placement locations to minimize impacts to invertebrate recruitment; placement is restricted during summer (Moffatt and Nichol 2006b).

Consideration of Effectiveness:

Sandy beach invertebrates have a seasonal recruitment and peak productivity period (spring-summer) and seasonal low (fall-winter) (Section 4.2.6). Studies have shown that recovery rates are faster when beach nourishment is concluded prior to the peak recruitment period, but may result in slower recovery during the first year after placement if beach nourishment activities occur in spring and/or summer and/or multiple sand placement events occur (Reilly and Bellis 1983, Versar 2004). Placement during spring and/or summer does not appear to affect long-term recovery. Diverse benthic invertebrate populations were observed two years after beach nourishment at three sites in the City of Encinitas that had received sand at different times between the months of June and August during the 2001 San Diego Regional Beach Sand Project (SAIC 2006).

The mitigation measure, which allows unrestricted placement during fall-winter, restricts sand volume and avoids repetitive placement disturbance during spring, and restricts placement during summer. This measure was developed by the primary author for the SCOUP program to minimize impacts to invertebrate recruitment and forage base development on an annual basis for opportunistic sand programs that may involve more than one placement in a year.

6.3.3.2 Multiple Small Rather than One Large Receiver Site

This measure involves a regional strategy of use of several smaller projects rather than a single large beach nourishment project to minimize impacts to biological resources.

Relevant Reports:

- A succession of small projects (0.5 mi, 0.8 km or less) carried out in non-sequential order should have less long-term impact than a single grand-scale nourishment project (Reilly and Bellis 1983).

- Choose a number of smaller projects (< 2,624 ft, < 800 m) rather than a single large nourishment project (Speybroeck et al. 2006).
- The 2001 San Diego Regional Beach Sand Project included placement of 2 million cy at 13 beach sites. The nourishment strategy included use of sites as feeder beaches to provide shoreline protection benefits at the receiver sites and downcurrent locations (SANDAG and USDN 2000). The sites ranged in size from 0.1 to 0.8 mi (0.16 to 1.3 km). Nearshore reefs and kelp beds were located in the vicinity of several of the smaller sites.

Consideration of Effectiveness:

Limiting the size of individual receiver sites appeared to be an effective strategy to minimize impacts to nearby sensitive resources during The 2001 San Diego Regional Beach Sand Project, which placed approximately 2 million cy of sand on 13 receiver sites ranging in size from 101,000 to 421,000 cy (SANDAG and USDN). A five-year pre- and post-construction monitoring program reported no significant adverse impacts to rocky intertidal, nearshore reefs, and kelp beds (AMEC 2005). Controlling the sand placement volume was the approach taken for minimizing the potential for sedimentation. The sand placement volumes in areas of hard bottom ranged from 101,000 to 132,000 cy, representing approximately a quarter of the volume placed at beaches with sand habitat offshore. Those sand volumes were based on site-specific considerations and should not be considered as prescriptive.

Use of smaller sites also may be a relevant consideration for minimizing impacts to nearshore biota. Siltation in the nearshore occurs during and after beach nourishment as a result of sediment reworking and deposition of fines outside the turbulent breaker zone. This will occur over a relatively shorter-time frame when sands are hydraulically pumped onto the beach than if placed near the backshore. The amount of silt deposition is a function of sand volume and percent fine content of the source materials, and persistence is a function of hydrodynamics. Parr et al. (1978) reported short-term silt-loading in the nearshore after hydraulic placement of approximately 1 million cy at Imperial Beach, California; siltation was not obvious after the first storm season. Parr et al. (1978) reported that there was short-term enhancement (mainly to crustaceans) from the siltation. In contrast, Rakocinski et al. (1996, 2001) found persistent silt-loading in the nearshore after hydraulic placement of > 5 million cy on the beach at Perdido Key, Florida. Substantial alteration of the benthic community was associated with the silt-loading with that project.

Use of smaller sites has been recommended to minimize impacts to secondary consumers such as fish and shorebirds (Reilly and Bellis 1983, Speybroeck et al. 2006). However, review of invertebrate recovery rates over a wide range of project sizes indicates that project timing and substrate characteristics are more influential to beach nourishment recovery rates than project size per se (Section 4.2.6). This primarily relates to seasonal recruitment patterns of invertebrates. However, if nourishment activities are prolonged and/or substantially extend through the seasonal recruitment period, recovery may be delayed (Section 4.2.6).

Based on the above considerations, it appears that use of multiple, smaller sites may be an effective strategy for minimizing impacts at any particular location. This may be particularly important in areas with nearby sensitive resources to minimize effects of indirect impacts due to sand transport and turbidity associated sedimentation. This

nourishment strategy also may be relevant for minimizing impacts in areas where hydrodynamics are less energetic and persistent, silt-loading may be an issue. In addition, this measure may be effective for minimizing area of disturbance to secondary consumers if project implementation would extend into the spring-summer productive season.

Because large projects require a longer time period to construct, the use of multiple, smaller sites may represent a strategy for minimizing duration of disturbance to recruitment. However, that would depend on project-specific schedule considerations. If a large project was completed during the fall-winter period when invertebrate recruitment is absent to minimal, then project size may make little difference in areas with few environmental constraints

6.3.3.3 Incorporate Refuge Areas to Minimize Recovery Rates

This measure includes retaining refuge patches within borrow site area to minimize benthic community recovery rates.

Relevant Reports:

- To minimize impacts and promote recolonization of mined areas, the total removal of substrate should be avoided and small areas within the project area should be left to serve as refuge patches that would promote recolonization and serve as habitat for mobile species (Diaz et al. 2004).
- Burlas et al. (2001) reported relatively rapid recolonization of the benthic community (within 2.5 years) after borrow site dredging that involved dredging of bathymetric peaks rather the depressions. It was suggested that strong currents and sand movement quickly infilled the dredged areas with similar sediment.
- Greene (2002) reviewed that relatively shallow, dredging (approximately 3 ft) by hopper dredge over larger areas that result in a series of ridges (undredged areas) and furrows (dredge areas) rather than deep dredging of smaller areas is advocated in South Carolina, whenever feasible. Studies showed that the dredge depressions had infill rates of 21 to 34% per year and the ridges were hypothesized as providing a immediate source of sediment and recolonizing fauna after dredging (Jutte et al. 1999a, 2001 cited in Greene 2002, Jutte et al. 2002).
- Slower recovery rates have been reported for deep pits created by anchored hopper dredges compared to relatively shallow furrows produced by trailer suction hopper dredges (Newell et al. 2004).

Consideration of Effectiveness:

Benthic community recovery, when complete, assumes that the community will be similar to that prior to disturbance. Invertebrates recover by two primary mechanisms: larval recruitment and immigration (Newell et al. 1998). Consequently, leaving undredged ridges between dredged furrows may be effective in facilitating recolonization after disturbance.

An important consideration with offshore borrow site dredging is intensity of disturbance. Boyd et al. (2004) reviewed that commercial marine aggregate extraction using trailer dredging leads to creation of furrows with undisturbed deposits in-between, with an increased proportion of undisturbed deposits at sites dredged at lower intensities than at high intensities. In a local context, controlling the level of dredging intensity and allowing undredged deposits to act as refugia was considered a potentially effective mitigation measure for enhancing the rehabilitation of commercially dredged areas. From a management context, however, it was pointed out that controlling the level of dredging intensity has the potential to increase the size of the area dredged and further information is needed to establish boundaries of dredging intensity to ensure maximum management value.

Limited information is available to support science-based decisions with respect to management of offshore borrow sites. Further work is required to understand overall ecosystem impacts (e.g., fish/shellfish populations, associated fisheries) associated with dredging larger areas, but to shallower depths versus dredging smaller areas, but to deeper depths.

6.3.4 Reduce Maintenance Frequency Over Time

6.3.4.1 Incorporate Dune Restoration

This measure involves incorporating dune restoration and/or rehabilitation into beach nourishment projects to decrease the frequency of renourishment and to enhance ecological functions of the beach-dune system.

Relevant Reports:

- The dune placement technique of beach nourishment with stabilization involving vegetation, sand fencing, and/or thatching has been used to provide natural shoreline protection in several areas along the east and Gulf Coasts of the United States and internationally (Section 3.3.1).

Consideration of Effectiveness:

Coastal dunes store sediments and may provide shoreline protection benefits from substantial storm wave runup (Section 3.3.1, coastal change hazard figure). In other geographic areas, dune restoration has been successfully combined with beach nourishment to provide a more natural shoreline to combat erosion.

Coastal dunes have been degraded and/or eliminated along most of southern California's coastline and habitat quality of many of the dunes in central and northern California have been degraded by non-native species that may provide less optimum shoreline protection (Section 3.3.1). The feasibility of incorporating dune restoration with beach nourishment projects in California likely will vary depending on site-specific constraints. Some beaches are backed by seacliffs and some end at urban development such as Pacific Coast Highway (101) and/or commercial/residential development. However, sufficient backshore may be present to support dune restoration in some areas. In addition, it may be possible to increase the shoreline stabilization function and habitat quality of existing dunes by removal of exotic, invasive

species and revegetation with native species. Dune revegetation generally requires a gradual program of replacement to minimize the likelihood of blowouts (CNPS 1996). Dune restoration and/or revegetation should take into consideration potential use of the beach by threatened snowy plovers, which prefer sparse vegetation. Based on lessons learned on the East Coast of the United States, Melvin (1991) reported that beach nourishment projects are more attractive to endangered piping plovers if it is not subsequently planted with beach grass or crisscrossed with snow fencing.

6.3.4.2 Use Sedimentation Basins and Source Control

This measure involves dredge design and watershed source control activities to minimize dredge maintenance frequency and adverse impacts associated with sedimentation in coastal embayments.

Relevant Reports:

- Ecosystem restoration of Upper Newport Bay, California incorporated sediment basins to trap erosion runoff from the watershed (USACE and County of Orange 2000).
- Lagoon-wide dredging of Agua Hedionda Lagoon, California incorporated a sediment basin to trap erosion runoff from the watershed (MEC 1997b).
- Addressing source control by identifying excess watershed sedimentation inputs and implementing management techniques to reduce excessive maintenance frequency is recommended as a measure to reduce cumulative impacts by the NMFS (Hanson et al. 2003).

Consideration of Effectiveness:

Incorporation of features in project design to reduce the frequency of maintenance dredging is desirable from ecological as well as economic perspectives. Studies have shown that invertebrate community structure and habitat quality relates to frequency of disturbance. Simple benthic communities dominated by opportunistic species characterize maintenance channels that are frequently dredged (McCauley et al. 1977, Newell et al. 1998). Benthic habitats also may be degraded by frequent sedimentation associated with depositional areas (MEC 1995c). Therefore, use of design features and/or source control BMPs to reduce sedimentation effects may be effective for minimizing impacts to biological resources associated with maintenance dredging in coastal embayments.

6.3.5 Habitat Buffers

Several sediment management projects have been implemented in California with protective buffers, barriers, and/or prohibition zones in areas with sensitive biological resources. Buffer distances from sensitive habitat typically are determined based on consideration of indirect impacts such as turbidity (Section 6.3.5.1) and sedimentation (6.3.5.2). For sensitive species, the primary considerations are noise and/or turbidity. Buffer considerations for sensitive species are reviewed in Section 6.3.6.

6.3.5.1 Buffer to Minimize Turbidity Impacts to Sensitive Habitats

Relevant reports and effectiveness considerations are reviewed separately below for beach nourishment, offshore borrow site dredging, and embayment dredging.

Relevant Reports:

Beach Nourishment

- Turbidity plumes during 7 California beach nourishment projects at Goleta Beach, Surfside-Sunset Beach, Dana Point, and Agua Hedionda Lagoon indicate plumes may range 1,500 ft upcurrent and > 1.9 mi (3.1 km) downcurrent under strong currents, but generally are less than 1,000 ft (< 300 m) (Section 5.5.3.6). Use of dikes or swales may limit plume lengths to ≤ 300 ft (≤ 100 m) under average wave conditions without rip currents.
- Review of TSS monitoring data from 2 California beach nourishment projects indicate TSS concentrations may be substantially elevated in the surf zone directly offshore the discharge location (e.g., mean values > 400 to >1,000 mg/L) during unconfined discharge. One study measured moderate TSS (> 200 mg/L) up to 1 mi (1.6 km) downcurrent and lower, but detectable elevations of TSS (96 to 127 mg/L at distances 1.9 mi (3.1 km) downcurrent (Sherman et al. 1998). Background concentrations during non-storm conditions ranged from 17 to 26 mg/L. TSS values of 24 to 66 mg/L were measured off the discharge location outside the breaker zone during a separate beach nourishment program, confirming that plumes do not always extend beyond t he breaker zone.
- Turbidity monitoring during 7 California beach nourishment projects confirm visual observations that plumes do not always extend beyond the surf zone. For example, values outside the breaker zone offshore the discharge location sometimes were similar to background values (e.g., 1 to 16 NTU). Other times values offshore the discharge location were 2 to 7 times higher (e.g., > 20 to 225 NTU) than outside the plume (< 10 to 110 NTU). Values outside the plume indicate monitoring covered average (≤ 16 NTU) through high wave and/or storm conditions (> 20 to 110 NTU). Too few sampling locations were sampled with the reviewed projects to determine the primary, longshore extent of the plume.
- Similar findings were reported during monitoring of beach nourishment projects on East Coast. Reilly and Bellis (1983) reported TSS concentrations in the surf zone off the discharge location of 1,760 to 4,700 mg/L during unconfined discharge.
- Turbidity plumes during the several million cy Asbury Park to Manasquan Inlet Beach Nourishment Project, New Jersey were primarily within the surf zone (Wilber et al. 2006). TSS values near the bottom in the surf zone (64 mg/L) and in the nearshore (34 mg/L) were 1.7 to 3 times higher than background concentrations (20 mg/L) (Wilber et al. 2006). Plumes generally were on the order of 1,312 ft (400 m) long. Background values of 81 to 425 mg/L were measured near the bottom during storms.

- Review of available reports suggest TSS values under high wave and substantial storm events may range from 400 to 2,900 mg/L near the bottom (< 1 ft, < 0.3 and 100 to 500 mg/L at elevations between 1 and 2 ft (0.3 and 0,6 m) off the bottom (Beach and Sternberg 1992, Ogston and Sternberg 1995, Wilber et al. 2006). Instantaneous (< 1 minute) maximum concentrations of > 10,000 to 40,000 mg/L may be measured at the bottom during high wave conditions (Beach and Sternberg 1988) or during large, river floods (Ogston et al. 2000, Warrick and Milliman 2005).

Consideration of Effectiveness:

Review of available turbidity monitoring data indicates that suspended sediment concentrations may be elevated in the surf zone over a considerable distance associated with rapid littoral transport. However, concentrations outside the breaker zone may be more localized (Section 5.5.3.5). Measured turbidity plumes may range from < 1,000 ft (300 m) to several miles (kilometers) long and from 50 to 1,000 ft (15 to 300 m) wide. Turbidity plumes may vary depending on presence or absence of rip currents and weather conditions (average versus high waves, average versus storm conditions). Use of dikes or swales appears to be effective at reducing length and presumably concentration of turbidity plumes (Sections 5.5.3.5, 6.4.4.2).

<u>Offshore Borrow Site Dredging</u>

The following buffer distances were recommended in several California CEQA and/or NEPA documents to minimize potential turbidity impacts to kelp beds and subtidal reefs from offshore dredge operations (Appendix D.2):

- 300 to 500 ft (91 to 152 m) for the 2001 San Diego Regional Beach Sand Project (MEC 2000a).
- 1,000 ft (305 m) for the BEACON Beach Nourishment Demonstration Project (Chambers 1992).
- 300 ft (91 m) for the Cabrillo Beach Nourishment Project (Tekmarine and Analytic Planning 1990).

The following monitoring studies indicate that turbidity plumes may be relatively localized during offshore dredging of sands.

- Monitoring at six offshore borrow sites during the 2001 San Diego Regional Beach Sand Project indicated that elevated turbidity occurred at distances between 250 and 500 ft (75 and 150 m) downcurrent, but similarly lower turbidity occurred between 250 and 1,500 ft (75 and 450 m) upcurrent (Section 5.5.3, Figure 5.5-6). Measurements at distances farther than 500 ft (150 m) downcurrent were not made; therefore, the downcurrent extent of the plume was not determined.
- TSS concentrations substantially declined within 820 ft (250 m) of four commercial aggregate dredges during normal operations off the United Kingdom, and rapidly decayed to background levels over a distance of 656 to 1,604 ft (200-500 m) during dredging in Moreton Bay, Australia (reviewed in Newell et al. 1998).

- The main deposition of sand during commercial hydraulic dredging was within 500 ft (150 m) of the dredge in the Baltic Sea (Gajewski and Uscinowicz 1993 cited in Newell et al. 1998) and within 984 ft (300 m) of the dredge off the South Coast of Britain (Hitchcock et al. 2002).

Consideration of Effectiveness:

Turbidity generated during dredging operations is influenced by type of dredge and equipment operation, sediment characteristics, and existing conditions (Section 5.5.3). Turbidity monitoring data from the above thirteen offshore dredging projects of sandy sediments, including commercial aggregate operations, suggest that most deposition occurs over distances within 500 to 1,6400 ft (150 to 500 m) of the dredge. Because several of the reviewed reports did not include a sufficient number of sampling locations to demonstrate the full extent of the plume, it may be precautionary to use a buffer distance of 1,640 ft (500 m) between offshore dredging sites and sensitive aquatic resource areas during project design. Based on project- and site-specific conditions, a shorter buffer distance also may be protective. A more standardized approach to plume monitoring during project implementation would enable future refinement of appropriate buffer distances (see Section 7.4.3).

<u>Embayment Dredging</u>

Relevant Reports:

- Mean TSS concentrations ≥ 100 mg/L were measured within 300 ft (91 m) downcurrent of the dredge for some California harbor dredging projects, but in most of the reviewed projects the mean concentrations were similar at distances up to 2,000 ft (610 m) away both up and downcurrent, suggesting TSS concentrations were influenced by broader environmental conditions than dredging (Section 5.5.2, Figure 5.5-2). Mean turbidity levels sometimes were elevated within approximately 500 ft (150 m) downcurrent of the dredge (Section 5.5.2, Figure 5.5-6). Secchi disk depths also showed water clarity depressions within 500 ft (150 m) of the dredge (Figure 5.5-8). Monitoring at distances between 1,000 to 2,000 ft (300 to 610 m) upcurrent indicated values were outside the plume. Few data were collected at distances > 500 ft (> 150 m) downcurrent; measurements appeared to be outside the plume at distances > 1,000 ft downcurrent when measurements were taken. However, the downcurrent extent of the plumes was not demonstrated with most of the 18 reviewed projects.
- A slightly elevated TSS concentration of 50 mg/L was measured at distances up to 1,312 (400 m) during dredging in San Francisco Bay (MEC and USACE-ERDC 2004). Concentrations between 100 and 390 mg/L generally were < 1,000 ft (< 300 m) from the dredge.
- LaSalle et al. (1991) stated that a generalized worst-case plume of ≤ 500 mg/L will occur at distances ≤ 1,640 ft (≤ 500 m) with the maximum concentrations generally restricted to the lower water column within 164 to 328 ft (50 to 100 m).
- Germano and Cary (2005) reviewed that while measurable sedimentation during dredging could range from 656 to 3,281 ft (200 to 1,000 m) away from source, the strongest effects occur less than 984 ft (300 m) from the source.

Consideration of Effectiveness:

Turbidity plumes and sedimentation in embayments will be influenced by type of dredge and equipment operation, sediment characteristics, and existing conditions (Section 5.5.2). In addition, physical conditions (e.g., confined basins) in harbors may substantially influence hydrodynamics. Similar to the above discussion for offshore borrow sites, sampling designs of many harbor dredging projects do not measure the full extent of the plume. Available information suggests that turbidity and sedimentation effects mainly occur within 1,000 ft (300 m) of the dredge. Similar to considerations discussed above, a buffer distance of 1,640 ft (500 m) between dredge and sensitive aquatic resource areas may be precautionary. A more standardized approach to plume monitoring during project implementation would enable future refinement of appropriate buffer distances (see Section 7.4.3).

A shorter buffer distance also may be protective based on evaluation of project size, equipment, and site-specific conditions (i.e., sediment grain size characteristics, currents). Appropriate buffer distance considerations also vary depending on type of sensitive biological resource (Section 6.3.6).

6.3.5.2 Buffer to Minimize Sedimentation Impacts

Relevant Reports

- No discharge at the river mouth was specified for Ventura Harbor maintenance dredging and beach placement to avoid potential impacts to steelhead trout spawning migration and/or juveniles using the Santa Clara River (USACE 1998b).
- A beach receiver site was located 2,500 ft (762 m) downcoast of the inlet of Carpinteria Marsh to minimize sand migration impacts associated with placement of up to 50,000 cy with implementation of the BEACON South Central Coast program (Chambers 2001c, Moffatt & Nichol 2005a).
- Beach receiver sites for the 2001 San Diego Beach Sand Project were not located according to a standard buffer distance from intertidal tidepools, nearshore reefs, and kelp beds, but instead were evaluated based on placement volume, reef heights, biological resource development, and predicted sand thickness in excess of historical profiles (MEC 2000a, Moffatt & Nichol 2000). Reefs ranged from low to high relief with variable resource development. Sand placement volumes at receiver sites that had reefs and kelp beds in the vicinity ranged from 101,000 to 245,000 cy. No significant impacts to sensitive rocky intertidal, nearshore reef, or kelp bed habitats were reported after four years of monitoring compared to before project conditions using a BACI sampling design (AMEC 2005).
- A total of 97,600 cy was placed over two years at Goleta Beach, which had eelgrass habitat approximately >1,600 ft (> 500 m) offshore, kelp habitat > 1,969 ft (> 600 m) downcoast and offshore, and rocky intertidal with surfgrass approximately 6,500 ft (2000 m) downcoast. No persistent sedimentation impacts were observed in the habitats during the first year of post-construction monitoring (Chambers Group 2004).

Consideration of Effectiveness

Discharge of sediments in river mouths or other shallow-water inlets to coastal embayments may increase shoaling rates and risks of inlet closure and/or result in increased maintenance dredging and/or excavation requirements. Therefore, restriction of sediment discharge at river mouths is considered desirable not only to avoid potential interference with migration of salmonids, but other species that transit shallow-water inlets to use embayments (lagoons, sloughs) as nursery areas. Use of a buffer distance between sand placement location and inlets also should be effective for minimizing impacts associated with inlet closure. Factors such as project size, prevailing current direction, and distance from inlet are important considerations with respect to potential sedimentation impacts to inlets. Therefore, a standard buffer distance may not be effective across a range of project sizes. The importance of distance from embayment inlets increases with increased project volume.

The above relevant reports indicate that protection of sensitive reef habitats from indirect sedimentation after beach nourishment projects requires consideration of factors such as sand placement volume, reef heights, resource development, coastal processes, and predicted increase in sand thickness across beach profiles relative to pre-project conditions. Other factors such as receiver site dimensions and placement location also may be influential. Therefore, a standardized buffer distance may not be effective across a range of project sizes. The importance of distance from sensitive resources increases with increased project volume. Appropriate protective buffer distances may vary depending on type of sensitive biological resources (Section 6.3.6).

6.3.6 Buffer to Avoid and Minimize Impacts to Sensitive Species

Turbidity and/or sedimentation may be of concern for sensitive fishery spawning areas. Noise also may be of concern for sensitive fish species. Turbidity and/or noise may be of concern to sensitive bird species. Noise may be of concern near sensitive marine mammals.

Significance thresholds have been established for marine mammals. Significance thresholds have been established for sensitive bird species in San Diego County (2007), but otherwise have not been formally adopted in the state.

The following noise disturbance thresholds are recognized:

- 60 dB – Sensitive terrestrial birds, including snowy plover (San Diego County 2007). In areas where this level is exceeded under existing conditions, noise significance is defined relative to exceedance of ambient.
- 70 dB (terrestrial), 153 dB_{RMS} (underwater) – Seabird, marbled murrelet (WSDOT 2006).
- 150 dB_{RMS} (re 1 μPa) – Salmonids (WSDOT 2006).
- 120 dB_{RMS} (re 1 μPa) (underwater) 58 dB (terrestrial) – Cetaceans (Federal Register 2005).

The following subsections review buffer considerations for fish, birds, and marine mammals.

6.3.6.1 Buffer to Protect Fishery Spawning Grounds

This measure involves use of a buffer distance and/or barrier to minimize direct and/or indirect impacts to sensitive fishery spawning grounds. Relevant reports and effectiveness considerations are reviewed separately below for different species and/or types of fish.

Pacific Herring Spawning Sites

Consideration of Effectiveness:

Relevant reports and considerations of effectiveness discussed for sensitive habitats in Section 6.4.2.1 (embayments) are relevant to buffer considerations for protecting spawning grounds of Pacific herring. However, additional consideration should be given to the sensitivity of demersal eggs of Pacific herring to thin-layer sedimentation (Section 4.3.2). Evaluation of whether a buffer distance would provide adequate protection during the herring spawning season would require consideration of project and site-specific factors such as proximity to spawning sites, sediment characteristics of dredge material, and hydrodynamics.

Salmonids

Dredge noises may be less than disturbance thresholds for salmonids at distances > 100 to 1,312 ft (30 to 400 m) for hopper dredges and at distances closer than that for clamshell bucket dredges (Section 5.3.2.6). Turbidity may represent an adverse or beneficial effect to migrating salmonids depending on concentration. Based on these considerations, distance may represent an effective measure for minimizing impacts to migration of salmonids when indirect effects of noise and turbidity are minimized. Actual buffer distances should be based on project- and site-specific considerations, including equipment, substrate characteristics, and hydrodynamics. Width of water body where the sediment management activity would occur also may be an important consideration with respect to the effectiveness of this measure; the effectiveness may be less in confined areas. During times of migration, other effective measures may include operational controls for turbidity and entrainment (Section 6.4.3.2, 6.4.3.3).

6.3.6.2 Buffer to Avoid and Minimize Impacts to Sensitive Bird Species

California Brown Pelican

A buffer distance may be used to minimize impacts of sediment management activities near large roost sites of California brown pelican.

Relevant Reports:

- No dredging within 300 ft (91 m) of large roosts between July and September during the time period between one hour before sunset and sunrise is specified for San Francisco Bay by the USACE San Francisco District (http://el.erdc.usace.army.mil/tessp) and San Francisco Bay LTMS (USACE et al. 2001).
- A buffer distance of 115 ft (35 m) between dredge operations and breakwater where pelicans roost was specified during dredging of contaminated sediments

at Marina del Rey Harbor (USACE 1999b). The measure also included provision for increasing the buffer distance by 50 ft (15 m) increments up to a maximum of 270 ft (80 m) if substantial roost abandonment (50% reduction in birds) was observed at night. In addition, a temporary barge was used to provide additional potential roosting area. If abandonment of the breakwater roost was observed at a distance of 270 ft (80 m) and pelicans did not use the barge for roosting, further dredging of contaminated sediment was to be restricted.

- Varanus (1999) reported that pelicans displayed startle reaction to sudden and/or close approach disturbance (e.g., clamshell dredge start up, illumination of breakwater after long periods of inactivity, and movement of a tugboat between the dredge and breakwater), but otherwise were tolerant of dredging activities near the breakwater during the above-noted monitoring program at Marina del Rey. Startle responses to dredging activities included shifting of birds along the breakwater and/or brief departures (minutes).
- Jaques et al. (1996) reported that brown pelicans did not appear to be disturbed by heavy equipment operation and rip-rap installation within 328 ft (100 m) of a roost site.
- A distance of 164 ft (50 m) was specified as a buffer distance between pelican roosts and maintenance dredging at Moss Landing (USACE 2002c).

Consideration of Effectiveness:

A buffer distance of 300 ft (91 m) from large roost sites is supported by monitoring studies that indicate startle response behavior (shifting of position, brief flushing) of pelicans to sudden disturbance associated with dredging activities at distances within 270 ft (80 m) and no obvious disturbance to heavy equipment activities at a distance of 328 ft (100 m) (Jaques et al. 1996, Varanus 1999). No available information was identified during the literature review to support smaller buffer distances. Assuming dredge noise levels of 76 to 88 dB within 50 ft (15 m) (Table 5.3-1), noise levels of 61 to 73 dB may occur within 300 ft (91 m) based on a standard attenuation rate of 6 dB per doubling of distance (Section 5.3.3.6). These values are near or below the 70 dB disturbance threshold estimated for marbled murrelet (diving seabird) (WSDOT 2006). Average noise levels during dredging would be expected to attenuate to 60 dB at distances of 328 to 1,000 ft (100 to 200 m) depending on dredge equipment. Based on the above considerations, the 300 ft (91 m) buffer distance appears to be justified.

<u>California Least Tern</u>

Generally, sediment management projects in California require consultation with the USFWS if there is the potential for turbidity generating activities to occur within 1 to 2 miles of least tern nesting sites during their breeding season (Section 4.4.2). Projects located > 2 miles from least tern nesting sites do not require consultation. Review of available information suggests that a 1 to 2 mile threshold may be overly protective. Shorter buffer distances, particularly when combined with operational control of turbidity, may be protective.

Relevant Reports:

- RGP 67 specifies no beach nourishment activities shall be conducted within 3,000 ft (914 m) of least tern nest sites during the breeding season.

- Least terns may forage on small, schooling fish beyond the surf zone with 1 to 2 miles (1.6 to 3.2 km) of shore and in embayments and lakes near the coast (Atwood and Minsky 1983, Collins et al. 1979).
- Construction mitigation measures (e.g., dike or swale discharge) during beach nourishment generally limit turbidity to the surf zone, except in areas of rip currents (MEC 1997, AMEC 2002, Moffatt & Nichol 2004).
- Permit requirements that water clarity not be < 3 ft (1 m) over an area > 2.47 acre (> 1 hectare) to protect potential least tern foraging were met with few exceedances during the 2001 San Diego Regional Beach Sand Project (AMEC 2002).
- Monitoring did not detect any obvious effect on least tern foraging behavior during beach nourishment with diked discharge at Surfside-Sunset Beach (MEC 1997).
- Turbidity plumes during beach nourishment are mainly confined within the surf zone unless carried offshore by rip currents. Under rip current conditions, turbidity plumes may be visible downcurrent for > 2 mi (3.2 km) and extend outside the breaker zone (MEC 1997, Sherman et al. 1998, AMEC 2002). Under non-rip conditions, plumes may be < 1,000 ft (305 m) long and within the surf zone (MEC 1997, AMEC 2002, Moffatt & Nichol 2003, other data files reviewed in Section 5.5.3.5).
- Turbidity generally dissipates to near background levels within approximately 1,000 ft (300 m) of hydraulic dredges during offshore dredging and mechanical and hydraulic dredges during maintenance dredging in embayments (Sections 5.5.2, 6.4.2.1).
- Turbidity plumes during dredging may range up to 2,297 ft (700 m), but a generalized worst-case plume is considered ≤ 500 mg/L at distances ≤ 1,640 ft (≤ 500 m) (LaSalle et al. 1991).

Consideration of Effectiveness:

Least terns are visual foragers that require adequate water clarity to see prey (small, near surface schooling fish). In the Biological Opinion for the 2001 San Diego Regional Beach Sand Project, a conservation measure to avoid and/or minimize impacts to visual foragers (California least tern and California brown pelican) was specified as surface turbidity of not less than 3 ft (1 m) over a 328-ft^2 area (100-m^2, 1 hectare), as measured by Secchi disk (USFWS 2000). Few exceedances of that criterion were measured during implementation of that project (AMEC 2002).

Available information indicates that turbidity during beach nourishment is largely confined within the surf zone unless there are rip currents (Section 5.5.3.5). Monitoring during periods with and without rip currents suggests that rip currents are not persistent; reports of very large plumes represented a small percentage of the monitoring observations (MEC 1997, AMEC 2002). Turbidity plumes during 19 California and 1 East Coast beach nourishment project reported turbidity plume lengths generally < 2,500 ft (762m) and often less than <1,000 ft (300 m) in length Section 5.5.3.5).

Available reports indicate turbidity plumes during offshore dredging and in embayments may reach 2,297 ft (700 m), but generally are much less than ≤ 1,640 ft (500 m) (LaSalle et al. 1991).

As noted above for California brown pelican, average noise levels during sediment management projects would be expected to attenuate to ≤ 60 dBA at distances of 328 to 1000 ft (100 to 328 m) from dredging operations depending on dredge equipment. Noise levels associated with equipment use during beach nourishment may range up to 96 dBA with average levels expected to be less than 85 to 90 dBA at 50 ft (15 m) (Section 5.3.2.6). Average noise levels over flat terrain would be expected to attenuate to 60 dBA within distances of 1,000 to 1,600 ft (328 to 487 m).

Based on the above considerations, the 3,000 ft (914 m) buffer specified by RGP 67 appears to be supported by available data. The data suggest that shorter buffer distances also may be protective, particularly combined with operational controls that limit turbidity.

Snowy Plover

A buffer may be used to minimize impacts to snowy plover nesting sites, which are stationary after establishment during the breeding season. Buffers are not considered a feasible measure for minimizing impacts to snowy plovers foraging in the intertidal zone because of their mobility. In addition, other measures such as single-point surf zone discharge within a small, restricted zone of operations may be used to minimize impacts to snowy plover foraging (Section 6.4.1.2).

Relevant Reports

- A vehicle use restriction to near the pipeline and construction of one or more fenced corridors between the dunes and surf were specified to protect snowy plovers if beach placement activities extended beyond March 15 near Ventura Harbor (USACE 1998b).
- Dredging and surf zone disposal has been conducted during the snowy plover breeding season at Morro Bay with no documented adverse effects on breeding (USACE 2001).
- Chambers Group (2001a) reported that snowy plovers foraged in the vicinity of surf-zone discharge of dredged material from Santa Barbara Harbor.
- Worden and Smith (2004) reported short-term disturbances to snowy plovers from vehicles and pipeline installation activities during surf zone discharge of dredged materials from Ventura Harbor.
- Chambers Group (2005) noted that snowy plovers avoided the immediate vicinity of inlet dredging and disposal on the upper intertidal near Talbert Channel, Huntington Beach, but foraged undisturbed nearby.
- Protective measures recommended for piping plovers during beach nourishment on the Atlantic coast of the United States include a 300 ft (91 m) buffer from nests or chicks, and seasonal restriction of placement activities, pipeline storage, and pipeline removal between April 1 and August 31, unless work will enhance habitat (Melvin 2005).

Consideration of Effectiveness:

Average noise levels during beach nourishment projects would be expected to attenuate to 60 dBA within distances of 1,000 to 1,600 ft (328 to 487 m). Therefore, nesting sites of snowy plovers would not be expected to be adversely affected at distances > 1,640 ft (500 m) from beach nourishment activities.

Available literature indicates that few disturbances occur to snowy plovers at distances greater than 98 ft (30 m) (Lafferty 2000). Therefore, potential impacts to snowy plover foraging and/or resting may be more a function of how much of the beach area is affected by vehicles and equipment rather than distance from activities. Therefore, project- and site-specific considerations likely will influence the applicability of a buffer distance as an effective mitigation measure to minimize impacts to snowy plover foraging and/or resting activities. Site conditions should be evaluated on a case-by-case basis in coordination with the USFWS to develop appropriate mitigation measures for snowy plover if the project is within critical habitat.

Peregrine Falcon

Peregrine falcons may nest on cliff ledges and/or man-made structures (e.g., bridges) in harbors. The also nest and roost on Morro Rock at Morro Bay (USACE 2001). Average dredge noise levels would be expected to attenuate to 60 dBA at distances of 328 to 1,000 ft (100 to 328 m), depending on equipment (Section 5.3.2.6).

Average noise levels would be expected to attenuate to 60 dBA within distances of 1,000 to 1,600 ft (328 to 487 m) during beach nourishment, depending on equipment. Therefore, nesting sites of peregrine falcon would not be expected to be adversely affected at distances > 1,640 ft (500 m) from beach nourishment activities.

6.3.6.3 Buffer to Avoid and Minimize Impacts to Marine Mammals

Dredge noises (airborne) would be expected to attenuate to below marine mammal harassment levels at distances of 300 to 1,600 ft (91 to 488 m). Actual buffer distances should be based on equipment, sensitivity of marine mammal, and use patterns in the project area. For example, sea lions and harbor seals are relatively tolerant of disturbance (Section 5.3.2.6).

Pre-construction buffer distances cannot be specified for mobile marine mammals while in the water. Other measures such as limiting intentional approaches and using slow vessel speeds are appropriate during construction (Section 6.4.1.5).

6.3.7 Environmental Coordination and Notifications

Several measures may be implemented as part of final design, permitting, and/or just prior to construction that include coordination and/or final planning activities relevant to environmental protection. These may include preparation of a hazardous materials management plan, inlet monitoring and response plan, notice to mariners, and/or environmental training. Each of these coordination activities has relevance to biological resource protection.

6.3.7.1 Prepare Hazardous Materials Management Plan

This measure includes preparation of a Transport and Discharge Operations Plan, including a Spill Prevention, Containment and Countermeasures Plan (SPCCP) that specifies fueling, equipment maintenance procedures to prevent spills and leaks, and containment and cleanup measures to be followed in the event of a spill.

Relevant Reports:

- RGP 67 (USACE 2006) specifies that (1) a Transport and Discharge Operations Plan shall include a Spill Prevention, Containment and Countermeasures Plan (SPCCP) that specifies fueling, equipment maintenance procedures to prevent spills and leaks, and containment and cleanup measures to be followed in the event of a spill.
- Preparation of a SPCCP that addresses (1) on- and offshore activities and use and refueling equipment, (2) handling and storage of construction and maintenance fluids, and (3) control, containment, and cleanup of released fluids was specified as a mitigation measure in the EIS/EIR for the Imperial Beach Shoreline Protection Project (USACE 2002).

Consideration of Effectiveness:

Accidental leaks and/or spills are of concern because of potential impacts to water quality and/or biological resources. Therefore, preparation of a SPCCP should be effective for minimizing the potential for adverse impacts from accidental spills or leaks.

6.3.7.2 Prepare Inlet Monitoring and Response Plan

Relevant Reports:

- The implementation guidelines for the BEACON South Central Coast Beach Enhancement Program specifies monitoring during, immediately after, and for six months following construction to determine if inlet closure occurs due to sedimentation. If closure is observed, then material will be removed as necessary until the inlet area has stabilized (Moffatt & Nichol 20005a).
- Monitoring and opening inlet if closure occurs was specified as a mitigation measure for the Goleta Beach Nourishment Demonstration Project (Chambers Group 1992).

Consideration of Effectiveness:

This type of planning has been conduced for several opportunistic sand programs. In addition, beach profile monitoring was conducted to determine inlet status and shoaling in lagoons during the 2001 San Diego Regional Beach Sand Project. Commitments for monitoring, response action, and/or funding have been specified with these project examples. The mitigation measure formalizes this process. Monitoring during construction is reviewed in Section 6.4.5.3.

6.3.7.3 Conduct Environmental Training Program

This measure involves conducting a pre-construction meeting and/or environmental training program with contractors, environmental monitors, and other agencies, as appropriate to ensure compliance with construction mitigation measures.

Relevant Reports:

- Implementation of an environmental training program to communicate environmental concerns and appropriate work practices, including spill prevention and response measures was specified as a mitigation measure in the EIS/EIR for the Imperial Beach Shoreline Protection Project (USACE 2002).
- A pre-project meeting with contractors, monitors, Corps, resource agencies, USACE, and local and federal lead sponsors (SANDAG, and U.S. Navy) to understand the roles and responsibilities of monitoring was specified in the biological opinion for the 2001 San Diego Regional Beach Sand Project (USFWS 2000).

Consideration of Effectiveness:

Sediment management projects occur in and/or in close proximity to marine and/or estuarine waters and may be implemented in proximity to sensitive biological resources, and/or habitats. Several types of monitoring and/or protective measures may be required during construction. An important element of successful environmental compliance is adequate coordination among contractor field personnel and monitors with respect to roles of individuals, monitoring requirements, safety issues, and communication protocol. At a minimum, a pre-construction field meeting may be adequate. When sensitive species are an issue, a pre-construction training program for field personnel may be effective to ensure successful compliance with mitigation.

6.3.7.4 Conduct Coast Guard Notification to Minimize Environmental Hazards

This measure addresses notifying the U.S. Coast Guard of planned in-water sediment management activities to minimize the potential for environmental hazards associated with collisions and oil spills.

Relevant Reports:

- Publication of dredge locations via a U.S. Coast Guard Notice to Mariners, written notices to local fishing representatives, and posted notices in local harbors was specified to avoid conflicts and fishing gear loss of commercial fishermen (SANDAG and USDN 2000).

Consideration of Effectiveness:

The U.S. Coast Guard Notice to Mariners provides up-to-date marine safety information (http://www.navcen.uscg.gov/lnm/default.htm). Therefore, notifications should be effective for minimizing potential for collisions and hazardous materials spills. In addition, the measure should be effective for minimizing interference with commercial fishing activities.

6.3.8 Mitigation and Monitoring Plan

The mitigation and monitoring plan generally is prepared as part of the requirements for a MND or EIR/EIS. The following measures include finalization of the plan prior to construction to include any relevant updates during final design, and briefly review types of monitoring that may be conducted during the pre-construction phase. Pre-construction monitoring is described further in Section 7.3.

6.3.8.1 Finalize Mitigation and Reporting Plan

This measure involves preparing a final mitigation, monitoring, and reporting program prior to construction.

Relevant Reports

- RGP 67 requires conducting a Sensitive Aquatic Resource (SAR) survey, including preparation of a MMRP for turbidity plumes in ASBSs, Pismo clam, and grunion monitoring and protective measures if activities are scheduled between March 1 and August 31. A Biology Report that specifies how impacts to threatened or endangered species are avoided also is to be prepared (USACE 2006).
- A final MMRP addressing pre- and post-project monitoring of sensitive habitats and construction monitoring of sensitive resources was required for the 2001 San Diego Regional Beach Sand Project (USACE 1999-15076-RLK, AMEC 2002, 2005).
- A final MMRP was prepared for the Goleta Beach Nourishment Demonstration Project (USACE 200200666-JCM, Moffatt & Nichol 2003).

Consideration of Effectiveness:

The effectiveness of this measure will depend in part on the detail provided in the plan. Ideally the plan should include description of the monitoring objectives, methods, field communication and agency notification protocol, and reporting schedule and contents. The decision process during construction and description of types of additional protective types that may be implemented during construction should be described, as appropriate. Plans that include pre- and post-project impact significance verification monitoring should specify significance criteria, detection level requirements, sampling design, data analysis methods, and reporting schedule.

6.3.8.2 Pre-Construction Surveys and Monitoring

Pre-construction surveys may be specified as mitigation measures to provide updated information on sensitive habitat boundaries, species occurrence, and/or invasive species occurrence to support logistic decisions with respect to project implementation. Results of pre-construction surveys may be used to determine whether additional protective measures and/or monitoring may be warranted during construction. Results also will support decisions with respect to minor adjustments to construction boundaries to avoid direct impacts to sensitive resources, if necessary, and will approval by resource and regulatory agencies.

Pre-construction surveys may be appropriate in areas where sensitive resource occurrence varies within and/or between years. They also may be appropriate in areas where sensitive habitats have patchy occurrence and detailed boundary information is not needed until construction and/or access plans are finalized.

The following types of pre-construction monitoring mitigation measures may be conducted to facilitate impact avoidance and/or minimization. The mitigation measures assume an environmental review process that includes preparation of a MMRP that is submitted to resource and regulatory agencies for comment and approval as part of informal coordination and/or the permitting process prior conducting surveys (Section 6.3.8.1). Monitoring considerations and effectiveness are reviewed in greater detail in Section 7.3.

- Sensitive aquatic resource (SAR) survey – Conduct SAR survey and submit results to resource agencies according to requirements specified in the MMRP. This measure is applicable to project footprints, access routes, pipeline routes, and/or vessel anchorages.
- Grunion habitat suitability survey – Conduct grunion habitat survey if project is scheduled between March 1 and August 31 and submit results to resource agencies according to requirements specified in the MMRP. If habitat is suitable, implement construction monitoring and protective measures specified in the approved MMRP or reschedule project.
- Pismo clam survey – Conduct Pismo clam survey in areas where there is potential for direct impacts (e.g., nearshore placement or borrow site dredging) and submit results to resource agencies according to requirements specified in the MMRP.
- Local Important Fishery Grounds – Conduct survey for other locally important fishery grounds (e.g., Dungeness crab) if project is located in an area of identified potential concern and the project schedule overlaps seasonal period of vulnerability.
- Snowy plover occurrence survey – Conduct snowy plover survey if site is within critical habitat, within 1 mile of known nesting sites, and/or is known to support a substantial wintering population and submit results to resource agencies according to requirements specified in the MMRP. If nests, chicks, or substantial wintering population are observed, implement construction monitoring and protective measures specified in the approved MMRP or reschedule project.
- *Caulerpa* survey – Conduct *Caulerpa* survey of dredge locations and submit results to resource agencies according to established protocols. If *Caulerpa* is found, eradication will be conducted prior to dredging to avoid spread of this invasive species.
- Conduct pre-project baseline monitoring of sensitive habitats – Conduct monitoring to establish existing conditions at adjacent sensitive habitats and at reference sites to support post-project impact significance verification and submit results to resource agencies according to requirements specified in the MMRP. The MMRP will include description of criteria and methods for determining impact, including thresholds of significance.

6.4 Construction Phase Mitigation Measures

Several different methods may be used to avoid direct and/or minimize indirect impacts to biological resources from equipment, burial, sedimentation, and turbidity related impacts during construction. These measures may include location controls, schedule restrictions, construction method and operational controls, best management practices, and monitoring (Table 6.4-1). These measures are briefly reviewed in the following sections.

6.4.1 Location Controls

6.4.1.1 Avoid use of equipment, pipelines, and construction materials in sensitive habitats

This measure involves specification of areas where construction activities are prohibited and/or restricted to avoid and/or minimize impacts to sensitive resources.

Relevant Reports:

- Establishment of no work zones, restriction of pipeline alignment and transportation corridors outside vegetated areas, where possible, and restriction against use of all-terrain vehicles in vegetated habitat were identified as environmental commitments for sediment management projects at Morro Bay Harbor and Ventura Harbor, California (USACE 1998b, 2001).
- At Morro Bay, pipeline placement was restricted to within a 50-ft (15-m) corridor if complete avoidance was not possible to minimize impacts to vegetation (USACE 2001). Avoid placement of pipelines and/or use of equipment in sensitive habitat areas.
- Use of aggregates (sand, gravel, asphalt, concrete) to support pipeline placement during maintenance dredging and beach nourishment Is prohibited in eelgrass beds in Morro Bay (USACE 2001). Use of concrete sleeves, heavy steel, or steel pipe casing for protecting, anchoring, or stabilizing sections of pipeline are allowed when placed and removed with pipeline.

Consideration of Potential Effectiveness:

Restriction of equipment in sensitive habitats is considered the most effective method to avoid direct impacts. Effectiveness of the measure may be improved on land by clearly marking restricted areas (e.g., visible flagging, temporary snow fencing).

When temporary pipeline placement is necessary in a sensitive habitat, restriction of introduction of materials that may change substrate characteristics should be effective for avoiding a change in habitat quality in sensitive habitat areas. Before and after construction monitoring may be necessary to assess direct damage effects, if any. For example, pre- and post-project eelgrass surveys for the area of pipeline placement, with mitigation of loss according to the Southern California Eelgrass Mitigation Policy are specified as an EFH conservation measure for 2001 to 2007 maintenance projects at Morro Bay (USACE 2001).

Table 6.4-1. Types of construction phase mitigation measures to reduce direct and indirect impacts during sediment management projects.

Construction Mitigation Measures	Equipment	Burial	Sedimentation	Turbidity/ Water Quality
Location Controls				
Avoid use of equipment, pipelines, and construction materials in sensitive habitats	X			
Avoid anchoring and/or operation of dredges, drill rigs, and/or barges in or above SAV habitats	X			
Surf-zone discharge location	X	X		X
Upper beach discharge location			X	X
Limit intentional approaches within 300 ft (91 m) and use slow vessel speed around sensitive marine mammals	X			
Schedule and/or SeasonalRestrictions				
Environmental windows	X	X		X
Avoid repetitive disturbance in same year[1]	X	X		
Avoid peak recruitment and productive period	X	X	X	X
Dredge Equipment and Operational Controls				
Dredge equipment selection			X	X
Use dredge controls - entrainment	X			
Use dredge controls - turbidity			X	X
Construction Equipment, Methods, and Best Management Practices (BMPs)				
Use silt curtains or gunderbooms to minimize turbidity				
Use dikes or swales to minimize turbidity			X	X
Minimize potential hazardous materials leaks or spills	X			X
Reduce noise levels below sensitive wildlife harassment or disturbance thresholds	X			
Minimize artificial lighting in sensitive wildlife areas	X			
Barrier reduction	X			
Environmental Training	X	X		X
Construction Monitoring				
Sediment compatibility inspections and testing		X		
Water quality compliance				X
Inlet status			X	
Sensitive species, as necessary	X	X		

6.4.1.2 Avoid anchoring and/or operation of dredges, drill rigs, and/or barges in or above SAV habitats

Relevant Reports:

- Dredging within specific limits has been used to minimize impacts to eelgrass habitat during required maintenance dredging at Agua Hedionda Lagoon, San Diego County (USACE Permit 87-171-SK). Permit requirements specify mapping of eelgrass before and after dredging and mitigation of any eelgrass removal outside prescribed dredge limits.
- WSDOT (2006) specifies that construction barges will not be anchored in or above eelgrass or kelp beds, and drill rigs will not operate in or above eelgrass or kelp beds to prevent damage to eelgrass and kelp beds as a result of shading or disturbance by anchors or drilling equipment.

Consideration of Effectiveness:

The effectiveness of prescribed dredge limits to minimize impacts to eelgrass is considered effective with use of navigational aids (e.g., GPS coordinates) and permit requirements that require pre- and post-dredge eelgrass mapping and mitigation for removal outside prescribed limits according to Southern California Eelgrass Mitigation Policy.

Restriction of anchoring and/or operating of vessels and/or dredges over eelgrass or kelp beds should be effective for avoiding direct impacts and minimizing indirect impacts to these SAV habitats. Sediment management projects may not span durations sufficient to result in decline of vegetation from vessel shading; however, restriction of operation of vessels above eelgrass and kelp canopies should reduce impacts associated with propeller entanglement and/or turbidity as a result of sediment resuspension from propeller wash.

6.4.1.3 Single-Point, Surf-Zone Discharge

Surf-zone discharge of hydraulic dredged materials has been used to avoid direct impacts to grunion spawning and/or snowy plover nesting habitats. Sometimes, the activity is restricted within a specified length of beach to minimize disturbance associated with pipeline operations. Pipeline placement and removal operations generally are restricted to outside spawning and/or breeding seasons if sensitive resources are present to avoid potential direct impacts to these species.

Relevant Reports:

- The use of a single-point surf zone discharge has been specified for beach placement disposal operations associated with maintenance dredging projects at Channel Islands/Port Hueneme Harbors, Marina del Rey Harbor, Morro Bay Harbor, Oceanside Harbor, Santa Barbara Harbor, and Ventura Harbor, California (USACE 1993, 1994a, 1994b, 1998a, 1998b, 1999b, 2000a, 2000b, 2001).
- Pipeline and discharge activities have been limited within a 500 ft (150 m) wide corridor associated with Marina del Rey Harbor and Santa Barbara Harbor

maintenance dredging and surf-zone disposal projects (USACE 1993, 1998a, 1999b).

- A 50-ft (15-m) wide corridor was specified for surf-zone disposal at Morro Strand State Beach near snowy plover nesting sites (USACE 2001).
- A five-year study by the Corps during March-April surf zone discharge at Santa Barbara did not detect significant differences in grunion spawning distribution or hatching success within project and reference areas (USACE 1998a). However, a limitation noted by that study was the lack of information later in the season when larger spawning runs may occur.
- The USACE (2001) reviewed that surf-zone disposal during fall-winter did not appear to affect subsequent nesting success of snowy plovers at Morro Strand State Beach after 1993, 1995, and 1997 maintenance dredging projects or successful nesting after the 1992-1993 beach disposal at Ventura. Successful nesting also was reported during and after surf-zone disposal at the Morro Bay sand spit in 1987.
- Chambers Group (2001a) reported that snowy plovers foraged in the vicinity of surf-zone discharge of dredged material from Santa Barbara Harbor.
- Worden and Smith (2004) reported short-term disturbances to snowy plovers from vehicles and pipeline installation activities during surf zone discharge of dredged materials from Ventura Harbor.

Consideration of Effectiveness:

Available information, although largely qualitative, suggests that single-point, surf zone discharge does not adversely affect grunion egg hatching or snowy plover nesting success, which occur at higher elevations of the beach. Placement and removal operations outside the spawning and/or breeding seasons are considered effective for avoidance of direct impacts to these species.

Single-point, surf zone discharge may be unnecessary for grunion if habitat conditions (e.g., beach width and/or sand depth) are unsuitable for spawning. The measure may be effective during the grunion season since grunion spawn higher on the beach (i.e., near spring high tide line). Limited information suggests that grunion spawning is not precluded by turbidity associated with single-point surf zone discharge and/or after storms. Relationships between turbidity and grunion spawning are not well understood. Insufficient information is available to assess to what extent confinement of turbidity plumes mainly to the surf zone (Section 5.5.3.5) lessens potential turbidity effects on grunion spawning behavior.

Snowy plovers forage in the swash zone; therefore, single-point surf zone discharge has the potential to interfere with their foraging behavior. Restriction of pipeline operations within corridors ranging from 50 to 500 ft (15 to 152 m) in beach length have been specified for several of the above-noted USACE sediment maintenance projects. Available literature indicates that few disturbances to snowy plovers occur at distances greater than 98 ft (30 m) (Lafferty 2000). Therefore, small corridors that confine operations are considered more protective than larger corridors.

Whether this measure is appropriate to implement should not only consider schedule and potential habitat suitability for grunion spawning and occurrence of snowy plover

nesting activity, but also proximity to sensitive resources in the surf zone and/or nearshore. Surf zone discharge may be expected to produce greater turbidity than diked beach placement. Project volume and duration may be important factors to consider with respect to this placement method depending on existing conditions.

6.4.1.4 Hydraulic Discharge on Upper Beach

Hydraulic discharges sometimes are placed high on the beach to allow a more gradual migration of the pumped slurry seaward. This measure also may be used to control turbidity associated with minor changes in sediment characteristics of dredged materials.

Relevant Reports:

- This measure was identified to minimize impacts to Pismo clams during beach nourishment at Surfside-Sunset and West Newport beaches in Orange County, southern California (USACE 1995a).
- Greene (2002) stated that this measure may minimize impacts to sandy beach invertebrates because it allows more time for animals to move away and/or burrow through overburdens.
- Moving the location of hydraulic discharge from the swash zone to upper beach has been used to control turbidity from sand placement of sands during maintenance dredging of Aqua Hedionda Lagoon in Carlsbad, California (B. Dyson, dredge contractor, personal communication 2000).

Consideration of Effectiveness:

This operational control method may be a common practice of experienced dredge contractors; however, limited information is available on the effectiveness of this measure. Beach width may be important consideration. When beach width is limited other measures such as slower discharge volume rates may be more effective for reducing turbidity and/or migration rates associated with hydraulic discharges (Section 6.4.3.3).

6.4.1.5 Limit Intentional Approaches Within 300 ft (91 m) and Use Slow Vessel Speed Around Sensitive Marine Mammals

This measure involves use of a buffer distance and vessel operational controls to minimize direct and/or indirect impacts to marine mammals.

Relevant Reports:

- A buffer distance of 164 ft (50 m) between dredge operations and sea otters was established for maintenance dredging at Moss Landing (USACE 2002c).
- Monitors are required year round to avoid injury from hopper dredges in areas where sea otters occur (http://el.erdc.usace.army.mil/tessp).
- Limiting intentional approaches within 300 ft (91 m) and reducing vessel speed to 4 kn has been specified by some Corps Districts to limit the potential for vessel strikes with marine mammals (Reine et al. 1998).

Consideration of Effectiveness:

Studies indicate sea otters are relatively tolerant of vessel activity (Richardson et al. 1995). However, Bodkin and Rathbun (1988) noted a temporary decrease in sea otters in Morro Bay during maintenance dredging that they thought might have been due to increased human activity. Average noise levels during dredging would be expected to attenuate to 60 dB at distances of 328 to 650 ft (100 to 200 m) depending on dredge equipment.

Seals and sea lions are sensitive to disturbance on land, but are relatively tolerant of vessels while in water (Richardson et al. 1995). Disturbance to pinnipeds is of primary concern at haul-out areas (Section 4.5.2). Therefore, a buffer distance between sediment management activities and haul out and/or rookeries areas may be an effective measure to minimize potential disturbance effects on land. Important considerations for determining an appropriate buffer distance on land includes proximity to human activities and noise. Sea lions rarely react unless a vessel approaches within 328 to 656 ft (100 to 200 m) (Bowles and Stewart 1980). Average noise levels during dredging would be expected to attenuate to 60 dB at distances of 328 to 650 ft (100 to 200 m) depending on dredge equipment. Average noise levels during beach nourishment may be expected to attenuate to near ambient levels within distances of 1,000 to 1,600 ft (328 to 487 m) depending on equipment used and existing noise levels (Section 5.3.3.6). Therefore, the distance over which noise is reduced to ambient may be a more conservative buffer. A buffer restriction is considered unnecessary for pinnipeds while in the water.

Whales may be affected by disturbance associated with noise and approach of vessels, and ship strikes may result in injury particularly at high vessel speed (Section 4.5.3). Whales may display avoidance behavior by changing course from vessel approach within 656 to 984 ft (200 to 300 m) (Richardson et al. 1995). Protection from vessel disturbance has been legislated for whales in areas where high numbers may occur and there is greater likelihood of disturbance. For example, it is unlawful to intentionally approach humpback whales off Alaska and Hawaii within 300 ft (91 m) (FR 2001). This distance also may be relevant to sediment management projects given that underwater noise levels from dredges generally attenuate below Level B harassment levels within 328 to 500 ft (100 to 150 m) (Section 5.3.3.6). A buffer distance of 300 ft (91 m) and slow vessel speed has been specified to reduce potential adverse impacts to whales in some Corps districts, but have not been specified for California districts (Reine et al. 1998).

California gray whales may follow a nearshore migration route within 5.7 mi (9 km) of the mainland; therefore, disturbance is a possibility for sediment management projects involving offshore dredge and/or disposal operations (e.g., Chambers Group 1992, SANDAG and USDN 2000). NOAA whalewatching guidelines to protect California gray whales specify that vessels should do nothing to cause a whale to change direction, maintain a constant vessel speed and not move faster than the whale(s) when paralleling within 300 ft (http://swr.nmfs.noaa.gov/psd/watching.htm). Limiting intentional approach of dredges and/or dump scows within 300 ft (91m) of gray whales and/or maintaining a constant vessel speed that is not faster than movement of whales may be effective for reducing potential disturbance effects during migration if whales are present in the project vicinity.

6.4.2 Schedule and/or Seasonal Restrictions

Schedule and/or seasonal restrictions often are permit requirements to protect sensitive species during dredging and discharge projects throughout the United States (Reine et al. 1998). Regional long-term sediment management plans may specify environmental windows based on site-specific consideration of sensitive species occurrence and use patterns (e.g., LTMS for San Francisco Bay region, USACE et al. 2001).

Reine et al. (1998) reviewed that environmental window restricted periods create logistical challenges and increase costs of sediment management projects. They noted that this is particularly so for waterbodies which support sensitive species with life stage and/or spawning/recruitment periods that cumulatively span most if not the entire year. Compliance with environmental windows based on rigorous technical evidence was not viewed as an issue; however, they noted that conflicts often arise during project coordination because data used to justify certain environmental windows are limited, subjective, or nonexistent. Environmental windows based on fish entrainment and/or migration were specifically questioned because of low observed entrainment rates for all examined fish species, including anadromous fish, and lack of conclusive evidence that turbidity plumes interfere with migration of anadromous adult and juvenile fishes.

The USACE Threatened, Endangered, and Sensitive Species Protection and Management System (http://el.erdc.usace.army.mil/tessp) lists the following environmental window restricted periods for California Corps districts (Table 6.4-2). Environmental windows may vary within a Corps district by life stage, habitat, and/or geographic location within large embayments. For example, several site specific differences in restricted periods are detailed in the San Francisco LTMS (USACE et al. 2001, http://swr.nmfs.noaa.gov/overview/sroffice/2Disposal_windows.html).

Table 6.4-3 lists seasonal periods for California habitats and species reviewed in this document. The seasonal periods generally reference reproductive periods, although for anadromous fish the migratory periods for adults and juveniles are also listed. Superimposed on this table are environmental work window restricted periods from Table 6.4-2. This comparison suggests that restricted periods generally overlap sensitive reproductive and/or migratory periods.

Coastal habitats are productive year-round, but display some seasonal differences in productivity depending on habitat and resources. Spring-summer seasonality is most pronounced for resources that use sandy beach as reproductive habitat (invertebrates, grunion, least tern, snowy plover) (Table 6.4-3).

Table 6.4-2. Environmental window restricted periods specified by the USACE for California sensitive species that have the potential to be affected by sediment management projects associated with beach nourishment.

Species	Los Angeles District	Sacramento District	San Francisco District
Submerged Aquatic Vegetation (SAV)			
Eelgrass	Year round		Year round
Invertebrates			
Dungeness crab			May 1 – Jun 30*
Fish			
California grunion	Mar 15 - Sep 15		
Chinook salmon		Sep 30 – Jun 1	Sep 30 – Jun 1*
Coho salmon			Sep 30 – Jun 1*
Delta smelt		Annual	Jan 1 – Dec 31*
Longfin smelt			Dec 1 – Aug 31*
Pacific herring			Nov 1 – Mar 1*
Sacramento splittail		Jun 1 – Aug 31	Feb 1 – Oct 30*
Steelhead trout	Winter - Spring	Sep 30 – Jun 1	Sep 30 – Jul 31*
Tidewater goby	Apr 1 – May 31		
Recreational finfish			May 1 – Oct 31*
Birds			
California brown pelican			Jul 1 – Sep 30
California clapper rail			Jan 1 – Dec 31*
California least tern	Apr 1 – Sep 15		Mar 15 – Sep7*
Peregrine falcon	May 1 – Jun 30*		
Western snowy plover	Mar 1 – Sep 15		Jan 1 – Dec 31*
Mammals			
Sea otters	Monitors year round		

Note: * Restricted period varies geographically

Lobsters display onshore migration in spring and offshore migration in fall. Winter-spring characterizes spawning periods for many fish species, and several reef fish coincide with kelp occurrence. Several fish species display seasonal onshore movement in summer-fall and offshore in winter. Migratory salmonids have different seasonal spawning runs that help minimize hybridization, and depending on river may include several runs per year (Johnson et al. 1999, CDFG 2001). Most coastal birds that breed in California do so at estuaries and/or the offshore Channel Islands. Coastal areas also provide important stopover and/or overwintering grounds for several migratory bird species. Beaches are primarily used by shorebirds and gulls in summer though early spring and less in May and June. Marine mammals are present year-round.

The topic of environmental windows is reviewed further below for relevant species.

Table 6.4-3. Seasonal recruitment, breeding, and/or spawning periods for representative and high interest California marine resources.

TAXA	J	F	M	A	M	J	J	A	S	O	N	D
Submerged Aquatic Vegetation (SAV)												
Eelgrass (growth)	1	x	x	x	x	x	x	x	x	x	x	31
Surfgrass												
Giant Kelp												
Invertebrates												
Abalone												
California Lobster			i	i	i							
Dungeness Crab	H	H	H	S	1 S	30 S					H	H
Pismo Clam												
Sea Urchin												
Beach Invertebrates												
Subtidal Sand Inverts												
Intertidal Rock Inverts												
Subtidal Reef Inverts												
Fish												
California Grunion			15	x	x	x	x	x	15			
Pacific Herring	x M	x M	1 M				J	J	J	J,M	1 M	x M
Salmonid Migration Chinook	x M,J	x M,J	x M,J	x M,J	x M,J	1 M,J	M,J	M	30 M	x M	X M,J	x M,J
Coho	x M	x M	x J	x J	x J	1			30	x	x M	x M
Steelhead	x M,J	x M,J	x M,J	x M,J	x M,J	x M,J	31 M,J	M,J	30 M,J	x M,J	x M,J	x M
Demersal Fish												
Pelagic Fish						i	i	i	i	i		
Subtidal Reef Fish												
Tidepool Fish												
Birds												
CA Brown Pelican							1	x	30			
CA Least Tern			15	1	x	x	x	x	15			
Western Snowy Plover	x	x	1	x	x	x	x	x	15	x	x	x
Gulls	W	W	W							W	W	W
Terns												
Shorebirds	W	W	M	M			M	M	M	M	W	W
Wading Birds												
Waterfowl	W	W	W							W	W	W
Marine Mammals												
Sea Otters	x	x	x	x	x	x	x	x	x	x	x	x
Pinnipeds												
Cetaceans		M	M	M	M	M					M	M

Sources: Abbott and Hollenberg 1976, Morris et al. 1980, Phillips 1984, Foster and Schiel 1985, Stewart 1989, Cross and Allen 1993, Ware 1993, Williams 1995, Love 1996, CDFG 2001

Notes:

A = adult, J = juvenile; H = eggs hatch, S =larvae settle,

I = inshore distribution, M = migration (only salmonids, shorebirds, and gray whales shown), w = overwinter

Darker Shading represents peak reproductive and/or occurrence period in nearshore coastal zone. Lighter blue shading indicates non-peak reproductive period. Lighter green shading indicates when pelicans congregate in northern California.

Numbers indicate start and end dates of existing environmental window restricted period; x = period between start and end date.

6.4.2.1 Eelgrass

Eelgrass has a year round environmental window restriction in northern and southern California.

Relevant Reports:

- The San Francisco Bay LTMS specifies that resource agency consultation is required year round for eelgrass beds in Central San Francisco Bay, Richardson Bay, South San Francisco Bay, South Central San Francisco Bay, and Waters of Marin (USACE et al. 2001).
- USACE, Los Angeles District and San Francisco District require monitors year round for any dredge type and disposal activities in areas with eelgrass to avoid impacts associated with turbidity, sedimentation, burial and physical removal of plants (http://el.erdc.usace.army.mil/tessp/).

Consideration of Effectiveness:

Eelgrass may exhibit seasonal growth and die-back of blades, but is a highly persistent habitat as a result of buried rhizomes. Eelgrass habitat supports numerous ecological functions and values and is regulated to avoid any net loss (NMFS et al. 2005, Section 3.3.8). A year round environmental window restriction is considered effective for highlighting habitat sensitivity and necessity of resource agency coordination as part of permitting process.

6.4.2.2 Invertebrates

Few seasonal restrictions have been used to minimize impacts to invertebrates.

Dungeness Crab

Relevant Reports:

- Dredging is restricted between May 1 through June 31 for shallows in San Francisco Bay/Delta Estuary and San Pablo Bay to protect against entrainment of early life stages (http://el.erdc.usace.army.mil/tessp/) (Table 6.4-2).

- Dredging has been scheduled during late August to late September in Crescent City Harbor to avoid direct impacts to mating Dungeness crabs (USACE 1998c).

Consideration of Effectiveness:

The use of environmental window restricted periods to protect this species is supported by relevant reports of increased vulnerability to dredge impacts (physical and/or entrainment) in areas where the species may congregate (Section 4.2.3). Most larval settlement occurs between April and June (Wild and Tasto 1983) and mating occurs from February to June (CDFG 2001). Therefore, restrictions from May through June may minimize (not fully avoid) entrainment during larval recruitment and potential physical disturbance of adult crab mating congregations. The environmental window does not address when berried females are more sedentary.

In contrast, other Northwest Pacific UCACE districts have longer duration environmental window restricted periods to protect Dungeness crabs from entrainment and physical disturbance (http://el.erdc.usace.army.mil/tessp/). The prolonged environmental windows cover most of the time period associated with mating, berried females, and larval recruitment.

Differences in level of protection associated with environmental window restrictions among USACE Districts in California, Oregon, and Washington suggest that appropriate application of environmental window restrictions should consider existing conditions in the area of potential effect; e.g., if and at what life stage Dungeness crabs concentrate in the area. Generally, environmental window restrictions have been applied in embayments. Dungeness crabs also may congregate in the nearshore (Section 4.2.3), therefore, this measure may be a relevant consideration for projects involving nearshore dredging and/or disposal depending on existing conditions.

Invertebrate Community

Relevant Reports:

- Avoidance of peak recruitment periods has been suggested to minimize recovery times of sandy beach invertebrate communities (Parr et al. 1978, Reilly and Bellis 1983, Peterson et al. 2000a, Greene 2002).
- Small, opportunistic sand placement projects in San Diego County that are conducted between March 1 and May 31 are required to not exceed 25,000 cy per month, be scheduled no less than two weeks apart, spaced at least 150 ft (46 m) apart, and not involve disturbance of previous placement locations to minimize impacts to invertebrate recruitment; placement is restricted during summer (Moffatt and Nichol 2006b).

Consideration of Effectiveness:

No environmental work window restrictions have been specified for invertebrate communities. The recommendation that impacts may be minimized by project schedule is supported by monitoring studies that have documented rapid invertebrate recovery when projects were completed prior to the onset and/or early in the spring recruitment period (Parr et al. 1978, Gorzelany and Nelson 1987, Versar 2004) or later in the season coinciding with natural seasonal decline with primary recruitment the following spring (Burlas et al. 2001, Versar 2004). Depending on beach type, sandy beach invertebrate populations may be highly seasonal with recruitment and growth over spring and summer and decline over winter, although this is less so for beaches with less sand mobility (Section 4.2.6).

Extent of recovery within the first year after beach nourishment is influenced by project timing. For example, populations have more time to recover when disturbance ends prior to spring recruitment and less time if a project is completed later in the season. This may be an important consideration for beaches that support wintering snowy plovers and/or overwintering populations of shorebirds since invertebrate biomass represents primary prey for those species.

A mitigation to avoid repetitive placement of the same area during the same year and to minimize placement volume during spring and summer is described in Section 6.3.3.1.

6.4.2.3 Fishes

Programmatic EFH Conservation Recommendations for adverse effects of dredging (turbidity and loss of benthic organisms) include time-of-year restrictions; avoidance of SAV and shellfish beds; post-dredging restoration of gravel spawning beds and other provisions in the 1996 NOAA Fisheries National Gravel Extraction Policy (NOAA 2004). Table 6.2-3 lists schedule restrictions to protect fish species.

California Grunion

Relevant Reports:

- RGP 67 normally restricts beach deposition between March 1 and August 31, but specifies that that deposition outside that period may be conducted when the following conditions are satisfied: consultation with CCDFG, approval of a monitoring and reporting program including approved contingency measures, limited to 24 to 72 hours prior to a predicted run (based on grunion calendar produced by CCDFG), and restricted immediately following a documented run (USACE 2006).
- Dredge discharge on the beach may be restricted from March 15 through September 15 by the USACE, Los Angeles District to avoid physical disturbance of spawning (http://el.erdc.usace.army.mil/tessp/) (Table 6.4-2).
- Sand placement restriction from March 30 to September 30 for Surfside-Sunset Beach Nourishment Project (USACE 1995a).
- Sand placement restriction from March 15 and August 15 recommended for BEACON Beach Nourishment Demonstration Project (Chambers Group 1992).
- Sand placement restriction from March 1 to Aug 31 recommended for Bolsa Chica Lowlands Restoration Project (Chambers Group 2000a).
- Sand placement restriction on the beach from May through August and allowance for single-point surf zone discharge in March and April has been specified for several harbor maintenance dredging and beach disposal projects at Oceanside, Santa Barbara, and Ventura (USACE 1994b, 1998a, 1998b, 2000b).
- Sand placement restriction on the beach from May through September with allowance for surf-zone discharge and monitoring in March and April was specified for harbor maintenance and beach disposal at Santa Barbara (USACE 1993).
- Sand placement restricted or allowed with monitoring between March 15 and September 15 was specified as implementation guidlines for the BEACON South Central Coast Beach Enhancement Program (Moffatt & Nichol 2005a).

Consideration of Effectiveness:

Avoidance of the grunion spawning season precludes any potential impacts to spawning activities as a result of beach nourishment activities that disturb the upper intertidal zone. The above-noted relevant reports indicate there has been some variability in specification of environmental window restricted periods; i.e., March 1, 15 or 30 specified for the start and August 15 or 31 or September 1, 15, or 30 for the end of the restricted

period. The spawning season may begin as early as late February or March and extend as late as August or September, with heaviest runs from April through June (Martin 2006). Therefore, any of the above-noted restricted periods would be effective at protecting most of the grunion season and the majority of spawning activity. A standardized environmental window restricted period of March 1 though August 31 is recommended to simplify environmental documentation and consistency among permitted projects; that period coincides with the predicted run schedule posted by the CDFG (http://www.dfg.ca.gov/mrd/gruschd.html).

The effectiveness of this measure is directly associated with whether or not grunion spawn during the period of planned beach nourishment activities. This may be related to time of year, habitat suitability, and/or local variation in grunion behavior. A schedule restriction may be unnecessary at erosive beaches early in the grunion season due to unsuitable habitat, which may be determined with a habitat suitability survey (Section 6.3.3.3). Sand placement during the grunion season with monitoring and coordination with resource agencies is further discussed in Section 6.4.5.4

Pacific Herring

Relevant Reports:

- Dredging may be restricted between November 1 through March 1 by the USACE, San Francisco District to avoid disturbance to spawning, fishing, and roe collecting industries (North Coast) (http://el.erdc.usace.army.mil/tessp/) (Table 6.4-2).
- Dredging may be restricted between December 1 through February 28 by the USACE, San Francisco District to avoid entrainment and interference with spawning activities and habitat in historical spawning areas in San Francisco Bay/Delta Estuary (http://el.erdc.usace.army.mil/tessp/, USACE et al. 2001).

Consideration of Effectiveness:

The above-noted environmental window restricted periods apply to the four commercial fishing areas in the state (Crescent City Harbor, Humboldt Bay, Tomales Bay, and San Francisco Bay). The open fishing seasons for those areas range from December/January through February/March depending on location (http://www.CDFG.ca.gov/mrd/_herring/index.html). For example, 2007 open fishing seasons (start and end dates vary by location) range from December through March (San Francisco Bay), December through February (Tomales Bay), and January through March (Humboldt Bay, Crescent City Harbor). The above-noted relevant reports of dredging restricted periods may be longer (e.g., Humboldt Bay, Crescent City Harbor) or shorter (San Francisco Bay) than the allowed open fishing seasons. Therefore, the environmental window restricted periods may be overly restrictive or not fully effective at minimizing potential interference with fishing and roe collection activities depending on project location and existing conditions.

Pacific herring spawning may occur from late October through April; however, most spawning occurs from December through March and peaks in January–February (Section 4.2.3). Eggs hatch after 10 days and juveniles may remain in estuaries until summer, adults leave shortly after spawning. The environmental window restricted

periods cover most (not all) of the potential spawning season and all of the peak spawning period, and therefore, may be effective at minimizing potential impacts to spawning. The CDFG conducts Pacific herring spawning assessments, which summarize detected spawning events at the regulated embayments (http://www.CDFG.ca.gov/mrd/herring/index.html). The assessments indicate that the dredging schedule restrictions may exceed actual spawning events depending on year and geographic location. Therefore, the environmental window restricted periods may be overly restrictive depending on location and existing conditions. The CDFG maintains a Herring Hotline for San Francisco Bay that provides information on location of herring schools and spawning events (http://www.CDFG.ca.gov/mrd/herring/sf_bay.html). The Hotline may be effective for review of dredging schedules in that embayment in the event of project delays affecting potential construction start and/or end dates.

The environmental window restricted periods may be effective at minimizing potential entrainment impacts during the spawning season. However, young herring remain in estuaries until summer to early fall. Therefore the above-noted environmental window restricted periods may not be fully effective at minimizing potential entrainment impacts, which may have higher risk during the day when herring may congregate near the bottom and less risk at night when herring are near the surface to feed (Section 4.2.3).

LFR (2004) summarized that limited information is available on spatial and temporal distribution of herring larvae and juveniles in San Francisco Bay, and such information could contribute to refinement of environmental windows and enable more effective (i.e., focused) protection of populations. This concern also may apply to other embayments used as nursery areas. Therefore, operational controls to reduce entrainment risk (Section 6.4.3.2) may be appropriate in embayments used as nursery habitat by Pacific herring.

Salmonids

Relevant Reports:

- Dredging may be restricted from September 30 to June 1 by USACE, San Francisco and Sacramento Districts to avoid disturbance of migrating adults and smolts (http://el.erdc.usace.army.mil/tessp/) – Chinook, Coho, steelhead.
- Dredging may be restricted during different time periods (e.g., October 1-May 31, October 15-July 31, November 1-May 15, or December 1-May31) by USACE, San Francisco District based on geographic location to avoid interference with migration, degradation of water quality, direct habitat loss or degradation, interference with foraging or food resources, entrainment (juveniles) ((http://el.erdc.usace.army.mil/tessp/, USACE et al. 2001) – Chinook and/or Steelhead.
- Dredging may be restricted during winter-spring by USACE, Los Angeles District to avoid detrimental impacts on migration (http://el.erdc.usace.army.mil/tessp/) – steelhead.

Consideration of Effectiveness:

LFR (2004) summarized that limited information is available on spatial and temporal distribution of juvenile Chinook and Coho salmon and steelhead in San Francisco Bay,

and such information could contribute to refinement of environmental windows and enable more effective (i.e., focused) protection of populations. This concern also may apply to other embayments with tributary streams used by migrating individuals and/or used as nursery areas.

Generally, entrainment of salmonids is not an issue because dredging occurs below the depth where salmonids migrate (Larson and Moehl 1990, Carlson et al. 2001, NMFS 2002). However, entrainment rates are of concern in constricted waterways, river channels, and/or shallow depths where it may be difficult for juvenile salmonids to avoid the dredge operation (LaSalle et al. 1991, Reine and Clarke 1998). Therefore, environmental window restrictions may be effective for minimizing impacts to migrating salmonids in narrow waterways, shallows, and/or mouths of rivers and/or estuaries where effects of entrainment and/or turbidity may be more pronounced. In open expanses and/or deeper water, operational controls to reduce entrainment and turbidity effects (Sections 6.4.3.2, 6.4.3.3) also may be effective for minimizing impacts to migrating salmonids.

Other Species

Relevant Reports:

- Dredging may be restricted by USACE, Los Angeles District between April 1 and May 31 to avoid physical disturbance of breeding and spawning of tidewater goby (http://el.erdc.usace.army.mil/tessp/).
- Dredging may be restricted by USACE, Sacramento and San Francisco Districts during different time periods (January 1-December 31) depending on geographic area to avoid entrainment, degradation of spawning habitat, and/or direct habitat loss of Sacramento splittail (http://el.erdc.usace.army.mil/tessp/, USACE et al. 2001).
- Dredging may be restricted by USACE, Sacramento and San Francisco Districts during different time periods (January 1-December 31) depending on geographic area to avoid entrainment and degradation of spawning habitat for Delta smelt (http://el.erdc.usace.army.mil/tessp/, USACE et al. 2001).
- Dredging may be restricted by USACE, San Francisco District during different time periods (December 1-August 31) depending on geographic area to avoid entrainment and degradation of spawning habitat for longfin smelt (http://el.erdc.usace.army.mil/tessp/, USACE et al. 2001).
- Disposal is minimized at SF-10 and SF-11 between May and October by USACE, San Francisco District to minimize impacts to recreational finfish (USACE et al. 2001).

Consideration of Effectiveness:

The effectiveness of environmental window restrictions on other sensitive fish species depend on project location and existing conditions (occurrence of species). Similar to salmonids, constricted waterways and/or shallows may be important considerations with respect to the effectiveness of this measure. Tidewater goby may inhabit shallow estuaries and lagoons. Delta smelt may inhabit rivers and sloughs.

An environmental window restricted period applies to disposal at sites in San Francisco Bay (SF-10 and SF-11) to minimize potential interference with recreational fishing. This restriction is based on minimizing interference with other uses rather than a biological criterion.

6.4.2.4 Birds

Appendix Table 6.4-2 lists schedule and prohibition zones used to protect sensitive bird species during beach nourishment. Schedule restrictions have been used to avoid and/or minimize potential impacts to sensitive bird species during sediment management projects. In most cases, the restrictions have coincided with breeding seasons of endangered and/or threatened species. In the case of California brown pelicans, a seasonal period is associated with a buffer distance restriction.

California brown pelican

Relevant Reports:

- Dredging and disposal activities are restricted within 300 ft (274 m) of large communal roosts one hour before sunset to sunrise by USACE, San Francisco District between July 1 and September 30 to avoid disruption of brown pelicans at large roost sites (http://el.erdc.usace.army.mil/tessp, USACE et al. 2001) (Table 6.4-2).
- In southern California, environmental windows specified for least tern (e.g., April through September) generally have been considered protective of brown pelican (e.g., USACE 1995a, 2000b).

Consideration of Effectiveness:

Mainland roost sites are essential to brown pelicans since they must come ashore to dry their plumage. Large communal roosts are considered essential habitat throughout their range (American Trader Trustee Council 2001). The July through September restricted period in northern California is supported by the migratory pattern of the species. Post-breeding pelicans disperse to central and northern California beginning in May, with peak numbers in July through September (Small 1994). Monitoring studies suggest brown pelicans become habituated to repetitive activities, but startle to sudden loud noises and/or spot lighting (Jaques et al. 1996, Varanus 1999). This suggests that a buffer distance should be an effective mitigation measure.

California least tern

Relevant Reports:

- Dredging and disposal activities may be restricted by USACE, San Francisco District from January 1 to December 31 to avoid turbidity effects on foraging activities and degradation of eelgrass beds, which represent important foraging habitat (http://el.erdc.usace.army.mil/tessp/).

- Dredging and disposal activities may be restricted by USACE, Los Angeles District from April 1 to September 15 to avoid impacts on nesting and foraging activities (http://el.erdc.usace.army.mil/tessp/).
- An environmental work window restricted period of April 1 to September 15 has been used for several dredging and/or beach nourishment projects (e.g., USACE 1999b, Batiquitos USACE permit); however, in areas where both least tern and snowy plover occur, one environmental window restriction that covers both species (e.g., March 15 to September 15) has been specified (e.g., USACE 1995a, 1998b, 1999b, 2000b, Chambers Group 2001).

Consideration of Effectiveness:

A fall-winter environmental window (restricted during months of April - September) has been used to avoid disruption of nesting activities of least terns. This measure is effective because of the migratory behavior of least terns, which do not occur in California during the non-breeding season.

Sometimes sediment management activities during the breeding season of least tern have been approved in coordination with resource agencies with implementation of other mitigation measures such as construction monitoring (e.g., MEC 1997). Review of available information suggests that use of a buffer and operational control of turbidity may be effective measures to protect California least tern during sediment management activities (Sections 6.3.6.2, 6.4.3.2, 6.4.4).

Snowy Plover

Relevant Reports:

- Dredging and disposal activities may be restricted by USACE, Los Angeles District from March 1 to September 15 to avoid disruption of nesting activities (http://el.erdc.usace.army.mil/tessp/).
- Dredging and disposal activities may be restricted by USACE, San Francisco District from January 1 to December 31 to avoid degradation of mudflat foraging habitat (http://el.erdc.usace.army.mil/tessp/).
- The environmental work window restricted period has varied among sediment management projects, for example:
    - March 1 to September 15 (USFWS 2000, USACE 2001).
    - March 1 to September 30 (USACE 1995a, 1999a)
    - March 15 to September 15 (USACE 1994a, 1994b, 1998b, 2000, Chambers Group 2001).
    - March 15 to August 15 (Chambers Group 1992).
    - Year round for San Francisco Bay (USACE et al. 2001).
- Protective measures recommended for piping plovers during beach nourishment on the Atlantic coast of the United States include a seasonal restriction of placement activities, pipeline storage, and pipeline removal between April 1 and August 31, unless work will enhance habitat (Melvin 2005).

Consideration of Effectiveness:

Because snowy plovers may occur throughout the year on California beaches, the environmental window restricted period has been used to avoid disruption of nesting activities of snowy plovers. Human disturbance of nesting has been considered a primary contributing factor to the decline of the species (Bruce et al. 1994). Therefore, avoidance of the breeding season in areas where snowy plovers nest is considered effective for minimizing impacts to populations.

Similarly, a seasonal restriction during the breeding season is used to minimize impacts to endangered piping plover on the East Coast of the United States, unless work will enhance habitat. Temporary benefits to snowy plover habitat from beach nourishment also is recognized (SAIC 2006, USFWS 2001).

Sometimes sediment management activities that have extended into the breeding season of snowy plover have been approved in coordination with resource agencies with implementation of other mitigation measures such as surf zone or single-point, diked discharge (Sections 6.4.1.3), construction monitoring (Section 6.4.5.5), and/or additional predator control (USFWS 2000).

(4) Peregrine Falcon

Relevant Reports:

- An environmental window restriction period from May 1 to June 30 is specified by the USACE, Los Angeles District to avoid the sensitive nesting period. (http://el.erdc.usace.army.mil/tessp).
- The May 1 to June 30 environmental window restriction has been applied to sediment management projects at Anaheim Bay Harbor, Los Angeles Harbor, Morro Bay Harbor, Newport Harbor, Port Hueneme Harbor, and Ventura Harbor (http://el.erdc.usace.army.mil/tessp).

Consideration of Effectiveness:

Peregrine falcons may nest on cliff ledges and/or man-made structures (e.g., bridges) in urban areas. They feed on other birds (Hunt 1994); therefore, no impacts to food resources are expected from dredging activities. The primary impact concern is from noise and activity disturbance during their nesting season. This suggests that a buffer distance may be as effective a measure to minimize impacts. The effectiveness of this measure relates to project location and existing conditions, which may be more effectively addressed by use of a buffer distance. Average noise levels would be expected to attenuate to 60 dBA at distances of 328 to 650 ft (100 to 200 m) depending on dredge equipment (Section 5.3.3.6). Therefore, peregrine falcon nesting activities would not be expected to be adversely affected by dredging activities at distances > 650 ft (200 m).

6.4.2.5 Marine Mammals

Relevant Reports:

- The USACE, Los Angeles District specifies that monitors are required year round to avoid injury/mortality to sea otters from collisions (http://el.erdc.usace.army.mil/tessp).

Consideration of Effectiveness:

Available information suggests that sea otters are relatively tolerant of vessel activity, but may avoid heavily used areas (Richardson et al. 1995). A temporary decline in sea otters abundance was observed during maintenance dredging in Morro Bay (Bodkin and Rathbun 1988).

Vessel strikes of sea otters and pinnipeds have been associated with fast moving vessels (Carretta et al. 2004, Harvey 2004). Generally, no effects occur when vessels travel between 4 and 6 kn (Laist et al. 2001). Dredge vessels generally operate at a relatively slow speed while dredging. Risk of collision from support work boats may be minimized by limiting vessel speed in areas near pinniped haul-outs and areas where sea otters congregate. This may be as or more effective than use of monitors.

6.4.3 Construction Equipment and Operational Controls

Several impact minimization measures involve methods associated with construction. These may include selection of certain types of equipment, operational controls, use of best management practices (BMPs), and/or modification of discharge locations. Many of the construction method minimization measures seek to reduce indirect impacts to biological resources associated with turbidity, entrainment, discharges, and/or noise. Examples of types of construction method mitigation measures are given below.

The review of water quality monitoring data in Section 5.5.3 suggests that contractors are effective in controlling the spatial extent of turbidity plumes. However, the specific effectiveness of any particular measure is difficult to evaluate because water quality reporting requirements do not require specification of what control measures were in place at the time monitoring measurements were collected, and few monitoring reports include that information.

6.4.3.1 Dredge Equipment Selection

Dredges vary in operational characteristics, which result in differences in suspended sediment plumes and concentrations (Sections 5.5.2). Generally, turbidity plumes and suspended sediment concentrations range from smallest to largest for the following types of dredge equipment:

- Cutterhead dredge, Hopper dredge without overflow, closed bucket dredge.
- Open clamshell bucket dredge, hopper dredge with overflow.

Dredge equipment has been modified to increase operational performance and/or effectiveness in minimizing environmental impacts. Use of closed buckets to reduce

turbidity and use of larger bucket size to reduce duration of impact exposure are two of the more commonly referenced modifications, which are reviewed below.

Closed bucket dredge

Turbidity is minimized because there is less overflow spillage from closed bucket relative to conventional bucket dredges.

Relevant Reports:

- Turbidity levels up to 79% less than observed with a conventional bucket were reported for the Cable Arm closed bucket when dredging soft sediments (USACE 2001b cited in Anchor Environmental 2003).
- Analyses indicate that closed buckets may generate 30 to 70% less turbidity (Palermo and Pankow 1988 cited in Chambers Group 2001b).
- The effectiveness of a closed bucket may be reduced if air is trapped in the bucket at impact. Collins (1995) reported TSS concentrations of 150 mg/L with a closed bucket and 250 mg/L with a conventional bucket for one project. However, TSS concentrations were 150 mg/L for a closed bucket compared to 55 mg/L for a conventional bucket in another study. Air trapped in the bucket possibly contributed to greater bucket impact in the second study.
- Sediment type may influence effectiveness. Closed buckets have been reported to be ineffective and/or less effective at dredging consolidated material (Anchor 2001, Chambers Group 2001b).

Consideration of Potential Effectiveness:

The above noted report indicates a closed bucket is effective at reducing turbidity. Available reports indicate that turbidity plume extent and TSS concentrations generally are greater with a conventional bucket dredge than with a closed bucket dredge (Section 5.5.3.1).

Bucket Size

Bucket size may influence project schedule as a result of differences in sediment capacity. Bucket size also may influence generated turbidity as a result of differences in weight impacting the bottom.

Relevant Reports:

- Anchor Environmental (2003) reported that larger than normal dredges provide fewer disturbances due to less traffic and fewer dumps.
- Chambers Group (2001b) statistically determined that there was significantly less turbidity generated by a 10-cy bucket compared to a 14-cy bucket during the 1998 Marina del Rey, California maintenance dredging project (Chambers Group 2001). The small bucket released less water as it was raised through the water column. Chambers Group (2001b also considered that environmental impacts may be less in situations where larger buckets can remove more sediment per load than smaller buckets and reduce overall length of project schedule.

- Less sediment resuspension appears to result from small versus large bucket dredges (Collins 1995).

Consideration of Potential Effectiveness:

The effectiveness of bucket size as an impact minimization measure may vary depending on project and site specific environmental conditions. Some situations may favor selection of a small bucket, while others may favor a large bucket. For example, a small bucket may be preferred to reduce sediment resuspension near areas with sensitive resources. Use of a larger dredge may be effective in reducing overall impacts if the construction schedule is substantially shortened (e.g., weeks to days, months to weeks), but would not substantially minimize impacts if the project only realized a small incremental difference in construction duration (e.g., days).

6.4.3.2 Dredging Operational Controls – Entrainment

The following types of measures may be appropriate considerations for reducing entrainment impacts based on the following relevant reports and consideration of behavior of resources of concern:

- Restrict operation of suction pumps when dredge cutterhead and/or draghead are above the sediment surface.
- Use bucket dredge in confined and/or shallow water work areas for limited footprint and duration projects during periods when ecologically sensitive resources are concentrated in consultation and with approval from resource agencies.
- Alter daily dredge cycle (day, night operations) to minimize impacts near ecologically sensitive areas where resources of concern undergo daily vertically migration in the water column.

Relevant Reports:

- Maintain, to the extent possible, the cutterhead or draghead below the substrate surface, and stop pumping if cutterhead or dragarm is raised more than 3 ft (1 m) above substrate (NMFS 2002).
- Restrict use of suction dredges in waters that are < 15 ft (4.6 m) deep during the migratory period of salmonid fry, and restrict activation of suction pumps to when cutterhead or draghead is < 5 ft (1.5 m) from the bottom (Arseneault 1981 cited in LaSalle et al. 1991).
- Use dredge types that are less likely to entrain fish in areas where there is a high risk of entrainment. It may also be possible to moderate inflow velocities of the [suction] dredge, although this would also stretch out the required dredging time (IMG-Golder 2004).
- Studies have shown little correlation between entrainment rates and bottom depth, hopper dredge speed or cutterhead rates of advance, flow-field velocities generated at the draghead or cutterhead, or volume of dredge material (Reine and Clarke 1998).
- Direction of dredging relative to tidal flow, with higher entrainment rate while dredging against ebb tide was reported during one study, but was not duplicated

in three years of follow-up studies (Larson and Patterson 1989 cited in Reine and Clarke 1998).

- Modified dragheads produce similar entrainment rates as conventional dragheads (McGraw et al. 1988 cited in Reine and Clarke 1998).

Consideration of Potential Effectiveness:

Entrainment results when dredge operations remove animals along with water (Section 5.3.2.3). Entrainment concerns mainly are associated with suction dredges when the suction field is still in operation above the sediment surface (LaSalle et al. 1991, Reine and Clarke 1998). For example, a mean entrainment rate of shrimp was 0.69 shrimp/cy when the suction field was at or near the bottom, but reached 3.38 shrimp/cy when the cutterhead or draghead was raised and clean water was pumped to wash out the system (Armstrong et al. 1982 cited in Reine and Clarke 1998). Therefore, a restriction on the depth above the bottom at which the pumps are allowed to operate should be effective for minimizing entrainment effects. Of the above-noted relevant reports, the recommendation by NMFS (2002) is most protective; i.e., maintain the suction dredge below the substrate surface to the extent possible and stop pumping if the suction head is more than 3 ft (1 m) above the sediment surface.

Use of bucket dredges instead of suction dredges in areas where entrainment is more of a concern (e.g., confined waterways, shallows) may be effective for minimizing impacts. Two factors may contribute to reduced entrainment with clamshell dredges: avoidance of low-frequency vibrations produced by lowering the bucket through the water, and increased turbidity when the dredge hits the bottom (Stevens 1981 cited in Reine and Clarke 1998). A bucket dredge often is the dredge of choice in situations where small volumes of material in spatially restricted areas need to be removed (LaSalle et al. 1991). However, a bucket dredge may be less effective for channel maintenance projects requiring removal of large sediment volumes, unless a large capacity bucket dredge is used (LaSalle et al. 1991). The overall benefit of this measure also should be considered in balance with turbidity impacts, which may be higher for mechanical than hydraulic dredges (Section 5.5.3.1).

Limited available information suggests that other operational controls designed primarily to address turbidity issues (e.g., dredge speed or rates of advance, suction velocities, volume of dredge material) do not appear to affect entrainment rates (Reine and Clarke 1998). Insufficient information is available to assess whether entrainment rates may be influenced by tide stage.

Altering the daily dredge cycle (day, night operations) to the time when resources of concern are above the bottom may be another consideration for minimizing entrainment effects. For example, Pacific herring congregate near the bottom or mid-water schools during the day, but migrate towards the surface to feed at night (Section 4.3.2). Therefore, it is possible that conducting dredging at night may minimize entrainment concerns in areas nearby and after major spawning events. Although distribution of juvenile herring may not be well known, there is some evidence that larvae and young juveniles concentrate near their spawning sites and/or in shallows and older juveniles are more dispersed (CDFG 1992 cited in LFR 2004). Therefore, This measure may be more effective within 90 days of major spawning events. The overall benefit of this measure should be considered in balance with potential night-time light attraction and increased predation.

In areas where there is more risk and/or concern for entrainment (e.g., constricted waterways, shallows, adjacent to spawning and/or nursery areas), operational controls may not be fully effective for minimizing impacts. In such situations, environmental window restrictions may be more effective (Section 6.4.3).

6.4.3.3 Dredging Operational Controls – Turbidity

Bucket Dredges

Several factors contribute to sediment resuspension by bucket dredges, including sediment impact, penetration, and withdrawal, and loss of sediment during bucket ascent, removal from the water, and as the bucket is swung to the point of bucket release (Hayes et al. 1988, Collins 1995). Operational controls address each of those steps of bucket operation.

Relevant Reports:

The following operational controls have been reported for bucket dredges (LaSalle et al. 1991, Collins 1995, Chambers Group 2001, Anchor Environmental 2003):

- Slow the cycle time – This measure reduces the velocity of the bucket hitting the bottom and may reduce sediment wash out as the bucket is raised through the water column.
- Eliminate multiple bites – The practice of multiple bites involves repetitive lowering, raising, and reopening the bucket to obtain a fuller sediment load. Eliminating multiple bites reduces the number of times an impact wave of suspended sediment travels along the bottom away from the dredge and reduces sediment loss in the water column associated with reopening the dredge.
- Eliminate bottom stockpiling – Stockpiling of silty dredge material on the bottom increases sediment resuspension; therefore, restricting this practice may reduce suspended sediment concentration.
- Bucket Wash – Rinsing the bucket out at the barge to clean off excess sediment between loads may reduce sediment release in the water column.
- Waterline Pause – Briefly stopping the bucket at the waterline allows excess water to drain before raising the bucket from the water.

Consideration of Effectiveness:

The above-noted measures may be effective at reducing turbidity because they address limiting bottom disturbance, sediment resuspension, and sediment leakage and/or washout of the bucket. Some measures are more applicable to conventional than closed buckets, however, measures applicable to both include slowing the cycle time to reduce physical disturbance of the bottom and washing of the bucket. The applicability of both these methods likely depends on sediment characteristics and hydrodynamics in the project area; being more effective for fine sediments than sands. A potential disadvantage with slowing the cycle time may be an increase in project duration. Slowing the velocity of the bucket may reduce the volume of sediment obtained by the bucket during each bite (Chambers Group 2001, Anchor Environmental 2003).

Cutterhead Dredges

Sediment resuspension from a cutterhead dredge results when the suction does not keep pace with sediment agitation/slurry, resulting in sediment resuspension or release (Collins 1995). The operational controls primarily address slowing sediment slurry production to the speed the suction pump can handle and/or keeping the cutterhead at or near the sediment surface.

Relevant Reports:

The following operational controls have been reported for cutterhead dredges (LaSalle et al. 1991, Collins 1995, Anchor Environmental 2003):

- Reduce cutterhead rotation speed – Reducing the rotation speed reduces the potential for side casting of sediment away from the cutterhead and slows production rate.
- Reduce swing speed of dredge head (ladder) – Reducing the swing speed ensures the dread head does not move through the cut faster than it can hydraulically pump the sediment. Typical swing speeds are 5 to 30 ft/minute (Anchor Environmental 2003).
- Increase pump rates – Increasing the suction rate will tend to reduce the amount of resuspended sediments around the cutterhead.
- Operate cutterhead below sediment surface – Maintaining, to the extent possible, the cutterhead just below the substrate surface minimizes sediment resuspension turbidity associated with partial cutting (some blade exposure) and fully buried cutting (sediment cave-in).
- Eliminate bank undercutting – Removal of sediment in lifts ≤ 80% of cutterhead diameter reduces cave-ins and sloughing.

Consideration of Effectiveness:

Collins (1995) provides a comprehensive review of the factors and effectiveness of most of the above-noted operational controls. That reference is the primary basis for the following summary of effectiveness considerations. The rotation speed of the cutterhead and swing speed of the dredge head are primary factors that influence the amount of sediment resuspension and may be optimized by dredge operators to control turbidity. The direction of the ladder swing relative to cutterhead blade rotation also is important, with greater resuspension when the cutterhead is overcutting (shear velocity higher) than undercutting (shear velocity lower). This generally is more pronounced with cohesive than non-cohesive sediments. Increasing the rate at which the slurry is drawn into the suction pipe may reduce the amount of sediment around the cutterhead.

Maintaining the cutterhead below the sediment surface has been shown to significantly reduce resuspension compared to partial burial (exposure of blades above the mudline allows more opportunity for wash off) and deep burial (results in slouging and cave-in along the dredge path). Maintaining the cutterhead below the sediment surface also reduces entrainment rate (Section 6.4.3.2).

Hopper Dredges

Sediment resuspension from a hopper dredge results when hoppers are intentionally overfilled so excess water runs overboard while greater density is achieved in retained sediment-laden slurry; this practice is used to maximize sediment load. Spillage also may occur while the vessel is underway if hoppers are too full. Operational controls address minimizing intentional overflows and/or unintentional spillage. In addition, a water recirculation system may be used to return overflow waters to the draghead.

Relevant Reports:

The following operational controls have been reported for hopper dredges:

- Eliminate Overflow – Minimizing sediment overflow spillage from the vessel reduces turbidity plumes and suspended sediment concentration (LaSalle et al. 1991, Collins 1995, Anchor Environmental 2003).
- Reduce Fill Level – Lowering the hopper fill level minimizes overflow spillage during rough sea conditions (Anchor Environmental 2003).
- Use a Recirculation System – Recirculation of overflow water to the draghead may increase sediment load in hopper (Anchor Environmental 2003).
- Equip with morning glory spillway – This conveys overflow water subtidally.

Consideration of Effectiveness:

Hopper dredge overflow produces substantially higher (e.g., an order of magnitude) suspended sediment concentrations than the dredging action itself (reviewed in LaSalle et al. 1991, Section 5.5.2.2). This results from the high suspended sediment concentration of slurry waters only having a short retention time in the hoppers (Collins 1995). Therefore, elimination of intentional overflows should be effective for reducing turbidity. A reported disadvantage of this operational control is increased costs and project duration due to less efficient production rates (Anchor Environmental 2003).

Use of a morning glory spillway that conveys overflow water 15 to 20 ft (4.5 to 6 m) below the water surface to reduce surface turbidity was listed as a conservation measure in the biological opinion for the 2001 2001 San Diego Regional Beach Sand Project (USFWS 2000), which was specified as requirement in the 404 permit for that project (USACE No. 1999-15076-RLK). Monitoring showed that depression of water clarity was primarily within 500 ft (152 m) of the dredge (Section 5.5.3.5, Figure 5.5-7) and turbidity plumes complied with permit requirements (i.e., ≤ 1 hectare, 2.47 acres) with few exceptions (AMEC 2002). Therefore, this measure appears to be effective at controlling surface water turbidity.

Other measures such as recirculating overflow water near the draghead and/or discharge of overflow water to mid-depth or deeper water enable more efficient production rates and reduce surface turbidity, which may be effective for meeting water quality Receiving Water Limitations. Those measures may increase suspended sediment concentrations at depth beyond that without overflow, which should be taken into consideration if sensitive habitats (e.g., reefs, SAV, spawning grounds) are in the vicinity.

Limiting the hopper fill level addresses unintentional overflows during rough seas, which may be more or less effective depending on existing conditions

Halt operations

Relevant Reports:

- Anchor Environmental (2003) reported that halting dredging can be an effective measure for reducing turbidity during periods of extreme tidal fluctuation when currents are strongest.
- RGP 67 specifies that if turbidity is greater than one-half mile from discharge site (either upcoast or downcoast) for five (5) consecutive days, the discharge shall be halted or modified to reduce turbidity.

Consideration of Effectiveness:

Halting construction operations may be necessary to stop significant and/or unpermitted adverse impacts, if necessary, until operations can be modified to reduce turbidity to acceptable levels or until environmental conditions moderate. This measure may be effective when implemented infrequently, but may increase project duration and costs if frequent halts to construction are required.

Inspection and Repair of Pipeline Leaks

This measure involves pipeline inspection and repairs to avoid and/or minimize sediment loss from hydraulic pipelines.

Relevant Reports:

- Leaky hydraulic pipeline connections may increase turbidity (LaSalle et al. 1991).
- Leaky hydraulic pipeline connections pose a threat to snowy plover nest sites, if present (Hutchinson et al. 1987).

Consideration of Effectiveness:

Sediment loss from pipeline leaks or breaks has the potential to increase suspended sediment concentrations and/or sediment burial in unwanted locations. This may be of particular concern in areas where pipelines are placed in close proximity to sensitive reef, SAV, and/or coastal strand habitats. Pipeline leaks deposit fine aprons of sand, making the area homogenous and unsuitable for snowy plover's, which require the sand surface to be heterogeneous to camouflage their nests (Hutchinson et al. 1987).

Periodic inspections of above water pipelines should be effective for early problem identification and repairs. This is of particular importance in areas where snowy plovers may be nesting. In areas lacking nesting activity, increased turbidity is the primary concern. Monitoring of the discharge should be effective for detection of a drop in

production rate that may signal a pipe break. Turbidity monitoring may be effective for detection of a substantial change in surf zone or nearshore turbidity characteristics that may signal pipeline leakage.

6.4.4 Construction Methods and BMPs

Best management practices (BMPs) may be implemented during dredging and/or discharge activities to control turbidity and/or other discharges.

6.4.4.1 Use Silt Curtains or Gunderbooms to Minimize Turbidity

Turbidity sometimes is controlled by use of silt curtains, which are flexible, vertical barriers, constructed of permeable or impermeable materials. Francinques and Palermo (2005) reviewed that there are three types of devices that have been used to control turbidity, which sometimes are generically referred to as "silt curtains":

- Silt/turbidity curtain – Impermeable barrier to contain turbidity. Usually deployed from surface to within 1 to 2 ft (0.3 to 0.6 m) of the bottom.
- Silt/turbidity screen – A permeable barrier that allows water flow-through and retains suspended sediment.
- Gunderboom – A turbidity screen modified by addition of adsorbent geotextile material to control oil spills. Usually deployed from surface to bottom.

Francinques and Palermo (2005) reviewed that silt curtains are generally constructed of polyester-reinforced thermoplastic (vinyl) fabric that is maintained in a vertical position by floatation material at the top and a ballast chain along the bottom. The Depending on water depth and type of sediment management activity, silt curtains may or may not extend to the bottom substrate. Silt curtains are designed to control the dispersion of turbidity and facilitate suspended sediment settlement, but do not prevent turbidity outside the area of deployment. When there is hydraulic discharge, a gap between the bottom of the curtain and substrate is maintained to allow escape of fluid mud, which otherwise could accumulate and bury the curtain.

Silt curtains may be deployed in several different configurations (e.g., circular, elliptical, semicircular, U-shaped, maze of two or more curtains) (Francinques and Palermo 2005). Generally, deployment configurations are based on physical, hydrodynamic, and vessel traffic considerations.

Relevant Reports:

- Francinques and Palermo (2005) reviewed that silt curtains are most effective in areas with slow to moderate currents, stable water levels, and relatively shallow depths. The effectiveness of silt curtains is reduced under the following conditions:
    - Strong currents (> 1 to 1 ½ knot are problematic). In high currents, silt curtains may be difficult to maintain and can easily become dysfunctional.

- o Fluctuating tide levels. Anchoring on both sides of the curtain is recommended prevent the curtain from overrunning the anchors and pulling them out when the tide reverses. Extra curtain length (10 to 20 %) and depth (slack) should be included to allow for tidal fluctuations and exchanges of water within the curtain.
- o Water deeper than 10 to 15 ft (3 to 4.5 m). At greater depths, loads or pressures on curtains and mooring systems become excessive and could result in curtain failure.
- o Excessive wave heights (including ship wakes).
- o High winds. Can lift curtains like a sail.
- o Drifting debris and/or ice.

- Anchor Envioronmental (2003) reviewed that silt curtains, if deployed properly, can protect adjacent resources and control surface turbidity, but have no effect on bottom turbidity (where turbidity is highest). They also reviewed that gunderboom advantages included surface to bottom turbidity control and water exchange, but greater expense and potential clogging by silt were considered disadvantages.
- Chambers Group (2001) reviewed that silt curtains can be effective under calm conditions, but they require substantial maintenance, can be difficult to hold together, may become fouled, and storms can dislodge anchors.

Consideration of Effectiveness:

Use of silt curtains appears to be effective at containing turbidity within localized project areas in embayments where current speed and water depth

6.4.4.2 Use Dikes or Swales to Minimize Turbidity

This measure involves construction of temporary sand dikes or swales where hydraulically pumped materials would be discharged to slow the rate of release to the swash zone. This measure is designed to settle sands on the beach and minimize turbidity in the nearshore.

Longitudinal Dikes

Temporary earthen berms (dikes) may be created parallel to shore during beach nourishment to reduce turbidity of return water from hydraulic pumping of sands to the beach.

Relevant Reports:

- This method and/or single-point surf zone discharge has been widely applied to projects to minimize potential impacts to snowy plovers and/or California grunion (USACE 1993, 1994a, 1998a, 1998b, 2000a, 2001), to minimize turbidity effects on least tern foraging (USACE), and/or to minimize turbidity (U.S. Navy 1997a, b).

- This method was used during the 2001 San Diego Regional Beach Sand Project, and apparently was effective since turbidity was largely restricted to the surf zone (AMEC 2002).
- This method also was used during the Surfside-Sunset beach nourishment project; least tern monitoring showed no apparent influence between turbidity plumes and least tern foraging behavior (MEC 1997).

Consideration of Potential Effectiveness:

Limited data indicate diked discharges may be effective in lessening turbidity plume effects outside the surf zone. Data also suggest that resulting turbidity plume characteristics do not result in obvious alteration of least tern foraging behavior; although, catch success rates within and outside plume areas have not been compared.

Swales

Temporary earthern swales may be created during beach nourishment to reduce turbidity associated with pumping sands to the beach.

Relevant Reports:

- This method was employed during the Goleta Beach Nourishment Demonstration Project, and apparently was effective based on turbidity being localized and restricted to the surf zone (Moffatt & Nichol 2003).

Consideration of Potential Effectiveness:

Monitoring information indicates that use of dikes and/or swales are effective in lessening turbidity plume effects outside the surf zone (AMEC 2002, Moffatt & Nichol 2003). Data also suggest that resulting turbidity plume characteristics do not result in obvious alteration of least tern foraging behavior (MEC 1997); although, catch success rates within and outside plume areas have not been compared.

6.4.4.3 Use Dikes to Protect Sensitive Resources

Temporary protective dike

Construction of temporary dikes (berms) sometimes has been identified as a measure to protect sensitive resource areas.

Relevant Reports:

- This measure was identified as a measure to prevent creek blockage, if necessary, at Morro Bay (USACE 2001).
- Protective dikes were identified as a measure to protect grunion spawning areas and/or eggs during beach nourishment, as necessary (Tekmarine and Analytic Planning Service 1990, Chambers 2001c).
- Monitoring during construction with specification of a diked buffer (100 feet up and downcoast of spawning area and 65 feet shoreward of highest high water

mark) if spawning was observed was specified as a mitigation measure for a planned beach nourishment project in San Diego County, California (U.S. Navy 1997a) .

Consideration of Potential Effectiveness:

Temporary dikes may be effective at providing a temporary barrier to block undesired impacts. Use of a dike to prevent creek blockage by discharged material is considered less effective than placement of material sufficient distance away and downcurrent of entrance channels to minimize potential blockage. Furthermore, construction of a temporary sand dike in a creek channel could contribute to shoaling as the dike erodes.

Use of diked discharges during grunion season requires careful design consideration. An important consideration is suitable access for construction equipment to the area to construct and then remove the temporary dikes without disturbing spawning areas. Removal of dikes is necessary to permit egg hatching and to prevent fish stranding during subsequent grunion runs. Placement of a longitudinal dike between the swash line and spring high tide line could strand grunion and is not recommended. Dikes constructed above the high tide line to provide a visible barrier between construction activities and spawning sites may be effective for avoiding impacts.

6.4.4.4 Minimize Potential Hazardous Materials Leaks or Spills

Accidental leaks and/or spills are of concern because of potential impacts to water quality and/or biological resources.

Mitigation Measures:

- All equipment shall be inspected for leaks (especially hydraulic lines, fittings, and cylinders) and the equipment cleaned each day or shift that the equipment is to enter the water. Equipment will be cleaned and repaired (other than emergency repairs) at least 500 ft (152 m) from the high tide line. No equipment with leaks will be allowed on the beach or to operate in waters.
- All contaminated water, sludge, spill residue, or other hazardous compounds will be disposed of at a lawfully authorized designation.
- Use biodegradable, nontoxic, vegetable-based hydraulic oil rather than petroleum-based hydraulic oil when practicable.

Relevant Reports:

- RGP 67 (USACE 2006) specifies that all equipment shall be inspected for leaks immediately prior to start of beach operations and regularly inspected thereafter until project completion, and vehicles with leaks shall not enter the beach area; and equipment shall be cleaned and repaired (other than emergency repairs) at least 500 ft (152 m) from the high tide line, and all contaminated water, sludge, spill residue, or other hazardous compounds will be disposed of at a lawfully authorized designation.

- NMFS (2002) recommended in the biological opinion for Columbia River Federal Navigational Channel Improvements Project that the contractor, where possible, use or propose for use, materials that may be considered environmentally-friendly in that waste from such materials is not regulated as a hazardous waste or is not considered harmful to the environment. If hazardous wastes are generated, disposal of this material shall be done in accordance with 40 CFR parts 260-272 and 49 CFR parts 100-177.
- Vegetable oil or other biodegradable, acceptable hydraulic fluid substitute may be recommended for all equipment entering waters containing sensitive fish species (WSDOT 2006).
- Prior to entering the water, all equipment will be checked for leaks and completely cleaned of any external petroleum products, hydraulic fluid, coolants, and other deleterious materials. Washwater will not be discharged to any water body without pretreatment to state water quality standards (WSDOT 2006).

Consideration of Effectiveness:

Preparation of a SPCCP should be effective for minimizing the potential for adverse impacts from accidental spills or leaks. Daily inspections for leaks and routine cleaning of equipment will prevent pollutants from entering natural water bodies and affecting fish or habitat. Additionally, the use of environmentally-friendly materials may be effective for further minimizing potential impacts from equipment use on the beach and in waters.

6.4.4.4 Reduce Noise Levels Below Sensitive Wildlife Harassment Thresholds

Noise may be of concern near areas with sensitive biological resources such as bird nesting colonies, pinniped rookeries and substantial haul-outs, and migratory routes of sensitive fish and cetaceans (Section 5.3.2.6). Significance thresholds have been established for marine mammals. Significance thresholds of 60 dBA have been established for sensitive bird species in San Diego County (2007), but otherwise have not been formally adopted in the state. Disturbance thresholds for salmonids were recommended by Hastings (2002) and have been generally adopted by the USFWS (WSDOT 2006).

Buffer distances during the design phase may be effective for minimizing potential impacts to known sensitive bird nesting sites (Section 6.3.6.2). Noise mitigation measures may be appropriate during construction to meet effective buffer distance criteria and/or to minimize impacts to mobile sensitive wildlife.

The following noise disturbance thresholds are recognized:

- 60 dBA – Sensitive terrestrial birds, including snowy plover (San Diego County 2007). In areas where this level is exceeded under existing conditions, noise significance is defined relative to exceedance of ambient.
- 70 dBA (airborne), 153 dB_{RMS} (underwater) – Seabird, marbled murrelet (WSDOT 2006).
- 150 dB_{RMS} (re 1 μPa) – Salmonids (WSDOT 2006).
- 120 dB_{RMS} (re 1 μPa) (underwater) 58 dB (airborne) – Cetaceans (Federal Register 2005).

Relevant Reports:

- Helicopters are prohibited for use to place or remove sand delivery pipelines to avoid potential noise impacts to peregrine falcons nesting on Morro Rock, Morro Bay, California during the nesting season (USACE 2001).
- Construction BMPs may include specification that equipment be properly maintained to minimize unsafe and nuisance noise effects (e.g., USACE 2001).
- Final EA on Issuance of an Incidental Harassment Authorization for the Take of marine Mammals During Dredging Operations at Pier 39, San Francisco, California (www.nmfs.noaa.gov/pr/pdfs/permits/pier39_ea.pdf).

Consideration of Potential Effectiveness:

Buffer distances based on attenuation are considered precautionary. Behavior of animals and existing conditions with respect to use patterns are important considerations with respect to avoiding and minimizing harassment. The following distances may be precautionary based on review of available information. However, actual buffers should be based on project-specific equipment and site-conditions.

Average noise levels on land would be expected to attenuate to ≤ 60 dB at distances of 328 to 1,000 ft (100 to 328 m) during dredging operations, depending on dredge equipment, and 1,000 to 1,600 ft (328 to 487 m) during beach nourishment (Section 5.3.2.6).

Average underwater noise levels would be expected to attenuate to 120 dB_{RMS} at distances of 400 to >3,281 ft (150 to >1,000 m) and to 150 dB_{RMS} at approximately 50 to 984 ft ft (300 m) depending on dredge equipment.

Dredge noises would be expected to be less than disturbance thresholds for salmonids at distances > 100 to 1,312 ft (80 to 400 m) for hopper dredges and at closer distances for clamshell and cutterhead dredges (Section 5.3.2.6).

Dredge noises (airborne) would be expected to attenuate to below marine mammal harassment levels at distances of 300 to 1,600 ft (91 to 488 m). Underwater noise levels would be expected to attenuate to 120 dB_{RMS} at distances of 400 to >3,281 ft (150 to >1,000 m), depending on dredge equipment.

6.4.4.5 Minimize Artificial Lighting in Sensitive Wildlife Areas

Artificial lighting may be of concern near areas with sensitive biological resources such as bird nesting colonies, wildlife corridors, and migratory routes (Section 5.3.2.7). Types of measures that may be applied to avoid and/or minimize effects of artificial lighting during construction include:

- Shield and direct lights away from sensitive bird nesting sites.
- Avoid spot lighting and/or sudden changes in illumination of large communal roosts.

- Minimize use of lights in areas of salmon migration.

Relevant Reports:

- The use of downward-directed shields on lights in less sensitive areas was recommended as a mitigation measure to minimize potential night-time lighting impacts to aesthetics for the BEACON Beach Nourishment Demonstration Project (Chambers Group 1992).
- The Biological Opinion for the 2001 San Diego Regional Beach Sand Project specified that all construction lighting at receiver sites shall be shielded and oriented to the ocean away from back beaches in order to ensure no measurable increase in light levels at tern and plover nesting colonies from March 1 to September 15 (USFWS 2000). In addition, monitoring before and at least once per night during night-time construction at receiver sites near nesting colonies was required to ensure no measurable increase in pre-project light levels.

Consideration of Effectiveness:

Artificial lighting may disturb, increase predation rates, and/or mortality rates of a number of wildlife (Section 5.3.2.7). This is of particular concern during spawning runs of sensitive fish species, breeding seasons of sensitive birds, and/or near substantial roosts or rookeries. Several of these resource concerns are seasonal; therefore, the effectiveness of the measures will depend on time of year and proximity to sensitive resource considerations.

Limited studies indicate light attraction and increased predation for several species of salmonids (Section 5.3.2.7). However, Nightengale and Simenstad (2002) reviewed that additional study was warranted because of the limited number of available studies to better understand the extent of night lighting on fish distribution changes.

Artificial lights from vessels or other temporary sources are of concern near least terns and snowy plover nesting sites because of attraction and increased predation by gulls (CCDFG 2003b). Therefore, use of light-shields and directing lighting away from nest site locations should be effective when ambient light levels are not exceeded (USFWS 2000). Proximity of project area to nesting sites and project schedule relative to sensitive bird breeding seasons (Section 6.4.2.4) are important considerations to the applicability of this avoidance measure.

Lights from night-time dredge operations are of concern if operations are conducted near sensitive bird nesting and/or roosting sites. Buffers used to protect sensitive nest sites from noise disturbance also may be effective at minimizing potential lighting impacts.

California brown pelican roosting may be disturbed by a sudden change in night-time lighting conditions. Pelicans displayed brief disturbance to dredge illumination and/or engine start up after long periods of inactivity within 270 ft (80 m) of a breakwater roosting location in Marina del Rey Harbor, but otherwise showed little response (Varanus 1999). Use of downward-directed shields on lights of stationary dredge platforms and/or maintaining a buffer may be effective for minimizing potential artificial lighting impacts.

6.4.5 Construction Monitoring

Two types of monitoring may be conducted during construction: verification of permit compliance, and to ensure no significant impacts to sensitive resources during construction. Types of construction monitoring are listed below. Construction monitoring considerations are reviewed in 7.4.

6.4.5.1 Conduct Sediment Compatibiltiy Inspections and Testing to Ensure Substrate Characteristics Match Permit Requirements

This measure involves conducting regular inspections of substrate quality during sand placement to ensure substrate characteristics match permit requirements.

Relevant Reports:

- Inspection of the beach at the end of construction to determine if undesirable sediment size differences and shell fragment content occur and whether a sand sweeper (or alternative mechanical separation device) should be used to alleviate problem was specified as a mitigation measure in the EIS/EIR for the Imperial Beach Shoreline Protection Project (USACE 2002). This measure also included follow up monitoring at one month intervals, as warranted, until potential impacts are considered less than significant.
- Periodic visual observations and sampling to verify proper quality of source sands is specified in the implementation guidelines for the BEACON South Central Coast Beach Enhancement Program (Moffatt & Nichol 2005a).
- Peterson et al. (2000b) recommended that substrate characteristics by inspected during construction to ensure no substantial change in characteristics than planned. Rehabilitation of substrate after placement was considered impracticable

Consideration of Effectiveness:

Several examples of ecologically “bad” beaches resulting from beach nourishment placement of substrate with substantial shell hash, limestone cobbles, and/or mud on beaches in Florida and North Carolina have been identified (Peterson et al. 2000b, Pilkey and Coburn 2005). Once placed, no action was taken to remedy substrate problems.

Post-project remediation of undesirable substrate surface may result in disturbance to biological resources and be problematic from logistic and/or cost considerations. A program of sand remediation to remedy undesirable substrate surface has the potential to result in disturbance of biological resources that may reduce recovery rates and functional use of habitat.

Based on the above considerations, regular inspection of substrate quality during sand placement to ensure substrate characteristics match permit requirements may be more effective than a post-project inspection.

6.4.5.2 Conduct Water Quality Compliance Monitoring and Modify Activities if Necessary to Meet Turbidity Requirements

This measure includes monitoring and reporting consistent with requirements specified in a WDR or project-specific 401 Water Quality Certification.

Relevant Reports:

- Applicants for federal permits that involve dredge or fill activities in surface waters (including wetlands) are required to obtain certification from the state (401 Certification) verifying that the activity will comply with state water quality standards (ADD WEB).
- Turbidity monitoring for beach nourishment and dredging projects vary among WDRs and Water Quality Certification requirements in California (Section 5.5.2.1).

Consideration of Effectiveness:

Compliance with Basin Plan water quality objectives is effective for protection of ecosystem values and other beneficial uses of marine and estuarine waters where sediment management activities occur.

However, the effectiveness of compliance monitoring may be improved by a more standardized approach to monitoring requirements. The effectiveness of operational controls during project implementation may be improved by use of monitoring methods with increased relevance to biological resource concerns in areas where sediment management projects occur. Addition of more complete documentation of operational controls used during project implementation would increase the usefulness of data to support evaluations and adaptive improvement in operational control strategies.

6.4.5.3 Monitor Inlet Status and Take Action if Necessary to Maintain in Open Condition

Relevant Reports:

- The implementation guidelines for the BEACON South Central Coast Beach Enhancement Program specifies monitoring during, immediately after, and for six months following construction to determine if inlet closure occurs due to sedimentation. If closure is observed, then material will be removed as necessary until the inlet area has stabilized (Moffatt & Nichol 20005a).
- Monitoring and opening inlet if closure occurs was specified as a mitigation measure for the Goleta Beach Nourishment Demonstration Project (Chambers Group 1992).
- Monitoring to determine whether sand was transported into lagoons, and if so the volume and rate of transport, whether sedimentation increased the rate of shoaling, or altered the frequency or duration of lagoon mouth closings was a permit requirement for the 2001 San Diego Regional Beach Sand Project (USACE 1999-15076-RLK). SANDAG committed to provide funding for sediment removal or additional inlet opening in concert with other on-going maintenance efforts at each lagoon.

Consideration of Effectiveness:

Visual observations and beach profiles were used to monitor Goleta Slough was monitored during and after beach nourishment and the project did not close the inlet (Mofatt and Nichol 2005b). Coastal Frontiers (2004) used beach profiles to monitor inlets and shoaling in lagoons after the 2001 San Diego Regional Beach Sand Project. Results indicated response varied among lagoons, with some experiencing no measurable shoaling, minor additional shoaling, or substantial additional shoaling. Monitoring was effective for assessing sand level changes, change in frequency of open inlet status, and change in dredge rate.

Sand movement may vary considerably between years based on climatic and oceanographic variability. If source of sediment is an important consideration with respect to response to inlet closure and/or increased dredge volume, monitoring programs may require additional survey locations and/or use of other methods (e.g., tracers) (Section 7.4.4). Dredging and/or excavation to restore inlet function are demonstrated successful technologies. However, equipment access may be an important consideration to the feasibility of this measure in some areas.

Preparation of an Inlet Monitoring and Response Plan is described in Section 6.3.7.2.

6.4.5.4 Monitor Grunion Spawning and Modify Activities if Necessary to Avoid Impacts

This measure involves monitoring grunion to determine spawning activity and, if observed, to implement measures to avoid impacts to spawned eggs.

Relevant Reports:

- Construction monitoring and implementation of either diked beach or single-point, surf-zone discharge if construction extends into March and April has been specified for several USACE harbor maintenance projects with beach discharge of dredged materials (e.g., USACE 1993, 1994a, 1998a, 2000a, b).
- Construction monitoring and implementation of protective measures, as necessary to protect grunion, was specified as a mitigation measure for the 2001 San Diego Regional Beach Sand Project (SANDAG and USDN 2000).
- Monitoring during construction is specified for the SCOUP project if construction is scheduled during the spawning season and a pre-construction survey determines habitat is potentially suitable for spawning (Moffatt & Nichol 2006).
- RGP 67 specifies monitoring during construction if the project is scheduled between March 1 and August 31 and a pre-construction survey determines habitat is suitable for spawning (USACE 2006).

Consideration of Effectiveness:

Grunion monitoring was conducted during implementation of the 2001 San Diego Regional Beach Sand Project. Construction was redirected away from spawning sites when thousands of fish were observed, but no redirection was considered necessary when a few to a few hundred fish were observed (AMEC 2002). This result suggests a minimization rather than avoidance approach was taken with implementation of the mitigation measure.

The USACE monitored grunion spawning between 1993 and 1997 during March through April dredging at Santa Barbara Harbor and surf zone disposal at a nearby beach. Statistical analysis of the grunion data indicated that March-April dredging and single-point, surf zone disposal did not significantly affect grunion. They noted that all of the dredging and disposal operations occurred early in the spawning season when grunion spawning densities were low. No beach disposal occurred in May and June when a much greater number of grunion spawned. There was no significant difference in egg pod diameter, depth, or location between dredging and non-dredging periods. Ecologically, use of a single-point, surf zone discharge should be effective at avoiding impacts to spawned eggs because the discharge location (swash zone) is below that where spawning occurs (spring high tide zone). The effects of turbidity from surf-zone discharge on grunion spawning have not been tested; however, observations of grunion during monitored surf-zone disposal indicate spawning is not precluded (Section 6. 4.1.3).

The effectiveness of construction monitoring to avoid impacts to grunion spawning requires monitoring during appropriate time periods to detect grunion (Section 7.). In addition, effectiveness depends on the methods used to avoid impact should grunion be observed. The primary measure that will avoid impacts is to redirect construction activities above the high tide line until eggs hatch (i.e., after next spring high tide). A diked buffer (Section 6.4.2.2) between the spring high tide line and construction activities sometimes has been specified to clearly demarcate the avoidance zone. Halting of construction also would be effective, but would not be necessary unless the only work remaining was at and/or below the high tide line.

6.4.5.5 Monitor Sensitive Bird Species and Modify Activities if Necessary to Avoid Impacts

Relevant Reports:

- Surveys to detect nesting and/or snowy plover behavior have been specified if construction schedules extend into the breeding season for maintenance dredging projects involving beach discharge near Channel Islands/Port Hueneme Harbors, Marina del Rey Harbor, Morro Bay, Oceanside Harbor, Santa Barbara Harbor, and Ventura Harbor (USACE 1994a, 1998a, 1998b, 1999a, 1999b, 2000b).
- Surveys of least tern foraging and/or turbidity plumes have been conducted with a few beach nourishment and dredging projects (USDN 1996 cited in USFWS 2000, MEC 1997, AMEC 2002). were observed foraging in turbidity plumes during beach nourishment with diked discharge at Surfside-Sunset Beach (MEC 1997).

Consideration of Effectiveness:

Hutchinson et al. (1987) reported several types of coordination with the contractor and during monitoring of beach placement of dredged materials from Morro Bay to ensure impacts were avoided. Types of coordination activities included restriction of vehicle and foot traffic to a 20-ft (6-m) roadway adjacent to the sand delivery pipeline, creation of a temporary dike to contain runoff from leaky pipeline joints, day-by-day coordination

regarding removal of pipeline segments. There were no reported adverse effects of sediment management operations on snowy plovers.

The USACE (2001) reported that surveys conducted following the 1993, 1995, and 1997 beach placement operations at Morro Bay documented snowy plover nesting. Successful nesting was reported during and after disposal at the Morro Bay sand spit in 1987.

Worden and Smith (2004) observed temporary disruption of foraging and resting snowy plovers during surf zone disposal of maintenance dredge materials from Ventura Harbor to McGrath State Beach. Birds were observed moving to avoid the heavy equipment and trucks driven on the beach during installation, pumping, and/or removal of the dredge pipe.

Chambers Group (2001a) observed snowy plovers foraging in the vicinity of the beach discharge of dredged material from Santa Barbara Harbor (Chambers Group 2001). The plovers did not react adversely to beach nourishment activities, but were flushed by joggers and people with dogs.

Limited available monitoring studies suggest that impacts may minimized when turbidity is controlled. Additional monitoring with respect to least tern foraging behavior, water clarity, and turbidity plumes would enable a more rigorous evaluation of potential impacts under different project conditions.

Based on the above considerations, construction monitoring combined with authority to redirect and/or halt operations may to be effective for protecting snowy plovers during sediment management projects.

6.4.5.6 Monitor Marine Mammals and Modify Activities if Necessary to Avoid Impacts

Relevant Reports:

- Monitoring of sea otters was conducted during dredging at Morro Bay (Bodkin and Rathbun 1988, 1989).
- The USACE, Los Angeles District specifies monitors are to be used during dredging when sea otters are present (http://el.erdc.usace.army.mil/tessp/info.cfm).

Considerations of Effectiveness:

Bodkin and Rathbun (1988, 1989) documented a reduction in the abundance of wintering male sea otters that coincided with a dredge cycle at Morro Bay. A small, resident population, including a pup was reported in subsequent years (USACE 2001). No other monitoring reports during sediment management activities were found from the literature review for California. Monitoring is recommended during offshore dredging on the East and Gulf Coasts (RPI et al. 2001). Monitoring considerations are further discussed in Section 7.4.5.4.

6.5 Post Construction Phase Mitigation Measures

6.5.1 Verify Impact Significance in Areas Where There is a Potential to Impact Sensitive Habitat Resources

Pre- and post-construction monitoring in areas with sensitive resources may be required to verify significance of impacts associated with sediment management projects.

Relevant Reports:

- A final MMRP addressing pre- and post-project monitoring of sensitive habitats (rocky intertidal, nearshore reefs, kelp beds) was required for the 2001 San Diego Regional Beach Sand Project (USACE 1999-15076-RLK, AMEC 2002, 2005).
- A final MMRP was prepared for the Goleta Beach Nourishment Demonstration Project addressing pre- and post-project monitoring of sensitive habitats (eelgrass, surfgrass, kelp beds) (USACE 200200666-JCM, Moffatt & Nichol 2003).
- Pre- and post-project mapping of eelgrass distribution and determination of eelgrass density is required for dredging projects that occur in proximity to this habitat (e.g., USACE permit 200100328-SKB).

C*onsideration of Potential Effectiveness:*

The above-referenced monitoring plans included monitoring methods that addressed habitat reduction and quality issues. Monitoring to verify no loss of sensitive habitat are effective for ensuring that project implementation does not adversely impact ecosystems. Measures that include assessment of habitat quality are effective for ensuring ecosystem functions and values are protected. Monitoring in areas with sensitive resources is considered an effective measure to address uncertainties associated with sedimentation model predictions. For example, the sampling design of the 2001 San Diego Regional Beach Sand Project included stations that were located with respect to distance from receiver sites, within areas of predicted sand transport, and reference areas outside the influence of beach nourishment. Sand transport sedimentation was detected, but results did not suggest significant impacts to sensitive habitats (AMEC 2005).

6.5.2 Compensatory Mitigation

Example Mitigation Measures:

- Revegetate loss of coastal strand habitat.
- Replace eelgrass habitat loss according to Southern California Eelgrass Mitigation Policy.
- Compensate loss of nearshore reef habitat with creation of artificial reefs.
- Compensate for increase in dredge volume and/or frequency in dredging.

Relevant Reports:

- Fund if necessary for increased dredge volume and/or inlet opening of coastal lagoons. Artificial reefs if necessary to compensate for habitat loss (SANDAG and USDN 2000).

A disadvantage of compensatory mitigation is the high cost to replace lost ecosystem functions and values if post-project monitoring reveals significant impacts from project implementation. Mitigation requirements to compensate for losses in eelgrass habitat require mitigation according to the Southern California Eelgrass Mitigation Policy (Section 3.3.8). Mitigation requirements to compensate for significant loss of nearshore reef habitats (and/or kelp beds) may include construction of artificial reefs (e.g., Lindeman and Snyder 1998, Coastal Planning & Engineering 2004a, b).

6.6 Summary of Mitigation Measures

A variety of mitigation measures have been employed to avoid and/or minimize impacts during sediment management projects (Table 6.6-1). The measures span a variety of approaches ranging from project design to implementation restrictions, operational controls and BMPs during construction, and monitoring during and/or after implementation to verify permit compliance and/or the need for additional mitigation. Review of available information presented in previous subsections suggests that the range of mitigation approaches provides sufficient flexibility to address impacts issues likely to arise with most sediment management projects. In some situations more restrictive avoidance measures may be warranted whereas in other situations minimization measures may provide adequate protection of biological resources.

Several questions of interest to the CSMW with respect to mitigation measures relate to their effectiveness, particularly with respect to prohibition zones and seasonal restrictions. The following summary questions of interest to the CSMW are addressed in this section:

- *Has the effectiveness of any of these mitigation measures been demonstrated?*
- *What types of prohibition zones have been permit-required surrounding various sensitive bird nesting and foraging areas?*
- *What are the reported bases for these zones? Have the dimensions been based on scientific data, do they relate to potential foraging ranges or nesting territories, do they reflect measured impact ranges, are they based on professional judgment or uncertainty-based conservatism?*
- *Do typical bird breeding season limitations reflect the actual time that the area is used for breeding and nesting? Can historic lengths of time or areas under limitation be safely revised?*
- *What types of information and process are needed to objectively review and establish appropriate sediment management permit conditions associated with breeding season restrictions?*
- *Can an appropriate level of impact/mitigation measure be recommended for the species/habitat/ecosystem of concern?*

Four types of summaries are provided. Section 6.6.1 addresses the first five of the above-listed questions of the CSMW based on considerations of the effectiveness of mitigation measures that may be used during pre-construction, construction, and post-construction to avoid and/or minimize impacts. Section 6.6.2 presents an approach to facilitate effective project planning and coordination with resource agencies with respect to selection of appropriate mitigation measures to protect EFH and listed sensitive species. Section 6.6.3 provides further summaries of mitigation measures by impact of concern and habitats. The following summaries are not intended to be prescriptive. Selection of mitigation measures should be based on project features and existing conditions. This is considered particularly relevant to project size. For instance, measures appropriate to large projects may be overly restrictive for small projects of short duration.

6.6.1 Considerations of Mitigation Effectiveness

6.6.1.1 Available Information on Effectiveness

The literature review indicates that few reports are available that describe effectiveness of mitigation measures applied during sediment management projects. Notable exceptions are reviews or relevant information on controls for turbidity (e.g., silt curtains, gunderbooms, type of dredge equipment).

Many monitoring reports lack information on project implementation methods, operational controls, and mitigation activities and their effectiveness. This data gap, if filled could improve the usefulness of monitoring data to support adaptive decisions on how to improve mitigation effectiveness. Very few comparisons are available that permit evaluation of percent reduction in impact with respect to mitigation measures.

There may be notes and references to be gleaned from various reports relevant to mitigation effectiveness that perhaps could be compiled to a greater extent than was done for this review, but were outside the scope of this effort. Instead a substantial effort of this report section is associated with the discussions of considerations of effectiveness for the reviewed measures. These discussions are based on considerations of species biology, habitat ecology, physical processes, and mechanisms of potential impact so that the rationale and/or scientific basis of the measure can be examined. This approach was taken to provide some basic background information on mitigation measures to facilitate future application of measures to assist environmental design of projects and protection of resources during their implementation.

It is recommended that monitoring reports include in their introduction an abstract of the project description that includes information on implementation, including project volume, schedule (including hours of construction), equipment, and construction methods. Mitigation measures used during construction should be specified, and any measurements that are made during different operational conditions should be clearly identified. Additional actions taken to further minimize impacts should be described in sufficient detail that they may be repeatable, if successful. A summary of the effectiveness of the mitigation measure in meeting compliance objectives would be helpful.

6.6.1.2 Considerations Relevant to Prohibition Zones

Types of prohibition zones around sensitive bird nesting and foraging areas are reviewed in Section 6.3.6. The rationales have been based on sensitivity to close approach disturbance (California brown pelican, marine mammals), foraging range (California least tern), direct impacts and foraging interference (snowy plover), and harassment disturbance that affects migration, efficient capture of food, and/or reproductive success (marine mammals). With the exception of California least tern, buffer distances have been based on distance considerations associated with noise and proximity of activity-related disturbance.

While that is also true for California least tern, an additional consideration has been protection of the relatively large foraging range (2 mi, 3.2 km) of the species reported by available scientific literature. Least terns are visual foragers on schooling fishes, and may forage in the ocean, embayments, rivers, and lakes near the coast. A concern for turbidity interference with foraging has been addressed by buffer distances ranging from 1 to 2 mi (1.6 to 3.2 km) (Section 4.4.2). No available information was found with the literature review to suggest that buffer areas of this size were based on measured impact ranges.

Reviews presented in this document indicate that turbidity plumes may vary depending on type of project, equipment, sediment characteristics, and hydrodynamics. In addition, construction methods and operational controls during construction may lessen turbidity plumes. Consequently, large-scale buffer distances for least tern may be overly conservative in some circumstances depending on project- and site-specific considerations. There is evidence that least terns prefer to forage near their nesting sites to minimize time away from eggs and chicks. Therefore, buffer distances that minimize turbidity effects in water bodies near nesting areas may be an important consideration along with turbidity and noise controls.

6.6.1.3 Considerations Relevant to Environmental Windows

Although the primary questions of interest to the CSMW relate to the use of environmental windows with respect to birds, seasonal restrictions also have been used to protect other sensitive resources such as eelgrass, fish, and mammals. Seasonal restriction mitigation measures and their effectiveness are reviewed in Section 6.4.2.

Seasonal restrictions for birds primarily relate to breeding and nesting periods, which are scientifically supported by available literature (Section 4.4). There is no scientific basis for revision of critical seasonal reproductive periods. However, many of the impact concerns to sensitive bird breeding areas relate to direct impacts and/or proximity of disturbance issues, which should be avoidable with mitigation measures that address effectively address minimizing disturbance and interference with other critical functions such as foraging success below levels of concern.

Similar considerations apply to seasonal restrictions associated with protection of other sensitive wildlife. Protection of SAV habitats is a year round concern, which is reflected in the language of the environmental window.

The primary advantage of environmental windows is that species protection generally is assured by implementing a project during a period when the resource of concern is absent or less sensitive to impact.

The primary disadvantage is that environmental window restrictions reduce schedule flexibility and contingencies, which may contribute to substantially higher project costs (Reine et al. 1998). In some cases, other measures (e.g., buffer distances, operational controls) may be as effective in minimizing impacts. Sometimes sediment management projects are permitted during a restricted window in coordination with resource agencies, which may require monitoring and/or use of other measures to ensure adequate protection of populations.

The permitting process is effective at providing opportunity for informal coordination with resource agencies to identify and develop mitigation measures, when appropriate, based on project-specific and site-specific considerations. More effective use of this existing process is recommended. Based on review of several permits, it appears that environmental windows often are identified as the primary mitigation measure and other measures are then applied to further minimize potential impacts. The impression is that environmental windows have been used to simplify CEQA/NEPA documentation and streamline environmental review and permitting. This approach may be precautionary in areas where insufficient information is known about site-specific use patterns by sensitive resources. Site-specific data gaps may be addressed by conducting surveys and obtaining necessary information.

Another approach is to address potential impact risk factors for sensitive resources of concern. There are a number of aspects of project design and implementation that may be tailored to address impact issues of concern. Several types of information can be addressed to enable objective review and establishment of appropriate mitigation measures. Foremost are project- and site-specific impact risk factors, associated with the following considerations:

- Impact mechanism.
- Magnitude of impact.
- Exposure duration.
- Habitat suitability to support sensitive species.
- Proximity to sensitive resources.
- Historic use patterns.
- Unique site conditions.

Spatial and temporal scales of impact vary depending on a number of physical factors, including project size, equipment used, substrate characteristics, and hydrodynamics. This document review indicates that many aspects of mechanism, magnitude, and exposure duration associated with impacts can be controlled by distance (buffers), construction methods, and operational controls during construction. There also are examples of construction monitoring being used in combination with mitigation measures to ensure appropriate avoidance and minimization occurs.

Impact duration is an important consideration. The review suggests that most habitats and many coastal species are adapted to disturbance and can tolerate short-term and/or small-scale impacts. Therefore, common sense indicates that small projects that are

completed on the order of days generally should be within tolerance thresholds of habitats and species provided critical impact thresholds are not exceeded.

However, environmental windows may represent the best management choice in areas where avoidance of impact otherwise is not possible. Of particular concern, are protecting reproductive success of sensitive species in areas where buffers or construction methods may not be effective; e.g., avoidance of direct impacts to sensitive nesting, spawning, and/or nursery grounds could not be prevented or impacts would occur in a confined area that may magnify the level of impact above critical thresholds.

6.6.2 EFH and Sensitive Species Coordination and Mitigation Measures

[NEPA and CEQA require pre-decisional evaluation of impacts and mitigation measures. All of the topics discussed in this section, as well as less damaging alternatives to the proposed action, would typically be addressed in the appropriate NEPA or CEQA documentation before there is any other formal permit processing.]

The California Endangered Species Act (CESA) requires that each state lead agency consult with the CDFG to ensure that any action authorized, funded, or carried out by that lead agency is not likely to jeopardize the continued existence of any species that is state listed as endangered, threatened, or rare. CESA consultation is conducted when there is both a State lead agency and an EIR. Otherwise, CESA section 2081 allows DFG to issue an incidental take permit for a State listed threatened or endangered species. Specific criteria for 2081 permits are found at Title 14 CCR, sections 783.4(a) and (b).

Section 7 (a)(2) of the federal ESA requires a federal agency (e.g., USACE), in consultation with the Secretary of the Interior (USFWS) and the Secretary of Commerce (NMFS), to ensure that any action authorized, funded, or carried out by that agency (e.g., issuance of 404 permits) is not likely to jeopardize the continued existence of any listed species. Additionally, the action cannot result in the destruction or adverse modification of the species habitat if that habitat is determined to be critical (by the Secretary after consultation, as appropriate, with affected States), unless the action agency is exempted under Section 7(h) of the ESA. Section 9 prohibits unauthorized take of federally listed threatened or endangered species. Federal action agencies obtain incidental take authorizations via the Section 7 consultation process. Where there is no Federal action, Section 10 provides for incidental take authorization following completion of a Habitat Conservation Plan.

If a proposed federal action may adversely affect a listed species or designated critical habitat, formal consultation is required (except when, through informal consultation, the USFWS and NMFS concur, in writing, that a proposed action “is not likely to adversely affect” listed species or designated critical habitat). A formal consultation concludes with the issuance of a biological opinion and an incidental take statement by either or both USFWS and NMFS, depending on the species affected

There also may be the need to consult with respect to species of special concern identified during the planning stage. Typically, the USFWS will provide a list upon request, of species of concern that could potentially occur in the project area. The list may include species that are listed, that are candidates for listing, or that have been recommended for listing as endangered or threatened by a state or federal agency under the ESAs.

Useful Online References Regarding Federal and State Endangered Species Consultation

http://www.fws.gov/endangered/consultations/s7hndbk/s7hndbk.htm

http://www.dfg.ca.gov/hcpb/ceqacesa/cesa/cesa.shtml

http://www.dfg.ca.gov/legal/879regs.htm

Federal and state resources agencies both recommend informal early coordination to avoid potential impacts to rare, endangered, and threatened species. Advantages of early consultation include appropriate mitigation planning to offset impacts to listed species and their essential habitats and a streamlined consultation process (USFWS and NMFS 1998).

Informal coordination may involve the following recommended steps:

- Request a list of species of concern and current information from the USFWS, as available
- Meet with appropriate resource agencies (depending on federal and/or state status of species) to review project design, current available information on species occurrence, and mitigation measures to avoid and/or minimize impacts to sensitive species. Depending on project complexity, more than one meeting may be necessary.
- If a federal action agency determines that the proposed action "is not likely to adversely affect" listed species or designated critical habitat, a concurrence is obtained, in writing, from resource agencies. The project description cannot change after this concurrence unless the federal action agency reconsiders the "not likely to adversely affect" conclusion.

If a proposed federal action may adversely affect a listed species or designated critical habitat, formal consultation is required under Section 7(b)(2) and (3) of the ESA. The USFWS and/or NMFS will provide to the federal action agency (e.g., USACE) and the applicant, a biological opinion (BO) detailing how the proposed action affects the listed species or designated critical habitat, a summary of the information on which the opinion is based, and reasonable and prudent alternatives that are believed to not violate subsection (a)(2) of the ESA if taken by the federal agency or applicant in implementing the action. A formal consultation concludes with the issuance of a biological opinion and an incidental take statement by either or both USFWS and NMFS. The CDFG may provide concurrence with a federal BO or if not consistent will issue a separate Incidental Take Permit.

The federal Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) requires federal agencies to consult with the NMFS regarding the potential effects of actions on "essential fish habitat" (EFH) and respond in writing to NMFS recommendations. State agency activities which would impact EFH also require NMFS comment.

The following sections summarize types of mitigation measures that appear to be effective and/or have the potential to be effective for avoiding and/or minimizing impacts to biological resources during implementation of sediment management projects. While some measures may have broad applicability in a variety of potential project situations, there may be project- and site-specific factors that should be considered to ensure appropriate application of a mitigation measure. Those considerations are best reviewed during informal resource agency coordination.

The Corps of Engineers administered Clean Water Act Section 404 permit (regulating discharge of dredge or fill material in waters or wetlands of the U.S.) or Rivers and Harbors Act of 1899 Section 10 permit (structures and dredging in navigable waters) process may include a public notice requirement. During the public comment period for such a permit application, the resource agencies may provide comments on the subject project under authority of the Federal Fish and Wildlife Coordination Act and ESA.

6.6.2.1 Essential Fish Habitat

Mitigation measures may include activities both during the pre-construction and construction phases. The measures listed below are described in greater detail in Section 6.3 (Pre-Construction Mitigation Measures) and Section 6.4 (Construction Mitigation Measures).

- Conduct informal consultation with CDFG and NMFS if proposed project area is within essential fish habitat.
- Prepare mitigation, monitoring, and reporting plan (MMRP) if sensitive aquatic resources are within project area. Obtain resource agency approval of plan prior to construction. Submit reports of monitoring results and effectiveness of implemented mitigation measures according to reporting schedule specified in the plan. Sensitive aquatic resources include SAV (eelgrass meadows, kelp forests and/or beds, surfgrass beds), perennial hard bottom, and areas of special biological significance (ASBS).
- Conduct pre-construction survey within 30 days of construction to finalize pipeline and vessel routes and/or anchorage plans, if proposed activities will occur in areas with sensitive aquatic resources. Survey results will be used to select areas that avoid direct impacts to SAV and perennial hard bottom habitats. Any significant direct impacts (i.e., habitat loss or substantial reduction in habitat quality) will require compensatory mitigation.
- Use construction methods and/or schedule to minimize recovery rates of benthic invertebrate forage base.
- Avoid repetitive beach nourishment disturbance in the same location in the same year.
- Use construction methods and/or BMPs to limit turbidity, reduction of water clarity, and elevated suspended solids during beach nourishment and/or dredging to below levels that result in loss of SAV.
- In project areas that may affect SAV, conduct construction monitoring of light transmission, light levels, and/or water clarity to verify that critical thresholds are not exceeded. Measurements within any turbidity plume over SAV habitat should

be within 20% of ambient. If > 20% deviation occurs, the following thresholds may be useful for determining potential for impact and need for additional operational controls or change in activities: In the event that ambient conditions are also below the following thresholds (e.g., storm conditions, red tides), conditions would be considered within natural variability. The following light level thresholds should be verified with the RWQCB and resource agencies before use.

- Kelp forests and/or beds - Near bottom light levels < 10% of surface irradiance for a period > 1 week may affect juvenile growth and should be avoided.
- Surfgrass beds – Near bottom light levels < 40% of surface irradiance for a period > 2 weeks may affect growth and should be avoided.
- Eelgrass meadows – Near bottom light levels < 20% of surface irradiance for a period > two weeks may affect growth and should be avoided.

- Match project size and/or project location to environmental constraints to avoid burial and/or substantial sedimentation of sensitive aquatic resource habitats and/or reduction in habitat quality such as substantial thinning of vegetation, reduced species diversity, and/or loss of shelter functions.
- Any loss or substantial reduction in habitat quality of sensitive aquatic resource areas will require compensatory mitigation according to ratios specified in advance of the project in consultation with resource and regulatory agencies.
- Eelgrass, *Zostera marina*, as a significant marine aquatic resource is subject to a regional mitigation policy produced by NMFS and endorsed by USFWS and DFG.

6.6.2.2 Other Sensitive and/or Managed Fish

Mitigation measures may include activities both during the pre-construction and construction phases. The measures listed below are described in greater detail in Section 6.3 (Pre-Construction Mitigation Measures) and Section 6.4 (Construction Mitigation Measures).

Grunion

- Conduct informal consultation with CDFG and NMFS if proposed project would occur during the spawning season of March 1 through August 31.
- Prepare a MMRP and obtain resource agency approval on plan prior to construction. Submit reports of monitoring results and effectiveness of implemented mitigation measures according to reporting scheduled specified in the plan.
- Conduct pre-construction survey within 30 days of construction to determine habitat suitability for grunion spawning need for additional protective measures, as described below. If construction spans more than one predicted spawning run, conduct habitat suitability survey prior to each predicted run.
- Conduct construction monitoring by a qualified biologist if habitat is determined to be suitable for spawning (see Section 6.3.6.3). The biological monitor will have

authority to halt and/or redirect activities, as necessary to avoid impacts to spawning.

- Restrict placement and/or removal of any sediment delivery pipelines to outside the spawning season if spawning occurs in the project area during construction.
- Minimize interference with grunion spawning by use of construction methods such as single-point diked beach discharge within a confined work zone. The work zone limits will be determined on a project-specific basis in consultation with CDFG and NMFS, considering site-specific factors as beach length and receiver site dimensions.
- Use environmental window restricted period between March 1 and August 31 if mitigation measures will not be sufficient to reduce impacts below a below a level of concern by CDFG and NMFS.

Pacific Herring

- Avoid dredging during spawning runs in and/or near areas where spawning is known to occur or potential attachment sites for eggs occur (e.g., eelgrass, other SAV, shallows, rip rap, piles).

Salmonids

- Avoid interference with migration by ensuring that the project does not result in closure of stream inlets. If closure does occur, immediate action will be taken to mechanically open the inlet.
- Minimize interference with foraging and/or migration by use operational controls and/or BMPs (e.g., silt curtains) to limit turbidity reduction of water clarity during embayment dredging.
- Minimize night-time lighting in areas with active migration.
- Minimize potential entrainment from hydraulic dredging in depths less than 20 ft (6 m), dredge head must be maintained at or below substrate surface. Head may not be raised more than 3 ft (1 m) off the bottom for flushing and the pump will be turned off at the end of dredging when the head is no more than 3 feet off bottom.

6.6.2.3 Sensitive Bird Species

Mitigation measures may include activities both during the pre-construction and construction phases. The measures listed below are described in greater detail in Section 6.3 (Pre-Construction Mitigation Measures) and Section 6.4 (Construction Mitigation Measures).

California Brown Pelican

- Avoid dredging or other sediment management activities within 300 ft (91 m) of large, communal roosts during the time period from one hour before sunset to sunrise.

- In areas where sediment management activities are necessary at night within 300 ft (91 m) of large roosts, minimize disturbance by conducting engine start-ups father away than 300 ft (91 m), use slow speed to avoid sudden approach, and avoid direct lighting of roosts.

California Least Tern

- Informal consultation with CDFG and USFWS if proposed project area is within 1 mi (1.6 km) of least tern nesting sites and would occur during the breeding season of April 1 through September 15.
- Prepare a mitigation, monitoring, and reporting plan (MMRP) and obtain resource agency approval on plan prior to construction. Submit reports of monitoring results and effectiveness of implemented mitigation measures according to reporting schedule specified in the plan.
- Use buffer distance that attenuates noise to ≤ 60 dBA or ambient at active nesting sites to minimize potential noise and disturbance impacts. A distance of 1,000 ft (328 m) from dredging and 1,640 ft (500 m) from beach nourishment activities may be useful for planning purposes based on the assumptions that dredge noises do not exceed 88 dBA and average combined construction noise levels at the beach do not exceed 90 dBA at a distance of 50 ft (15.2 m) from the source. If the average noise level of equipment is more or less than these levels, then the buffer distance should increase or decrease as appropriate to meet attenuation guidelines.
- Minimize beach slope steepness (e.g., 10:1 horizontal: vertical) to enhance spawning habitat.
- Minimize interference with foraging activities by use of construction methods and/or BMPs to limit turbidity reduction of water clarity during beach nourishment and/or offshore borrow site dredging. Water clarity < 3.3 ft (1 m), as measured by Secchi disk, should not affect more than 1 hectare (2.47 acres) outside the surf breaker zone for beach nourishment projects or nearshore area in vicinity of dredge for offshore dredging projects.
- Use construction methods and/or BMPs to limit turbidity reduction of water clarity during embayment dredging. The amount of area that may be affected by water clarity reduction (< 3.2 ft, 1 m) in an embayment as a result of dredging, if any, will be determined on a project-specific basis in consultation with CDFG and USFWS, considering such factors as size of water body, proximity to other foraging locations, and nest site usage patterns.
- Use environmental window restriction between April 1 and September 15 if mitigation measures will not be sufficient to reduce impacts below a level of concern by CDFG and USFWS.

Western Snowy Plover

- Conduct informal consultation with CDFG and USFWS if proposed project area is within critical habitat and/or within 3,281 ft (1 km) of snowy plover nesting sites and would occur during the breeding season of March 1 through September 15.
- Prepare a mitigation, monitoring, and reporting plan and obtain resource agency approval on plan prior to construction. Submit reports of monitoring results and effectiveness of implemented mitigation measures according to reporting schedule specified in the plan.

- Conduct pre-construction survey within 30 days of construction to verify snowy plover occurrence within project area and need for additional protective measures, as described below.
- Use buffer distance that attenuates noise to ≤ 60 dBA or ambient at active nesting sites to minimize potential noise and disturbance impacts. A distance of 1,000 ft (328 m) from dredging and 1,640 ft (500 m) from beach nourishment activities may be useful for planning purposes based on the assumptions that dredge noises do not exceed 88 dBA and average combined construction noise levels at the beach do not exceed 90 dBA at a distance of 50 ft (15.2 m) from the source. If the average noise level of equipment is more or less than these levels, then the buffer distance should increase or decrease as appropriate to meet attenuation guidelines.
- Avoid direct impacts and minimize disturbance to snowy plovers with construction monitoring by a qualified biologist if snowy plovers are present in project area during the breeding season and/or the site supports substantial wintering populations. The biological monitor will have authority to halt and/or redirect activities, as necessary to ensure impacts are minimal.
- Restrict placement and/or removal of any sediment delivery pipelines to outside the breeding season if project area is within 500 ft (152 m) of known nesting sites.
- Minimize interference with snowy plover foraging by use of construction methods such as surf zone or single-point diked beach discharge within a confined work zone. The work zone limits will be will be determined on a project-specific basis in consultation with CDFG and USFWS, considering such factors as beach length, proximity to nesting sites, and/or any features that may represent barriers to movement.
- Shield and orient night-time lighting so that there is no measurable increase in light levels at least tern and/or snowy plover nesting sites during the breeding season.
- Use environmental window restricted period between March 1 and September 15 if mitigation measures will not be sufficient to reduce impacts below a below a level of concern by CDFG and USFWS.

<u>Migratory Birds</u>

Migratory Birds are protected from unauthorized take by the Federal Migratory Bird Treaty Act. Unauthorized take can occur when certain birds nest within a project area. Some examples of migratory birds that may nest in southern California wetland areas include, killdeer, black-necked stilts, American avocets, Forster's terns, Caspian terns, and several species of waterfowl.

- Avoid work during the breeding season, approximately March through August, when project boundaries are close to where breeding birds are present.
- Use buffer distance that attenuates noise to ≤ 60 dBA or ambient at active nesting sites to minimize potential noise and disturbance impacts. A distance of 1,000 ft (328 m) from dredging and 1,640 ft (500 m) from beach nourishment activities may be useful for planning purposes based on the assumptions that dredge noises do not exceed 88 dBA and average combined construction noise

levels at the beach do not exceed 90 dBA at a distance of 50 ft (15.2 m) from the source. If the average noise level of equipment is more or less than these levels, then the buffer distance should increase or decrease as appropriate to meet attenuation guidelines.

6.6.2.4 Marine Mammals

The following mitigation considerations were based on guidance provided by NOAA with respect to vessel distance and noise Level B harassment levels. Sensitivity to disturbance varies among species and existing noise conditions. In addition, NOAA is currently reviewing noise criteria. Therefore, site-specific information and current information from NOAA should be considered before use of the following guidelines.

- Avoid intentional vessel approaches within 300 ft (91 m) of sea otters and whales. Reduce and maintain a constant speed that is not faster than the whale(s) when paralleling within 300 ft (91 m).
- Use construction monitoring by qualified biologist in project areas where sea otters occur. The biological monitor will have authority to halt and/or redirect activities, as necessary to ensure impacts are minimal.
- Use buffer distance that attenuates noise to ≤ 58 dBA or ambient at pinniped rookeries and/or substantial haul outs areas when pups are present to minimize potential noise and disturbance impacts. A distance of 1,640 ft (500 m) from dredging and/or beach nourishment activities may be useful for planning purposes based on the assumptions that dredge noises do not exceed 88 dBA and average combined construction noise levels at the beach do not exceed 90 dBA at a distance of 50 ft (15.2 m) from the source. If the average combined noise level of equipment is more or less than these values, then the buffer distance should increase or decrease as appropriate to meet attenuation guidelines.
- Use buffer distance that attenuates noise to ≤ 60 dBA or ambient at active nesting sites to minimize potential noise and disturbance impacts. A distance of 1,000 ft (328 m) from dredging and 1,640 ft (500 m) from beach nourishment activities may be useful for planning purposes based on the assumptions that dredge noises do not exceed 88 dBA and average combined construction noise levels at the beach do not exceed 90 dBA at a distance of 50 ft (15.2 m) from the source. If the average noise level of equipment is more or less than these levels, then the buffer distance should increase or decrease as appropriate to meet attenuation guidelines.

6.6.3 Mitigation Measures by Sediment Management Activity, Impact of Concern, Habitats, and Species

A variety of mitigation measures may be used to avoid and minimize impacts to biological resources during sediment management activities. Some of the most effective are those that occur in the pre-construction phase, when impact avoidance and design may be incorporated in project design (Table 6.3-1). Construction measures are particularly useful for minimizing impacts during project implementation. The following sections summarize mitigation measures by sediment management activity (Section

6.6.3.1), particular impacts of concern (Section 6.6.3.2), and habitats and species (Section 6.6.3.3).

6.6.3.1 Summary of Measures by Sediment Management Activity

Several mitigation measures may be applicable to different types of sediment management activities depending on type of activity (beach nourishment, dredging) and location of activity (Tables 6.6-1 and 6.6-2). The list of measures is not intended to be prescriptive. Appropriate measures will depend on project- and site-specific considerations. Primary considerations may include project size, location, proximity to sensitive resources, and project schedule.

6.6.3.2 Summary of Measures by Impact of Concern

Specific summaries are listed below that address the following concerns identified in the literature. In addition, measures to minimize contaminant concerns are listed, many of which were identified from WSDOT guidance documentation (2006).

- Measures to minimize recovery rates of benthic invertebrate forage base for secondary consumers such as fishes and shorebirds.
- Measures to minimize maintenance frequency over time.
- Measures to avoid and minimize impacts to EFH and sensitive species.
- Measures to minimize potential for hazards.

Minimize Recovery Rates of Benthic Invertebrate Forage Base

- Minimize difference in grain size characteristics to existing beach unless change represents enhancement.
- Minimize change in surface substrate characteristics of beach and/or dredge areas unless change represents enhancement.
- Minimize shell and coarse substrate content of source sands.
- Conduct sediment compatibility inspections and testing.
- Minimize change in hydrodynamics and/or water quality unless change represents enhancement.
- Avoid repetitive disturbance at same location in same year.
- Avoid peak recruitment and productive time of year.
- Minimize project volume by use of multiple small sites rather than large site.
- Minimize project area by incorporating refuge areas into project design.

Table 6.6-1. Types of pre-construction phase mitigation measures to avoid and minimize impacts by type of sediment management project.

Pre-Construction Mitigation Measures	Beach Nourishment			Dredge	
	Dune	Beach	Nearshore	Off-shore	Bay
Maintain Sediment Compatibility and Quality					
Minimize difference in sediment characteristics unless enhancement is conducted	X	X	X		
Minimize change in surface substrate unless enhancement is conducted	X	X	X	X	X
Environmental Design					
Avoid direct impacts to sensitive habitats	X	X	X	X	X
Match project volume to environmental constraints		X	X	X	
Maintain hydrodynamics unless enhancement is conducted			X	X	X
Avoid steep scarps and slopes		X			X
Environmental Implementation Strategy					
Avoid repetitive disturbance in same year[1]		X	X	X	X
Use multiple small sites instead of one large site[1]		X	X		
Incorporate refuge areas[1]				X	
Reduce Maintenance Frequency Over Time					
Incorporate dune restoration[1]	X				
Use sedimentation basins and source control					X
Habitat Buffers					
Buffer to minimize turbidity impacts		X	X	X	X
Buffer to minimize sedimentation impacts		X	X		
Sensitive Species Buffers					
Buffer to protect fishery spawning grounds		X	X	X	X
Buffer to minimize impacts to sensitive birds	X	X			X
Buffer to minimize impacts to marine mammals		X			X
Environmental Coordination and Notifications					
Prepare hazardous materials management plan	X	X	X	X	X
Prepare inlet monitoring and response plan		X			
Conduct U.S. Coast Guard notification to minimize hazards and interference with other uses		X	X	X	X
Conduct environmental training program	X	X			
Mitigation and Monitoring Program					
Conduct EFH and/or sensitive species coordination, as appropriate	X	X	X	X	X
Finalize mitigation and monitoring plan	X	X	X	X	X
Conduct pre-construction surveys, as appropriate	X	X	X	X	X

Table 6.6-2. Types of construction phase mitigation measures to avoid and minimize impacts by type of sediment management project.

Construction Mitigation Measures	Beach Nourishment			Dredge	
	Dune	Beach	Nearshore	OffShore	Bay
Location Controls					
Avoid use of equipment, pipelines, and construction materials in sensitive habitats	X	X	X	X	X
Avoid anchoring and/or operation of dredges, drill rigs, and/or barges in or above SAV habitats			X	X	X
Surf-zone discharge location		X			
Upper beach discharge location		X			
Limit intentional approaches within 300 ft (91 m) and use slow vessel speed around sensitive marine mammals			X	X	X
Schedule and/or Seasonal Restrictions					
Environmental windows	X	X	X	X	X
Avoid repetitive disturbance in same year[1]	X	X	X	X	X
Avoid peak recruitment and productive period		X			
Dredge Equipment and Operational Controls					
Dredge equipment selection				X	X
Use dredge controls - entrainment				X	X
Use dredge controls - turbidity				X	X
Construction Equipment, Methods, and Best Management Practices (BMPs)					
Use silt curtains or gunderbooms to minimize turbidity					X
Use dikes or swales to minimize turbidity		X			
Use dikes protect sensitive resources		X			
Minimize potential hazardous materials leaks or spills	X	X	X	X	X
Reduce noise levels below sensitive wildlife harassment or disturbance thresholds	X	X			X
Minimize artificial lighting in sensitive wildlife areas	X	X			X
Construction Monitoring					
Sediment compatibility inspections and testing	X	X			
Water quality compliance		X	X	X	X
Inlet status		X			
Sensitive species, as appropriate	X	X			X
Post Construction Monitoring					
Verify impact significance, as appropriate	X	X	X	X	X

Minimize Maintenance Frequency of Impact Over Time

- Minimize frequency of beach nourishment by incorporation of dune restoration, where feasible.
- Minimize maintenance dredge frequency by use of over-dredge depths or advance maintenance dredging.
- Minimize sedimentation inputs from watershed using erosion control BMPs, sedimentation basins, and/or sand retention traps.
- Minimize sedimentation of embayment inlets and channels from beach nourishment by use of placement location downcurrent of inlet, buffer distance, and/or project volume controls.

Avoid and Minimize Impacts to EFH and Sensitive Species
Measures are reviewed in Section 6.6.2.

Minimize Potential for Hazards

- A Transport and Discharge Operations Plan shall include a Spill Prevention, Containment and Countermeasures Plan (SPCCP) that specifies fueling, equipment maintenance procedures to prevent spills and leaks, and containment and cleanup measures to be followed in the event of a spill.
- All equipment shall be inspected for leaks (especially hydraulic lines, fittings, and cylinders) and the equipment cleaned each day or shift that the equipment is to enter the water. Equipment will be cleaned and repaired (other than emergency repairs) at least 500 ft (152 m) from the high tide line. No equipment with leaks will be allowed on the beach or to operate in waters.
- All contaminated water, sludge, spill residue, or other hazardous compounds will be disposed of at a lawfully authorized designation.
- Use biodegradable, nontoxic, vegetable-based hydraulic oil rather than petroleum-based hydraulic oil when practicable.

6.6.3.3 Summary of Mitigation Measures by Habitats and Species

Mitigation measures applicable to coastal habitats and species are listed in Table 6.6-3.

Pre-construction project design is considered the most effective measure to avoid and/or minimize impacts to biological habitats. Important design considerations vary among habitats, as follows:

- Project location is relevant to all habitats, but is particularly important as an avoidance measure for sensitive hard bottom and vegetated habitats.
- Project size (volume) is an important consideration for minimizing impacts to sensitive hard bottom and SAV habitats located within distances that may be influenced by turbidity and/or sedimentation during and after beach nourishment and/or dredging projects.
- Sediment compatibility is relevant to beach nourishment projects and is particularly important for minimizing impacts to sandy habitats (i.e., coastal dune and/or strand, sandy beach, nearshore sands).

- A pre-construction survey to finalize construction plans is effective for avoidance of direct impacts to sensitive habitats in areas where site-specific information is limited or lacking. This measure may be relevant for coastal strand, hard bottom, and SAV habitats. This measure also may be relevant for dredging and/or nearshore placement project areas where sensitive spawning grounds and/or nursery areas of fishery species (e.g., Pismo clam beds, Dungeness crab breeding/brooding areas), have the potential to occur, but site-specific information is lacking.

Applicable mitigation measures during construction depend on habitat type.

- Buffers and/or prohibition zones, which may be verified with construction monitoring (e.g., turbidity, verification of buffers), may be applicable for projects conducted in proximity to sensitive hard bottom and/or vegetated habitats, and/or near entrances of shallow-inlet embayments.
- Construction methods and/or BMPs to control turbidity are applicable to all aquatic habitats. They also are applicable to all dredging projects and most beach nourishment projects (i.e., placement in intertidal and/or nearshore habitats).
- BMPs to control spills and/or leaks from equipment operation are applicable to all habitats and types of sediment management projects.
- Environmental windows, which are the most restrictive of construction mitigation measures, have been applied to protect sensitive or commercially important species rather than habitats, which support ecological functions year-round. Other mitigation measures such as buffers, equipment operational controls, and monitoring also may be protective and should be determined on a case-by-case basis.

Post-construction monitoring and/or compensatory mitigation measures may be relevant for sensitive hard bottom and/or vegetated habitats when there is uncertainty with respect to project impacts.

Table 6.6-3. Types of mitigation measures with demonstrated and/or likely effectiveness to protect biological resources during sediment management activities.

Resource	Pre-Construction				Construction Phase					Post Project	
	Sediment Compatibility	Project Design	Implementation Strategy	Buffers	Location Controls	Environmental Windows	Operational Controls	Construction Methods, BMPs	Construction Monitoring	Impact Verification Monitoring	Compensatory Mitigation
Impact Factor											
Equipment			X	X	X	X	X	X	X	X	X
Turbidity	X	X	X	X	X	X	X	X	X		
Burial	X	X	X	X	X	X	X		X	X	X
Sedimentation	X	X	X		X	X	X	X		X	X
Habitats and Species											
Coastal Dune and/or Strand	X	X	X	X	X		X		X	X	X
Sandy Beach	X	X	X				X	X	X		
Sandy Subtidal	X	X	X				X	X	X		
Rocky Intertidal		X	X	X	X		X	X	X	X	X
Rocky Subtidal		X	X	X	X		X	X	X	X	X
Kelp Forest and/or Bed		X	X	X	X		X	X	X	X	X
Surfgrass Bed		X	X	X	X		X	X	X	X	
Eelgrass Meadow		X	X	X	X	X	X	X	X	X	X
Embayment		X	X	X			X	X	X	X	X
Abalone		X	X	X			X				
California Lobster		X	X	X			X			X	
Dungeness Crab	X		X	X		X	X				
Pismo Clam	X	X	X	X	X		X				
Sea Urchins			X	X			X				
Beach Invertebrates	X		X				X	X			
Subtidal Sand Invertebrates	X		X				X	X			
Intertidal Rock Invertebrates		X	X	X			X			X	X
Subtidal Reef Invertebrates		X	X	X			X			X	X
California Grunion	X	X	X	X	X	X	X	X	X		
Pacific Herring			X	X		X	X	X			
Salmonids			X			X	X				
Demersal Fish	X		X				X				
Pelagic Fish			X				X	X			
Subtidal Reef Fish		X	X	X			X	X			
Tidepool Fish		X	X	X			X	X			
CA Brown Pelican			X	X		X	X	X			
CA Least Tern			X	X		X	X	X	X		
Western Snowy Plover	X	X	X	X	X	X	X	X	X		
Gulls and/or Terns	X		X				X				
Shorebirds	X	X	X				X				
Wading Birds, Waterfowl			X				X				
Sea Otters		X	X	X	X	X	X				
Pinnipeds		X	X	X	X		X				
Cetaceans			X	X	X		X		X		

7.0 REVIEW OF RESOURCE MANAGEMENT AND MONITORING APPROACHES

Section Topics

7.1 Overview of Ecosystem- and Species-Based Resource Management Approaches

7.2 Overview of Monitoring Considerations

7.3 Pre-Construction Phase Monitoring

7.4 Construction Phase Monitoring

7.5 Post-Construction Phase Monitoring

7.6 Summary and Recommendations

A mitigation and monitoring program (MMRP) is required for CEQA/NEPA documents that include mitigation measures to reduce impacts below a level of significance. The MMRP generally is the basis for monitoring requirements specified in project permits. Monitoring requirements also may be specified for projects that qualify for implementation under a regional general permit such as RGP 67, which requires turbidity monitoring for all projects and preparation of an MMRP for sensitive aquatic resources, as appropriate (USACE 2006).

MMRPs and permit monitoring requirements vary among sediment management projects. MMRPs may range from construction monitoring to meet 401 Water Quality Certification and/or WDR requirements to comprehensive, pre- and post-construction monitoring to verify impact significance. Differences in monitoring requirements among projects generally relate to project- and site-specific impact concerns. However, there also appear to be some differences in monitoring requirements that reflect inconsistencies in permit requirements (Section 5.5.2). Monitoring requirements also may vary from ecosystem-based to species-based. The CSMW desires better understanding of these differences in monitoring and resource management approaches. This report section addresses the following questions of interest to the CSMW:

Photo: SANDAG

- *What are the pros and cons associated with ecosystem versus single-species approach for regulating the environment and sediment management activities in general?*
- *What recommendations can be made concerning the most appropriate approach and what steps and information are needed to pursue and implement such an approach, if appropriate?*
- *What is the appropriate level of and type of pre- and post-project sampling needed to evaluate the project for significant changes?*

Section 7.1 provides an overview of differences between ecosystem- and species-based approaches to resource management. Section 7.2 gives an overview of monitoring approaches and considerations. Types of monitoring are reviewed by project phase in Sections 7.3 (Pre-construction), 7.4 (Construction), and 7.5 (Post-Construction).

7.1 Overview of Ecosystem- and Species-Based Resource Management Approaches

During the past three decades there has been a shift in environmental protection policy away from species management toward consideration of the entire ecosystem (Fulton et al. 2003). For example, the ecosystem rather than species management approach is specifically identified as an action in *Protecting Our Ocean: California's Action Strategy* (California Resources Agency and California Environmental Protection Agency 2004). That document states:

> *"A major aspect of ecosystem management is to move beyond case-by-case or species-by-species approaches to management that focuses instead on ecosystem protection needs - often at a regional scale."*

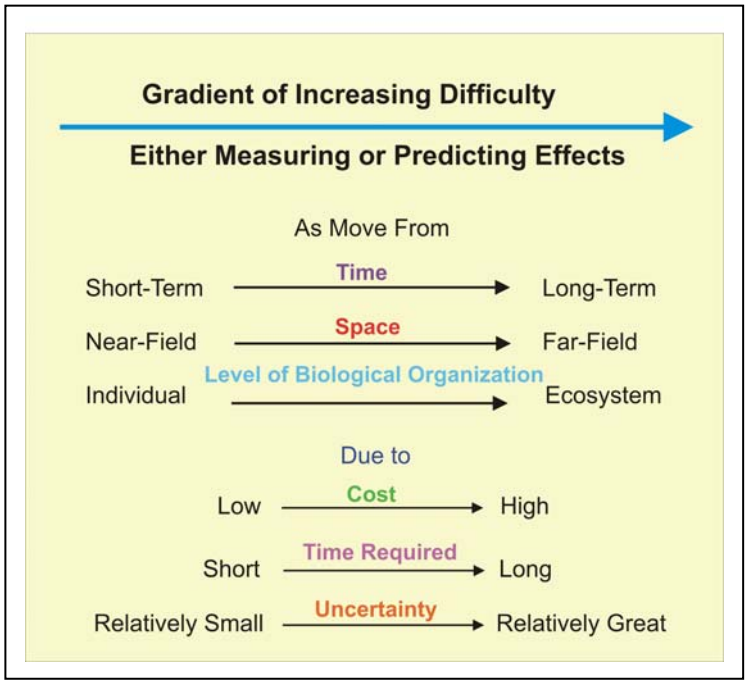
The primary advantage of the ecosystem management approach is the focus on protection of functions and values for all native resources, not just those of special interest due to endangerment status and/or commercial interest. In that sense, the ecosystem-based approach is more proactive in protection of ecosystem health than species-based management that reacts to substantial declines in population trends.

Examples of environmental regulations and policies reflective of the ecosystem-based management approach include:

- Porter-Cologne Water Quality Control Act and Clean Water Act 401 water quality certification requirements to comply with state and federal water quality objectives.
- Magnuson-Stevens Fishery Management and Conservation Act requirements to protect Essential Fish Habitat.
- California State Wetlands Conservation Policy to ensure no overall net loss and a long-term net gain in wetlands acreage.
- Southern California Eelgrass Mitigation Policy to ensure no overall loss of eelgrass habitat.
- Marine Mammal Protection Act, which was the first legislation that called for a need for an ecosystem-based approach to resource management.
- Migratory Bird Treaty Act, which protects most breeding birds in the U.S.
- Marine Life Protection Act (MLPA), which provides CDFG with authority to develop a Marine Life Protection Program, including a Master Plan for a network of Marine Protected Areas for California.

The ecosystem-based management approach is implicit in regional Multiple Species Conservation Plans that aim to preserve large blocks of healthy natural habitat for multiple species rather than to focus on saving individual species in a vacuum (Atkinson et al. 2004). Similarly, the ecosystem-based management approach is the basis for models such as HGM (hydrogeomorphic analysis) that focus on wetland function rather than on preserving habitat for specific species (Brinson 1993).

The advantage of the ecosystem-based management approach is that it simplifies management decisions by focusing on protection of native habitats and associated functions and qualities. By maintaining a healthy ecosystem, all species in the ecosystem, not just special interest species, will benefit. An advantage of ecosystem-based monitoring is that physical habitat boundaries are relatively easy to document. However, evaluation of impacts beyond loss (i.e., functions and quality) requires a more complex monitoring approach because many attributes of the ecosystem may need to be measured to determine whether it is functioning properly. Generally, it is easier to inventory habitats than to measure and/or predict impacts to ecosystem functions (Atkinson 1985).



Source: Modified after Christensen et al. 1976 as cited in Atkinson 1985

Monitoring to verify significance of impacts to sensitive habitats generally requires before-after assessments at impact and unaffected reference areas to distinguish project-related impacts from natural environmental variability (Section 7.2.2). Ecosystem-based monitoring can be expensive and challenging due the number of monitoring variables. This is particularly so for aquatic environments where sampling may require use of boats, divers, sophisticated sampling equipment, and/or laboratory analyses of collected samples. Therefore, a primary disadvantage of ecosystem-based monitoring is that it will likely be more costly than single-species monitoring. One strategy to minimize monitoring costs is to assess indicators and/or indicator species (Section 7.2.2.4).

Ecosystem-based management may be insufficient to ensure avoidance of direct impacts to federal- and/or state-listed sensitive species. The species-based management approach generally is focused on protection of sensitive, commercially important, and/or other special interest species. Examples of environmental regulations and policies reflective of the species-based management approach include:

- Federal Endangered Species Act, which protects federal-listed endangered and threatened species and candidate and proposed species for listing.

- California Endangered Species Act, which protects state-listed endangered and threatened species and candidate and proposed species for listing.

Fishery management plans (e.g., Groundfish Management Plan, Nearshore Fishery Management Plan) also are examples of the species-based management approach. The CDFG states that research will move marine management from a species-based focus to ecosystem-based, and will move the fishery management from a precautionary estimate of allowable catch to a scientific understanding of fishery facilitation (http://www.dfg.ca.gov/mrd/nfmp/index.html).

Management examples using a species-based approach include incidental take permits, time area closures, gear restrictions and/or other species-based limitations. Monitoring under the species-based management approach consists of direct assessment of individuals of a particular species.

This may be necessary to verify that impacts do not affect ESA species and/or managed species populations. Another example of species-based management is the use of indicator species as a metric of environmental heath. An advantage of the species-based approach is that it is relatively straightforward and cost-efficient to monitor individual species. A disadvantage is that information may provide limited understanding of broader environmental impacts. A concern is that individual species may fail to detect relevant impacts until threshold levels are exceeded, thereby, precluding potential early management intervention to protect broader ecosystem values. The primary issue with a species-based management approach is appropriate selection of species to meet management objectives.

Both ecosystem-based and species-based monitoring programs have been applied to sediment management projects. The ecosystem-based monitoring approach is habitat-based and focuses on verification that habitat quality and/or boundaries are not significantly altered by project implementation.

Water quality monitoring is routinely conducted to ensure compliance with regional Basin Plan water quality objectives. Compliance with these objectives is designed to protect beneficial uses of waters, including ecosystem functions for fish and wildlife habitat.

Analysis of benthic invertebrate community recovery rates has been routinely used as an indicator of ecosystem recovery after beach nourishment and/or dredging (Sections 4.2.6 and 4.2.7). Sometimes dominant invertebrates are used as indicators of recovery (e.g., Peterson et al. 2000a). Because invertebrates provide trophic support to fish and birds, they are a useful indicator of broader ecosystem support. Peterson and Bishop (2005) noted that of the 46 studies they assessed, 78% were of macroinvertebrates, 33% included fish, and only 4% were of shorebirds.

Habitat boundaries have been used to assess whether sediment management activities remove, bury, or damage sensitive coastal strand, eelgrass, or surfgrass habitats (Sections 3.3.1, 3.3.7, and 3.3.8). Habitat boundaries and use of indicators generally are used to assess impacts on sensitive reef and/or kelp forest habitats (Sections 3.3.4, 3.3.5, and 3.3.6).

The species-based monitoring approach has primarily focused on sensitive species protection issues. This may include pre-construction habitat suitability surveys to determine potential for species occurrence and need for additional protective measures during construction. Construction monitoring is conducted to ensure activities do not directly harm or indirectly harass sensitive species or damage critical habitat.

The selection of an ecosystem-based or species-based monitoring approach or a combination of the two approaches may best be determined on a project-specific basis depending on a number of considerations, including the nature of the sediment management activity, project size, schedule, and proximity to sensitive species. These and other considerations important to selection of appropriate types of monitoring are reviewed in the following Section 7.2.

7.2 Overview of Monitoring Considerations

The NRC (1995) defined monitoring for beach nourishment projects, as:

> *"The systematic collection of physical, environmental, and economic time-series data or a combination of these data in order to make decisions regarding the need for or operation of the project or to evaluate the project's performance."*

The types of monitoring were distinguished, as follows:

- *Physical monitoring* - to quantify the physical processes that comprise sources, sinks, and sand volume changes in the project area. This may include previous history of the site, beach profiles, waves, currents, water levels, structures, sediment characteristics, and photographic documentation.
- *Environmental monitoring* - to document a project's effects on biota, to determine whether any short- or long-term changes have occurred, and to ensure protection of sensitive resources.
- *Economic monitoring* – to evaluate the economic impacts of a project to determine whether a project's economic justification was valid (e.g., were economic benefits realized, where construction costs correct, were hidden costs incurred).

Therefore, monitoring addresses two primary purposes:

- *Operational* – to determine the need for remedial action (e.g., maintenance, repairs, renourishment). In addition, monitoring conducted during construction to support decisions of whether remedial actions are necessary to comply with permit conditions may be considered operational.
- *Performance* – to develop information and procedures for design verification and to document lessons learned that may be applied to future projects.

The following subsections address monitoring considerations for environmental monitoring relevant to biological resources.

7.2.1 Monitoring Program Elements

Monitoring is needed to answer a variety of management questions throughout all phases of project planning, implementation, and post-project evaluation. The analysis of data from an effective monitoring program should provide feedback to the design process (NRC 1995). In addition, monitoring should address management questions and support performance evaluations that may be applied to future projects.

Several types of management questions are relevant to biological resource protection and monitoring (Table 7.2-1). These may cover a range of project performance and impact concerns, application of lessons learned from monitoring to future projects, and appropriate management of multiple uses to avoid cumulative impacts.

Table 7.2-1. Example management questions relevant to biological resource protection and monitoring.

Environmental Performance Questions

- What are changes in beach width, sand level, and slope over time at the receiver site. How does that compare with distance downcurrent?
- Did the project result in persistent non-compliant water quality? If so, how long?
- Did beach nourishment result in an increase in shoaling and dredge frequency of downcurrent inlets and/or entrance channels of embayments (bays, creeks, lagoons, rivers, sloughs)? If so, how does that relate to sediment volume and proximity of receiver site to inlet.
- Did unacceptable environmental impacts occur? How can they be avoided in the future?
    - Did sensitive habitat loss and/or degradation occur?
    - Did any sensitive species and/or critical habitat experience unacceptable environmental impacts?
- Did the project require compensatory mitigation to replace loss of sensitive habitat? Was mitigation judged successful by resource agencies? Was mitigation cost-effective?
- How frequent will renourishment be necessary to maintain shoreline protection and persistent sandy beach habitat?
- Did renourishment result in exceedance of impact thresholds for sensitive habitats? How should future renourishment procedures or volumes be modified to avoid significant impacts and mitigation?
- Is dune restoration effective for reducing renourishment schedules?
- Have commercial fishing activities and/or catches in the project vicinity substantially changed?
- How frequent should the same borrow site be used? When should alternate borrow sites be sought?
- When should structures be included as part of a project to increase the time between periodic renourishments?

Source: Inspired by NRC 1995.

Ewing (1997) developed procedural guidance for monitoring shoreline protection and beach nourishment projects that is considered broadly applicable to environmental monitoring programs for sediment management projects. The guidance identifies that an effective monitoring program "*is a way to answer questions about project effectiveness and to identify project strengths and weaknesses"* and includes the following major components:

- Objectives – *Why* the monitoring is being proposed.
- Features to be monitored – *What* will be monitored.
- Monitoring methods – *Who* will perform the monitoring, *Where* will monitoring occur, and *How* will monitoring be conducted.
- Monitoring schedule – *When* will monitoring be conducted.
- Monitoring reports – *So What* documentation of program elements, analyses of results, conclusions, and/or recommendations with respect to maintenance and/or performance criteria, if appropriate.

Each of the components is briefly reviewed below in the context of monitoring questions relevant to biological resource protection.

Why – The questions to be answered by the monitoring should be clearly stated. Questions may span a range of information requirements specific to the project and/or to provide information to support regional management decisions. The goal and/or objectives of the monitoring should be explicitly stated. Peterson and Bishop (2005) state that monitoring of beach nourishment should have two goals: first, to answer questions regarding environmental impacts, and second to quantify injury to allow compensatory mitigation.

What – What will be monitored may vary with project phase and biological issues of concern. Generally, pre-construction monitoring answers questions with respect to sediment characteristics and disposal options (including beach nourishment), biological resource constraints, and/or collection of data to support post-construction evaluations of impact significance. Construction monitoring usually is focused on documentation of water quality and/or other permit compliance, answering questions regarding need for additional operational controls to achieve compliance, and/or sensitive species protection. Post-construction monitoring generally addresses project performance and/or significance of impacts.

Who – Monitoring may be conducted by a variety of professionals, municipal staff, and volunteers (Ewing 1997). The monitoring technical requirements are the primary consideration with respect to who performs biological monitoring.

Where – Monitoring locations will depend on the questions being addressed. The primary consideration is the area of potential effect. Specific questions may examine near- and far-field differences, spatial extent of effect, and sensitive resource areas of concern.

How – Methods of monitoring will vary depending on how the information will be used; e.g., support decisions made with respect to operational controls during construction, verify compliance with permit requirements, and/or support environmental evaluations and impact assessments. Generally, visual observations and/or simple measurements are taken to address operational issues and/or compliance. Impact assessments require more rigorous sampling designs that permit comparison of pre- and post-construction monitoring at

appropriate temporal and/or spatial scales with respect to project-specific factors and resource of concern.

The most important consideration with respect to how monitoring will be conducted relates to the questions of concern. For example, if turbidity impacts are of concern, the method of monitoring may vary depending on the type of biological resources at risk; e.g., water clarity is relevant to visual foragers; light transmission is relevant to SAV habitats; and suspended solids is relevant to all aquatic life, particularly filter-feeders, suspension-feeders, and planktivores.

When – Monitoring may occur during all three project phases; e.g., before, during, and after construction. In addition, monitoring elements may vary depending on when a project is scheduled. For example, grunion monitoring is only necessary if the project is scheduled during the spawning season and habitat is suitable for spawning, but would be unnecessary if scheduled outside the spawning season (e.g., USACE 2006).

7.2.2 Scale and Duration of Monitoring

The scope of monitoring for beach nourishment projects generally relates to project size and potential for significant impacts (NRC 1995). Generally, the level of monitoring should reflect, to an extent, the expected effects and the uncertainty in the significance of these effects, fitting somewhere between the following extremes identified by the Ewing (1997):

> *If the effects will be slight, there may be no justification for monitoring, regardless of the uncertainty about whether an effect will occur. Likewise if there is high uncertainty about an effect, monitoring may not provide any gain and it may be preferable to consider mitigation or project denial.*

The NRC (1995) concluded that a more comprehensive monitoring program is warranted for large projects and projects conducted in areas with sensitive resources. In project areas with sandy substrates, small projects may only require receiving water quality and/or turbidity monitoring to comply with 401 water quality certification requirements if the project is implemented at a location or time period without sensitive species concerns (Table 7.2-2, Appendix D.). This also has been the case for mid- to large size projects (USACE 1995a, USACE 2000a, Merkel and Associates 2005).

Additional monitoring of mid- to large-sized projects in sandy substrate project areas generally have addressed specific impact concerns, such as benthic recovery rates (e.g., Parr et al. 1978, Reish 1982, Chambers Group 1992, SAIC and MEC 1996), fish community differences (e.g., Chambers Group 1994, SAIC and MEC 1996), and/or disturbance of sensitive species (see below).

This also is true for monitoring conducted elsewhere in the United States, where the focus has primarily been benthic recovery rates (e.g., Soloman et al. 1982, Reilly and Bellis 1983, Van Dolah et al. 1984, 1994, Johnson and Nelson 1985, Gorzelany and Nelson 1987, Peterson et al. 2000a, Posey and Alphin 2001, Rakocinski et al. 2001, Jutte et al. 2002) and occasionally benthic recovery and fish response (e.g., Burlas et al. 2001, Versar 2004), bird behavior and resting (CZR 2003), or other species concerns (e.g., turtle nesting, horseshoe crabs) (Greene 2002).

Table 7.2-2. Example monitoring elements for representative sediment management projects.

Project	Volume (cy)	Duration (Years)	Monitoring Elements
Projects Conducted Within and Near Sandy Substrate Habitats			
Moss Landing Harbor Maintenance Dredging, California (USACE 2002c)	20,227	Construction	Water (turbidity, receiving water limitations)
Santa Barbara Harbor Maintenance Dredging with Beach Discharge, California (USACE 1998a)	350,000 up to 600,000	Construction	Water (bacteria, turbidity, receiving water limitations), Biology (grunion, snowy plover)
Imperial Beach Nourishment Project, California (Parr et al. 1978)	1,000,620	15 months (up to 5 months after)	Physical (sediment grain size, total organic carbon, beach profiles, temperature), Biology (Intertidal and subtidal benthic invertebrates)
San Diego Harbor Deepening with nearshore discharge at Imperial Beach (Merkel & Associates 2005)	1,700,000	Construction	Water (Turbidity, receiving water limitations effluent Limitations)
Bogue Banks, North Carolina (Reilly and Bellis 1983)	1,180,000	20 months (2 months after)	Water (TSS), Physical (sediment grain size), Biology (intertidal and subtidal invertebrates)
Bald Head Island, Caswell, Oak Island, Holden Beach, North Carolina (Versar 2004)	5,600,000	14 months (1 year after)	Biology (intertidal and subtidal benthic invertebrates)*
Asbury Park to Manasquan Beach Erosion Control Project, New Jersey (Burlas et al. 2001)	8,083,440	6 years (7 & 13 months after)	Water (turbidity, TSS), Physical (sediment grain size, total organic carbon), Biology (sandy beach, nearshore, and borrow site invertebrates, surf-zone and borrow site fish, ichthyoplankton)
Perdido Key, Florida (Rakocinski et al. 1996)	9,260,000	3 years (1 year after)	Biology (intertidal and subtidal invertebrates)*
Projects Conducted Within Sandy Habitat and Hard Substrate and/or SAV Nearby			
Goleta Beach Nourishment Demonstration Project, California (Moffatt & Nichol 2003, 2005)	79,000 in 2003, 18,600 in 2004	2 years (before, during, and up to 2 years after)	Water (Turbidity), Physical (beach profiles, inlet status), Biology (rocky intertidal, eelgrass, kelp)
San Diego Regional Beach Sand Project, California (Coastal Frontiers 2004, AMEC 2005)	2,104,000 receiver sites 101,000 to 421,000	5 years (before, during, and 4 years after)	Water (turbidity, receiving limitations, bacteria), Physical (beach profiles), Biology (grunion, snowy plover, seabird foraging, rocky intertidal, nearshore reefs, kelp beds)
Anna Maria Island Beach Nourishment Project Manatee County, Florida (Coastal Planning & Engineering 2004)	2,320,000	3 years (before and 2 years after)	Physical (sedimentation) Biology (nearshore reefs)*

* Note: construction monitoring requirements were not reviewed.

In areas and/or seasonal periods when sensitive resources occur, additional monitoring has been conducted. For example, California projects with beach discharge during the grunion spawning season and/or in areas where snowy plovers nest have included monitoring prior to and during construction (e.g., Hutchinson et al. 1987, MEC 1997, USACE 1998a, Chambers Group 2001, AMEC 2002, Worden and Smith 2004). Dredging and/or beach nourishment projects permitted in areas near least tern nesting sites during the breeding season have been monitored (e.g., MEC 1997, USDN cited in USFWS 2000, AMEC 2002). Monitoring also has been required in project areas where sea otters occur (Bodkin and Rathbun 1988).

Pre- and post-project monitoring may be conducted to verify impact significance in areas of sensitive habitats. For example, sensitive rocky and SAV habitats were monitored to verify impact significance of the relatively small, 97,000 cy, Goleta Beach Nourishment Demonstration Project (Moffatt & Nichol 2003). Similarly, pre- and post-project monitoring of sensitive rocky and SAV habitats were required for the larger, 2001 San Diego Regional Beach Sand Project, which placed volumes ranged from 101,000 to 225,000 cy at receiver sites where sensitive rocky and SAV habitats were downcurrent and/or offshore (AMEC 2005). Pre- and post-project monitoring also has been conducted in areas with nearshore reefs in other areas of the United States (e.g., Courtenay et al. 1972, Lindeman and Snyder 1999, Coastal Planning & Engineering 2004a,b,c).

7.2.3 Monitoring Study Design and Impact Detection

Biological monitoring may be conducted to support a variety of information needs and/or environmental evaluations associated with project performance, such as:

- Observations of whether sensitive resources occur in the project area.
- Observations of whether sensitive species experience disturbance and/or harm during construction activities.
- Observations, measurements, and/or sampling to determine water quality (including turbidity) compliance with receiving water quality limitations.
- Sampling and evaluation of recovery rates of benthic invertebrates after beach nourishment and/or dredging.
- Sampling and evaluation of response of secondary consumers (fish, birds) to effects of beach nourishment and/or dredging.
- Measurements and/or sampling and evaluations to verify impact significance to sensitive resources from direct impacts during construction and/or indirect effects after construction.

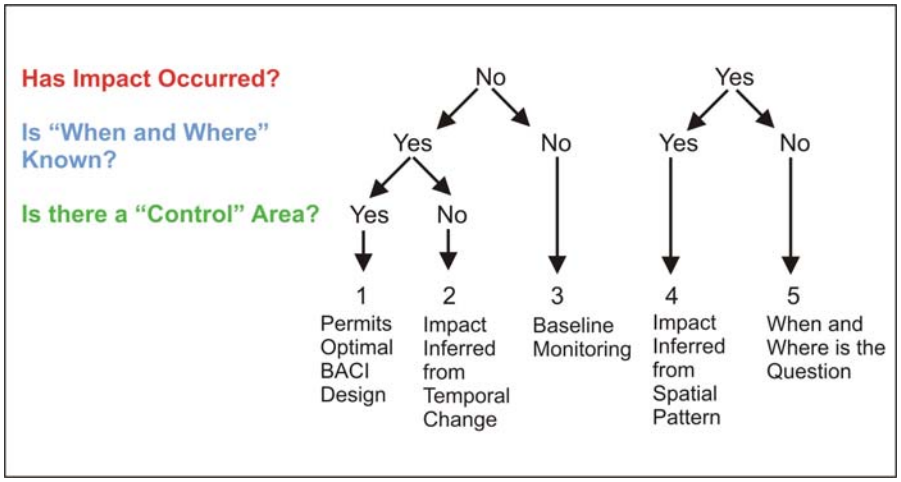
Generally, monitoring study design increases in scope as effort moves from observations, to measurements and sampling, to evaluation of impacts. For example, survey designs that address questions of sensitive resource occurrence in the area of potential effect may include reconnaissance or focused surveys involving presence/absence determinations and/or mapping of boundaries of sensitive habitats.

Survey designs during construction may include making systematic observations according to specific protocols to ensure activities do not directly or significantly impact sensitive resources.
Water quality compliance monitoring during construction may range from observations of turbidity plumes, taking *in situ* measurements, and/or taking samples for laboratory analysis to determine whether values are within or exceed established thresholds near and at specified distances away from the beach nourishment discharge or dredging source location.

In each of the above examples, the sampling designs are relatively simple, most of the effort is associated with the field work, and subsequent evaluations and reporting requirements are minimal.

In contrast, more rigorous sampling designs often are required to detect impacts to biological resources against the backdrop of natural environmental variability ("noise"). Before and after impact sampling must be conducted. A BACI (before-after-control-impact) sampling design generally is recommended to identify impacts when temporal and/or spatial scales of variability make detection of impact difficult (Green 1979, Stewart-Oaten et al. 1986, Peterson and Bishop 2005). For that sampling design, temporal replication before and after a disturbance is necessary to ensure that accurate estimates are made of average conditions, and spatial replication away from disturbance is essential for discriminating project-related impacts from those due to natural environmental variability (Underwood 2000).

Green (1979) reviewed that environmental studies generally fall within five categories with respect to an optimal BACI design. Determination of what category and type of impact analysis that can be conducted is shown in the following text box



Source: Redrawn and slightly modified from Green 1979

The level of sampling effort required to detect an impact will vary depending on how impact is defined. To allow precautionary decision-making, the type of predicted impact should be specified, along with the magnitude and duration considered significant (Underwood and Chapman 2003). It has been suggested that monitoring would be greatly improved if there was clearer upfront guidance from decision-makers with respect to what sorts, frequencies, and sizes of impacts they need to detect and manage (Underwood 2000).

For example, detection of a 10% decrease in population abundance and cover will require more sampling effort than detection of a 50% change. In addition, detection of habitat degradation will require more effort than habitat loss. The power of the BACI analysis to detect a certain level of change is an important consideration with respect to number of sampling locations and frequency of sampling.

A primary question addressed by many monitoring studies after sediment management projects is benthic invertebrate recovery rates (Sections 4.2.6, 4.2.7). Important considerations with respect to recovery relate to species composition, species-abundance relationships, and size distribution (or biomass) (Pearson and Rosenberg 1978, Reilly and Bellis 1983, Newell et al. 1998). Newell et al. (1998) reviewed that a practical approach to determination of "recovery" is that at least 80% of the species diversity and biomass is restored; abundance is not as informative since early succession may be characterized by high abundance of a few, opportunistic species. Therefore, the question of interest with recovery determinations is whether metrics such as species number and/or biomass are similar (e.g., within 80%) or greater than before impact and at control locations. This type of question has important implications with respect to hypothesis testing and sample size. Generally, fewer samples are required to test a one-tailed hypothesis (e.g., value is ≥ than before or control) than a two-tailed hypothesis (e.g., value is different, < or > than before or control) at the same level of power (Sokal and Rohlf 1969).

Sampling effort also may vary depending on the type of impact. Generally, more sampling locations are required to detect longer-term press disturbances while shorter-term pulse disturbances are best detected when the number of sampling periods is maximized (Underwood and Chapman 2003). Replication both at impact and "control" areas has been recommended to avoid confounding associated with natural variability that may occur between different locations (Lindegarth et al. 2000). This also may be an important consideration with respect to unbalanced temporal design. For example, the time period during which pre-construction data is collected often is limited, and more surveys may be conducted after impact to determine recovery rates or longer term press disturbance impacts. Differences between before and after periods may be greater than differences in the after period due solely to natural environmental conditions. Therefore, replication of reference sites will help overcome potential Type II errors (i.e., concluding an impact has occurred when it has not).

Peterson and Bishop (2005) reviewed 46 beach monitoring studies and identified a number of inadequacies in sampling designs. They concluded that only 11% controlled for both natural spatial and temporal variation, 56% reached conclusions that were not adequately supported by data, and 49% failed to meet publication standards for citation and synthesis of related work. Several specific short-comings of sampling designs were reviewed by the authors, including lack of independent controls, inadequate replication, insufficient pre-project baseline data to characterize natural differences between control and treatment sites, lack of formal statistical tests of significance, and insufficient study durations that terminated before recovery was demonstrated.

7.2.4 Use of Indicator Species and/or Indices

Use of indicator species sometimes is recommended to reduce the complexity of sampling designs and/or survey effort. The rationale is that the indicator is representative of broader habitat and/or ecosystem response.

An important consideration with respect to selection of indicator species is impact threshold. Sensitive indicator species may include those with a low tolerance of disturbance, water quality reduction, pollutant levels, and/or recovery from disturbance (Dayton et al. 1984, Foster and Schiel 1985, Moore and Orth 1997, Newell et al. 1998). Disturbance indicators often include early colonizing, opportunistic species (Daly and Mathieson 1977, Pearson and Rosenberg 1978, Littler et al. 1983, Stewart 1991, Newell et al. 1998). Many species fall between these extremes and generally are not used as indicators.

Another consideration is impact factor of concern. For example, different indicators may be relevant to questions regarding turbidity influence on SAV, interference with foraging of visual predators, and/or harm to early life stages. Examples of indicators are reviewed below.

Turbidity – Light Limitation

The literature review indicates that aquatic vegetation, herbivores, and suspension-feeders have substantially reduced diversity, abundance, and/or occurrence in areas with chronic turbidity and/or sedimentation (e.g., Bence et al. 1989, Pondella et al. 1996, CRM 1997). Large overstory algae such as giant kelp appear to be sensitive to prolonged turbidity.
Eelgrass is recognized as a good indicator of environmental health because it is sensitive to poor water quality (eutrophication, turbidity). It has been selected as an indicator species for which improvements in water quality conditions in the Chesapeake Bay and coastal lagoon systems are assessed on the East Coast of the United States (Moore and Orth 1997).

Substantial eelgrass die-back has been documented from substantial turbidity and light-limitation over a period of two to three weeks associated with severe storm conditions (Cabello-Pasini et al. 2002). Eelgrass die-back also has been documented from prolonged turbidity exposure in a confined basin during dredging (Sabol et al. 2005).

Overstory kelp and eelgrass may be effective indicators because of their sensitivity to critical turbidity levels and boundaries are easily mapped. Furthermore, the species are ecologically important in structuring kelp forest and eelgrass habitats and, thus, are suitable ecosystem-based indicators. Eelgrass blades and kelp canopy vary seasonally associated with natural periods of annual die-back or thinning. Therefore, short-term response may only be detected during seasonal growth periods; however, longer-term response may be determined over multiple seasons.

Monitoring turbidity effects on eelgrass and kelp may be unnecessary for small projects with potential exposure durations < 2 weeks based on considerations such as carbohydrate reserves (North 1981, Gerard 1982, Dean and Jacobsen 1984, Zimmerman et al. 1991, Cabello-Pasini et al. 2002). However, they may be very useful as indicators for ecosystem impacts resulting from prolonged turbidity, sedimentation, and/or equipment damage.

Turbidity – Foraging Interference

Secchi disk depths < 3 ft (1 m) have been used to identify unsuitable water clarity for visual foragers such as California least tern and California brown pelican (USFWS 2000). The rationale is that reduced water clarity will interfere with feeding efficiency of these visual predators, if present during sediment management activities. Secchi disk readings require use of a boat; otherwise equipment is inexpensive and easy to use. Secchi disk

measurements often are routinely collected during water quality monitoring to comply with WDRs or 401 Water Quality Certification.

Burial, Sand Scour, and/or Sedimentation

Several studies indicate reduced species diversity and dominance by sand, stress-tolerant species on hard-bottom habitat subject to seasonal sand accretion, erosion, and scour (Daly and Mathieson 1977, Ambrose et al. 1989, Litter et al. 1983, Stewart 1991, Pondella et al. 1996). Low-relief, hard substrate dominated by algal turf and having few to no associated invertebrate species was used as an indicator of sand, stressed reef (MEC 2000a).

Sensitive habitats differ in vulnerability to burial and/or sedimentation. Giant kelp is very sensitive to sand scour and sedimentation (Dayton et al. 1984, Foster and Schiel 1985). Therefore, this species may represent an effective indicator of reef ecosystem impacts from sedimentation in areas where this impact is of concern. Seagrasses may display a greater tolerance to sedimentation before critical thresholds are reached (Littler et al. 1983, Stewart 1989, Harrison 1990), but are still effective indicators because a substantial portion of their habitat value to other species relates to structural aspects of plant occurrence and density.

Reef Quality

The richest species assemblages are associated with rocky habitats with higher relief, diverse substrate characteristics, and microhabitats (Ambrose et al. 1989). The microhabitat aspect of reef function may relate to surface texture (pitted, cracked), ledges, and rock formations of different size. Perennial vegetation and long-lived species are associated with higher relief reefs with hard substrate extending above the sand level throughout the year ("perennial reefs").

Reefs that experience substantial sand level change, including filling-in along the reef base to the same level or overtopping the reef support opportunistic, annual species and/or sand tolerant species. Some reefs may only be seasonally exposed above the sand level ("ephemeral reefs").

Monitoring of rocky intertidal, nearshore reef, and kelp bed habitats in proximity to beach nourishment projects in California have included use of indicator species. For example, several indicators were used during the 2001 San Diego Regional Beach Sand Project (Table 7.2-3). Species have been selected that have been well studied, based on ecological importance in structuring communities, occurrence at discrete tidal elevations, vulnerability to human impacts, practical considerations for long-term monitoring, and relatively common occurrence (AMEC 2005, Engle 2005). Therefore, indicators may include species that vary in tolerance to disturbance and sand inundation. Explicit selection of species that differ in sand tolerance (e.g., "sand-loving", sand tolerant, sand sensitive) and longevity (annuals, long-lived) is recommended to increase ability to distinguish different levels of sand inundation impacts.

Invertebrate Indicators

Emerita mole crabs, *Donax* clams, and/or *Ocypode* ghost crabs have been used as indicators of sandy beach forage and/or habitat quality. Peterson et al. (2000a) compared *Emerita, Donax,* and *Ocypode* abundance at bulldozed and unbulldozed beach site, and used *Emerita* and *Donax* to examine short-term impacts of beach nourishment. *Emerita* and

Donax are important prey items for shorebirds, fish, and *Ocypode* (DeLancey 1989, Peterson et al. 2000a, Hubbard and Dugan 2003).

Table 7.2-3. Example hard bottom indicator species.

Rocky Intertidal	Nearshore Reefs	Kelp Beds
Rockweed (*Silvetia compressa*)	Giant kelp (*Macrocystis pyrifera*)	Giant kelp
Feather boa kelp (*Egregia menziezii*)	Feather boa kelp	Leafy red complex (*Rhodymenia/ Gigartina*)
Red algal turf (*Corallina* spp.)	Sea palms (*Eisenia arborea*)	Red turf algae (*Corallina/Bossiella*)
Surfgrass (*Phyllospadix* spp.)	Sufgrass	Understory kelp (*Pterygophora californica*)
Sargassum weed *(Sargassum muticum)*	California spiny lobster (*Panuliris interruptus*)	Gorgonian (*Muricea californica*)
Acorn barnacle (*Chthamalus* spp.)	Sea fans (*Muricea* spp.)	Stalked tunicates (*Styela montereyensis*)
Pink thatched barnacle (*Tetraclita rubescens*)		Red urchins (*Strongylocentrotus franciscanus*)
Goose barnacle (*Pollicipes polymerus*)		Purple urchins (*S. purpuratus*)
California mussel (*Mytilus californianus*)		Kellet's whelk (*Kelletia kelletia*)
Owl limpet (*Lottia gigantea*)		Boring clams (*Parapholas californica*)
Black abalone (*Haliotis cracherodii*)		
Ochre seastar (*Pisaster ochraceus*)		
Aggregating anemone (*Anthopleura elegantissima/sola*)		
Sand castle worms (*Phragmatopoma californica*)		

Emerita is a useful indicator of successful recruitment, biomass development, and sand persistence. *Emerita* recruits to California beaches in spring-summer, and size structure of the population is a useful indicator of growth and biomass development after recruitment (Reilly and Bellis 1983). Presence of large, adult sand crabs early in the season indicates successful overwintering, which is generally associated with sand persistence (Dugan and Hubbard 1996). Because *Emerita* is a substrate generalist (Dugan and Hubbard 1996, Dugan et al. 2000b), it may not be a sensitive indicator of substrate change.

Donax species exhibit varying tolerance to change in grain size characteristics (Nel et al. 2001, Peterson et al. 2002), suggesting that they may represent useful indicators of substrate change. However, sensitivity varies among species. Information is limited on substrate relationships for California *Donax* species. Recruitment variability of California *Donax* may be substantial among years (Morris et al. 1980). These limitations should be adequately considered with respect to use of *Donax* as an indicator species.

Barros (2001) proposed counting ghost crab (*Ocypode sp.*) burrows as an indicator of environmental degradation of beaches. Ghost crabs occur on the backshore of beaches,

particularly those backed by dunes. Although causal factors were acknowledged as being poorly understood, heavy recreational use and/or structural damage of dunes were suggested as being influential. Peterson et al. (2000a) reported ghost crabs were sensitive to beach bulldozing, with substantially fewer burrows observed after that activity.

Although ghost crabs do not occur on California beaches, other species indicative of the foreshore/backshore interface such as talitrid amphipods (beach hoppers) may be a useful indicator of sand persistence (when present) or erosional conditions (when absent). Prior to the 2001 San Diego Regional Beach Sand Project (2001), beach hoppers were not observed during spring but were seen at some beaches during summer (MEC 2000a). In contrast, beach hoppers were observed during spring and summer at some of the same sites after nourishment (SAIC 2006). Talitrid amphipods also are sensitive to beach grooming (Brown and McLachlan); therefore, they may be a useful indicator of human disturbance.

Based on consideration of the above relevant reports, invertebrate indicators such as *Emerita* can be used to answer basic questions with respect to presence of forage base, development of biomass after recruitment, and sand persistence. Occurrence of Talitrid amphipods may be useful as an indicator of habitat quality (e.g., beach width) or degradation (e.g., erosion, human disturbance). Talitrid amphipods feed on washed ashore wrack vegetation; therefore, food availability also would require consideration. Additional study is necessary to field-validate the usefulness of this species as a habitat quality indicator. The usefulness of *Donax* as an indicator may be limited by interannual recruitment variability. The utility of single species indicators is considered limited with respect to answering questions regarding habitat quality. Currently, assessment of species diversity and types of species (e.g., representing different feeding modes and life histories) are considered the most effective method for assessing effects of change in substrate and/or habitat quality.

<u>Mechanisms of Impact</u>

Wilber et al. (2003) reported that monitoring that focuses on mechanisms of impact may be more cost effective than monitoring of highly mobile populations such as surf zone fish that may result in inconclusive results. They suggested that examination of the physical condition of fish in the vicinity of the sediment plume may be more informative of potential impacts.

7.2.5 Monitoring Objectives

Ecological monitoring studies may include environmental and biological elements depending on the study objectives. The objectives vary depending on project phase. Monitoring during pre- and post-construction phases generally relate to answering questions with respect to sensitive resource constraints (Section 7.2.2). Monitoring during the construction phase focuses on compliance issues and sensitive resource protection.

Table 7.2-4 provides examples of different types of monitoring conducted during representative California sediment management projects (see Appendix D.2 for additional examples). Sediment testing during the pre-project phase to determine compatibility for placement on the beach or nearshore and water quality compliance monitoring during construction characterize many of the monitoring programs associated with dredging and beach nourishment in California. Exceptions include projects conducted during grunion spawning season, projects conducted near sensitive species nesting and/or roosting sites, and/or areas with sensitive habitats (reefs, SAV).

Table 7.2-4. Representative monitoring programs during beach nourishment projects.

Project (Habitat Types)	Volume (cy) and Habitat Types	Pre-construction	Construction	Post-Construction
Imperial Beach Nourishment Project:1977 (Parr et al. 1978)	1,000,620 Sandy beach, sandy subtidal	Sediment testing; faseline data for construction and post-construction monitoring	Intertidal and subtidal benthic invertebrates, grain size, total organic carbon, water temperature, beach profiles	Sediment grain size, total organic carbon, beach profiles, temperature, Intertidal and subtidal benthic invertebrates
Asbury Park to Manasquan Beach Erosion Control Project:1997-1999 (Burlas et al. 2001)	8,083,440 Sandy beach, sandy subtidal	Sediment testing; baseline data for post-construction monitoring	Turbidity	Sediment grain size, total organic carbon, sandy beach, nearshore, and borrow site invertebrates, surf-zone and borrow site fish, ichthyoplankton, recreational fishing
Santa Barbara Harbor Maintenance Dredging with Beach Discharge (USACE 1998a)	350,000 up to 600,000 Sandy beach, sandy subtidal	Sediment testing	Bacteria; if Mar and Apr schedule then grunion, snowy plover nesting	
San Diego Bay Channel Deepening Project with nearshore placement: 2004-2005 (Merkel & Associates 2005)	550,000 Sand-cobble	Sediment testing; *Caulerpa* at dredge location	Effluent limitations receiving water limitations, turbidity (light transmission)	
San Diego Regional Beach Sand Project: 2001 (SANDAG and USDN 2000, MEC 2000a, AMEC 2002, 2005, Coastal Frontiers 2004)	2,104,000 receiver sites 101,000 to 421,000 Sandy-cobble beach, sandy subtidal, rocky intertidal, rocky subtidal, kelp beds	Sediment testing; grunion habitat; baseline data for post-construction monitoring	Effluent and receiving water limitations, turbidity (water clarity, NTU), bacteria, seabird foraging, grunion, end of snowy plover nesting season	Rocky intertidal, Nearshore reefs, kelp beds, lobster, beach profiles
Goleta Beach Nourishment Demonstration Project:2003 (Chambers Group 2003, 2004, Coastal Frontiers 2003, 2004 cited in Moffatt & Nichol 2005)	79,000 in 2003, 18,600 in 2004 Sandy beach, rocky intertidal, eelgrass, kelp beds	Sediment testing; baseline data for post-construction monitoring	Turbidity plume	Rocky intertidal, eelgrass, kelp, beach profiles, inlet status

Monitoring objectives associated with the different project phases are reviewed below. Types of monitoring conducted during pre-construction, construction, and post-construction are reviewed in greater detail in Sections 7.3 through 7.5, respectively.

Pre-construction Phase

Pre-construction phase monitoring generally is undertaken to address one or more of the following objectives:

- *Determine substrate characteristics* - to determine compatibility for beach nourishment or disposal options and to predict turbidity plumes.
- *Characterize existing conditions* - to support project design and environmental review.
- *Identify biological constraints* – to identify resource concerns that may require implementation of mitigation measures during and/or after construction.
- *Establish baseline conditions* - to support post-project assessments of impact significance and/or project performance.

Types of monitoring questions that may be addressed during the pre-construction phase are listed in the box below.

Monitoring Questions That May Be Addressed During the Pre-Construction Phase

Determine Substrate Characteristics

- What are physical and chemical characteristics of source sands and/or dredged materials?

Characterize Existing Conditions

- What habitats occur in the project area?

Identify Constraints

- Are sensitive and/or managed species present and/or are habitat conditions suitable for their occurrence that may require implementation of protective mitigation measures?
- Does *Caulerpa* or other invasive species occur in project area?

Support Final Project Design

- What are the best routes for pipelines, vehicles, and/or vessels to avoid and minimize biological impacts?

Establish Baseline Conditions

- What habitat functions and values will be directly impacted?
- What are the boundaries and quality of sensitive habitats that may be indirectly impacted?

Generally, available existing information and/or reconnaissance level surveys are used to characterize biological existing conditions in support of CEQA/NEPA documents. In areas

with greater environmental complexity and/or sensitive resource issues, a reconnaissance survey may be conducted to describe different habitat types and resources and environmental constraints in the project area. Constraints generally refer to sensitive resources that need to be avoided or otherwise protected during sediment management activities.

Information on shoreline habitats and sensitive resources may be obtained from a variety of sources. For example, the CDFG Office of Spill Prevention and Response has GIS shapefiles available online of shoreline habitats and sensitive biological resources (http://www.dfg.ca.gov/itbweb/gis/ospr.htm). Information on some constraints such as federal and state endangered, threatened, and/or species of concern may be obtained by contacting the USFWS for current information.

The field portion of the constraints analysis may vary depending on site-specific data gaps. The following examples illustrate a range of level of effort conducted during reconnaissance level surveys in support of environmental review:

- Several types of reconnaissance level surveys were conducted for the 2001 San Diego Regional Beach Sand Project (MEC 2000a). Surveys included characterization of benthic invertebrates within receiver site footprints, types of biota on intertidal hard substrates, side-scan sonar mapping of nearshore reefs and diver surveys to describe dominant biota and reef heights, and surveys of macroinvertebrates and fish at borrow sites. Other available information was used to supplement the characterization of marine resources in the project area.
- Benthic infauna communities were sampled at receiver and borrow sites and documented in a technical appendix to the ERIR/EA for the BEACON Beach Nourishment Demonstration Project EIR/EA (Chambers Group 1992). Other available information was used to supplement the characterization of marine resources in the project area.
- Intertidal and subtidal reconnaissance surveys were conducted to identify habitat types (i.e., sandy, reefs, surfgrass) and dominant biota on reefs in support of the marine biological impact assessment in support of the San Clemente Beach Replenishment Program Criteria and Concept Design (CRM 2000).

In contrast, more extensive monitoring protocols may be used to establish pre-construction baseline conditions to support post-construction impact verification assessments (Table 7.2-4, also see post-construction monitoring below).

Construction Phase

Construction phase monitoring generally is undertaken to address one or more of the following objectives:

- Document water quality compliance and determine need for additional operational controls.
- Monitor sensitive species occurrence and determine need for additional protective measures.
- Verify habitat buffers and determine need for additional protective measures.

A primary consideration of construction monitoring is proximity to sensitive resources. For a project conducted in an area without sensitive biological resources, the only construction monitoring that may be required is water quality monitoring to ensure conformance with the California Ocean Plan. For example, small, opportunistic beach nourishment projects that qualify under RGP 67 (USACE 2006) may only require turbidity monitoring in sandy habitat areas if scheduled outside the grunion spawning season and no sensitive habitats or species are in the vicinity. Water quality monitoring requirements generally apply to any size or type of sediment management project with in-water activities and/or discharges. However, what parameters and how water quality is monitored has not been standard in California (Section 5.5.2.1). Protection of water quality represents the simplest form of ecosystem-based, operational compliance monitoring.

If sensitive habitats occur, monitoring may be used to ensure adequate buffers are maintained and turbidity is controlled to avoid excessive concentrations. If sensitive species occur in the project area, they may need to be monitored to ensure that project activities do not harm or disturb individuals.

Monitoring elements during the construction phase of California sediment management projects have addressed:

- Discharge effluent limitations.
- Receiving water limitations, often with additional specification for turbidity.
- Bacteria.
- Grunion spawning.
- Sensitive bird foraging, roosting, breeding, and/or nesting activities.
- Night-time light levels near nesting sites.
- Marine mammal behavior.

Post-Construction Monitoring

Post-construction monitoring generally is performed in combination with pre-construction baseline monitoring to verify the significance of project effects. Elements selected for monitoring should have a clear nexus to expected effects and uncertainty associated with significance of effects (CCC 1997).

Primary considerations include project size and proximity to sensitive resources. For small to moderate sized projects in sandy habitat areas, additional monitoring beyond the construction period may not be required (Table 7.2-2, e.g., USACE 1998a). This also was the case for beach receiver sites during the 2001 San Diego Regional Beach Sand Project that were implemented in areas with sandy habitat in the nearshore.

A number of moderate to large-scale sediment management projects have been conducted to answer questions with respect to benthic recovery after beach nourishment, borrow site dredging, and/or embayment dredging (Sections 4.2.6, 4.2.7). Substantially fewer have examined secondary trophic effects on shorebirds and/or fish (e.g., Burlas et al. 2001, Peterson et al. 2002, CRZ 2003, SAIC 2006). Linkage of effects between benthic recovery and recreational fishing also has received limited attention (Burlas et al. 2001).

7.3 Pre-Construction Surveys and/or Monitoring

Different types of surveys that may be conducted prior to construction include:

- Sediment testing.
- Sensitive resource occurrence.
- Invasive species occurrence.

Pre-construction surveys also may be required to establish baseline conditions as part of a BACI survey design to verify significance of impacts for projects conducted in areas with sensitive habitat concerns. The methods used for monitoring will depend on type of resource and impact issue of concern. Baseline surveys in support of post-construction impact significance evaluations are discussed in Section 7.5.

7.3.1 Sediment Testing

Sediment testing of the physical and chemical properties of the substrate is required prior to dredging, ocean disposal, and/or beach nourishment programs. The primary national guidance document for embayment dredge material and upland sediment source testing is the Inland Testing Manual (ITM) (EPA and USACE 1998). The "Greenbook" is used to evaluate sediments for ocean disposal (EPA and USACE 1991). A Sampling and Analysis Plan (SAP) should prepared for approval by regulatory agencies (EPA, USACE) prior to sample collection and testing to ensure the testing results meet testing requirements and information needs of decision-makers. Sediments used for beach nourishment must test "clean" per testing requirements and satisfy grain size characteristics for beneficial use (also see Section 5.2.3.3).

Online Sources Information Regarding Sediment Testing

Inland Testing Manual
http://www.epa.gov/waterscience/itm/

Ocean Testing Manual
http://www.epa.gov/OWOW/oceans/gbook/index.html

Beneficial Use Guidance
http://www.spn.usace.army.mil/conops/beneficialreuse.pdf
http://el.erdc.usace.army.mil/dots/budm/budm.cfm

Monitoring Considerations:

Sediment testing results are used to support several types of biological impact assessments, including:

- Prediction of turbidity plumes based on grain size distribution, percent content of fines, overlying water depths, and hydrodynamics.
- Prediction of benthic recovery rates based on similarity of source sediments with receiver sites.
- Identification of substrate characteristics of potential concern to sandy beach habitat functions (e.g., high shell content, coarse sand, silt/clay).

Adequate characterizations of source and receiver sediment characteristics are needed to support the above types of environmental evaluations.

From a biological impact perspective, sediment characteristics should be free of substantial contamination and closely match those at the receiver site. Sampling requirements specified for the SCOUP program address testing of different types of sand sources (Moffatt and Nichol 2006a), which are briefly referenced below with a few annotated comments.

- Sampling guidance specifies that beach receiver site samples should be collected along transects perpendicular to shore, with at least two profiles sampled for each receiver site 1 mi (1.6 km) in length or less and at least one additional profile for every additional ¼ mi (0.4 km) Along the profile samples would be collected every 6-ft change in elevation from the backshore to depth of closure; e.g., +12, +6, 0, -6, -12, -18, -24, and -30 ft MLLW. Sample collection is specified for summer when sand volume typically is greatest on the beach. All samples would be analyzed separately using standard sieve analysis and a grain size gradation "envelope" is prepared for the beach. *Comment*: it may be useful to prepare grain size distribution summaries for backshore, foreshore, and nearshore samples to facilitate definition of existing conditions for those areas that will provide baseline for comparison of conditions over time if the site is used for renourishment.
- Sediment guidance for source material specifies that sampling should be representative of material, reflecting volume, homogeneity, potential for pollutants, etc., and will be approved on a case-by-case basis. The sample locations should reflect the maximum volume of material to be removed, do not need to be evenly spaced, but located relative to thickness of deposit to be removed. Samples from individual boring locations should be collected from near-surface, mid-depth, and at the bottom of potential source. These samples can be homogenized into one bulk sample for individual analyses, assuming USACE compositing requirements have been met. *Comment:* Compositing requirements generally are based on geotechnical appearance of core; e.g., whether obviously different layers are present. Separate bulk composite samples should be prepared if obvious layers are present.

Vibracore sampling
Photo credit: Danny Heilprin, SAIC

- Sediment guidance for source material acceptability also addresses surface characteristics such as color (must be reasonable match of existing beach after natural color changes occur), particle shape (must not be substantially angular or jagged shaped), debris (must be free of trash, debris, and organic matter), and compactability/moldability (must not form hardpan crust if placed subaerially on beach). *Comment:* No criteria are given with respect to how to identify when compactability/moldability may be an issue, but guidance is given that material with this trend should be placed in nearshore. Speybroeck et al. (2006) note that compaction is a short-term problem that can be remedied by "tilling" the beach after construction; wave action will naturally soften the beach, especially during storms.

7.3.2 Sensitive Resource Surveys

Existing conditions in project areas must be described to support CEQA/NEPA environmental evaluation and review and/or permit applications. Reconnaissance surveys conducted to support existing condition assessments generally are documented in a project Biology Report that accompanies the CEQA/NEPA document. Those surveys are conducted to satisfy environmental review requirements.

Additional surveys may be conducted prior to construction to provide updated information on sensitive habitat boundaries and/or species occurrence to support logistic decisions with respect to final construction plans. These surveys also may represent mitigation measures to ensure impacts are avoided and/or minimized during project implementation (Section 6.3.8). Pre-construction surveys may be appropriate in areas where sensitive resource occurrence varies within and/or between years. They also may be appropriate in areas where sensitive habitats have patchy occurrence and detailed boundary information is not needed until construction and/or access plans are finalized. Results of the surveys may support decisions as to whether additional protective measures and/or monitoring may be warranted during construction.

The following types of sensitive resource surveys have been conducted prior to construction for California sediment management projects (Appendix D.2):

- Sensitive habitat boundaries.
- Pismo clam bed occurrence.
- Grunion habitat suitability.
- Snowy plover occurrence.

Sensitive resource surveys should be conducted by qualified biologists. A variety of surveys methods may be used depending on the resource and location of occurrence.

7.3.2.1 <u>Sensitive Aquatic Resource Survey</u>

Relevant Reports

- RGP 67 (USACE 2006) specifies that a Sensitive Aquatic Resource (SAR) survey be conducted and submitted as part of the permit application requirements. The MMRP

for the SAR must address turbidity plumes near any Areas of Special Biological Significance (ASBS), Pismo clam, and grunion habitat suitability and protection measures (as necessary depending on results of habitat suitability survey) (USACE 2006).

- Pre-construction surveys have been recommended to avoid direct impacts to coral reefs during borrow site dredging (Courtenay et al. 1972).
- Pre-construction surveys were recommended and used to finalize construction pipeline routes, monobuoy location, anchorages, and vessel routes prior to the 2001 San Diego Regional Beach Sand Project (MEC 2000a, AMEC 2002).
- Pre-construction surveys were recommended and used to refine pipeline routes and barge mooring locations for the Goleta Beach Nourishment Project (Chambers Group 1992, 2003, Moffatt & Nichol 2003).
- A pre-construction survey to determine occurrence of Pismo clam beds and/or sensitive hard bottom or SAV habitats was specified for the SCOUP program prior to implementation of a nearshore placement alternative (Moffatt & Nichol 2005b, 2006). Depending of survey results, receiver site boundaries may be adjusted and/or a different placement method used to avoid direct impacts.

Monitoring Considerations

Locations of ASBSs may be determined by reference to online sources (http://www.swrcb.ca.gov/plnpols/oplans/asbs_info.html). Methods for monitoring turbidity plumes, including additional measures if plumes exceed spatial criteria are included in RGP 67 (USACE 2006). The potential for turbidity to be an issue for an ASBS may be determined based on considerations of receiver site distance and orientation (up- or downcurrent) to an ASBS, placement location and method, and grain size distribution of source material. If it is likely that turbidity plumes will affect an ASBS, additional turbidity monitoring should be included in MMRP to satisfy RWQCB compliance requirements to address significance of plumes. Monitoring considerations for turbidity during construction are reviewed in Section 7.4.3. Monitoring considerations for sensitive habitat boundaries, grunion habitat suitability, and Pismo clam surveys are provided below.

7.3.2.2 Sensitive Habitat Boundaries Survey

This measure involves conducting a focused sensitive habitat survey to support logistic decisions for final construction plans. This measure may be appropriate in areas with coastal strand, reefs, and/or SAV habitats.

Monitoring Considerations:

Pre-construction surveys should be effective for finalizing equipment placement and/or access routes to avoid direct impacts to sensitive habitat resources (e.g., reefs, SAV, coastal strand). This measure should be used in areas where there is uncertainty and/or natural variability in boundaries of sensitive habitats. If there are potential impact concerns to sensitive habitats, pre- and post-construction monitoring will be necessary to verify

significance of impacts. Sampling design considerations differ in complexity depending on resource of concern (Section 7.5.1).

7.3.2.3 Pismo Clam Bed Survey

This measure involves conducting a survey to determine occurrence of Pismo clam beds.

Relevant Reports:

- RGP 67 (USACE 2006) specifies that a Sensitive Aquatic Resource (SAR) survey be conducted and submitted as part of the permit application requirements. Pismo clam is one of the marine resources to be addressed in the SAR survey.
- A pre-construction survey to determine occurrence of Pismo clam beds and/or sensitive hard bottom or SAV habitats was specified for the SCOUP program prior to implementation of a nearshore placement alternative (Moffatt & Nichol 2005b, 2006). Depending of survey results, receiver site boundaries may be adjusted and/or a different placement method used to avoid direct impacts.
- A pre-construction surveys from +3 to -10 ft MLLW to determine occurrence of Pismo clams, and if found a collection and relocation effort in coordination with resource agencies (DFG, NMFS, USFWS) were specified prior to discharge of maintenance dredge materials on the beach or in the nearshore at Hueneme Beach, Ventura County (USACE 1994a). This measure was not a requirement in the subsequent EA (USACE 2000).

Monitoring Considerations:

Pre-construction surveys should be effective for finalizing equipment placement and/or access routes to avoid direct impacts to important fishery grounds (e.g., Pismo clam beds, sensitive reproduction areas of Dungeness crabs, and/or other substantial fishery spawning ground identified by CDFG and/or NMFS as being of local concern). If an important fishery ground is identified, project boundaries may require adjustment to avoid direct impacts and an appropriate buffer distance may be required to minimize impacts (Section 6.3.8.3).

Pismo clam beds may be persistent areas due to limited larval dispersal and individuals being long-lived (Section 4.2.4); therefore, there is no need for a seasonal limitation with respect to timing of surveys. RGP 67 (USACE 2003) specifies that CDFG shall be contacted prior to the SAR survey to request current information on local populations of Pismo clam populations and review survey methods. It may be most effective for surveys to be conducted by certified diver biologists along band transects, the number of which should provide representative characterization with project footprints. The presence or absence of Pismo clams should be recorded for each transect. Pismo clams may have sparse occurrence, particularly juveniles due to opportunistic settlement. Therefore, estimating relative density within an area of known dimensions (e.g., count clam siphons in $1m^2$ quadrats) along band transects should be effective for determination of sparse occurrence versus presence of a clam bed.

Survey results may be used to determine the need for adjustment of construction boundaries. Therefore, if a Pismo clam bed is detected, the boundaries of the bed should be

determined. Although it may be technically feasible to relocate Pismo Clams, this is not recommended due to data gaps with respect to environmental requirements that promote formation of aggregated Pismo clam beds. Surveys results should be submitted to resource agencies according to requirements specified in the MMRP.

7.3.2.4 Locally Important Fishery Grounds

This measure involves conducting a survey to verify occurrence of important fishery grounds within borrow site and/or nearshore receiver site prior to construction activities and adjusting site boundaries to avoid significant impacts, if necessary. This measure may be applicable in areas where there may be concern for impacts to sensitive reproduction areas of Dungeness crabs, and/or other substantial fishery spawning ground identified as a concern by resource agencies (CDFG, NMFS) or local fishing organizations.

Relevant Reports:

- Commercial fishermen have expressed concern regarding the potential for impacts to Dungeness crabs with nearshore placement of dredged materials (K. Berresford, USACE, San Francisco District, personal communication 2005).

Monitoring Considerations:

Dungeness crab populations may be more vulnerable during the mating season when adult crabs concentrate in shallows (peak between March and June), females are in berried condition (between September and December, may vary geographically), and males are soft-shelled (summer-fall) (Section 4.2.3). During these periods, female and male crabs are less mobile and/or may be buried nearly completely in sediment. Therefore, in areas where impacts to the Dungeness crab fishery are of local concern, surveys should be scheduled with consideration of project schedule and seasonal periods of concern in consultation with CDFG. Other mitigation measures to avoid and/or minimize impacts may include use of environmental windows or dredging operational controls (Section 6.4.2 or 6.4.3.2).

RGP 67 (USACE 2003) specifies that CDFG shall be contacted prior to the SAR survey to request current information on local populations of Pismo clam populations. It is recommended that the request also seek current information on other substantial fishery grounds of local concern (e.g., Dungeness crab sensitive reproduction areas, other local fishery spawning grounds of concern). That step may increase the broader effectiveness of this measure over time in response to changes in commercial fishing activities.

7.3.2.5 California Grunion Habitat Suitability

This measure involves conducting a survey to determine if beach habitat is suitable for spawning, if scheduled between March 1 and August 31. Survey results may be used determine the need for additional monitoring and/or protective measures during construction. This measure would not be necessary for projects scheduled outside the grunion spawning season (Section 6.4.3).

Relevant Reports:

- RGP 67 (USACE 2006) specifies that a Sensitive Aquatic Resource (SAR) survey be conducted and submitted as part of the permit application requirements. Grunion spawning habitat is one of the marine resources to be addressed in the SAR survey.
- Grunion habitat suitability surveys were conducted prior to construction for the 2001 San Diego Regional Beach Sand Project (AMEC 2002). Beaches that were erosive and lacked suitable habitat did not require further measures during construction. Beaches with potentially suitable habitat were monitored during construction and additional protective measures implemented, as necessary.
- Grunion habitat suitability surveys were conducted prior to construction for the Goleta Beach Nourishment Demonstration Project (Moffatt & Nichol 2003).
- Grunion habitat suitability surveys are recommended as part of the SCOUP project (Moffatt & Nichol 2006).

Monitoring Considerations:

Beach site visits to determine grunion habitat suitability should be conducted during high tide conditions to examine available width to support spawning (i.e., upper intertidal sand habitat not inundated during neap high tides). Sand depth measurements and substrate characteristics should be assessed in the upper intertidal zone at spring high tide level. Factors indicative of unsuitable habitat include wave inundation of neap high tide zone, sand depths < 5 in (13 cm), and extensive cobble cover on substrate surface.

Grunion runs may occur at approximately two-week intervals during the spawning season. During this period, habitat suitability may naturally improve as sand accretes to beaches between spring and summer. Habitat suitability surveys should be effective if conducted prior to each predicted grunion run spanned by the construction period. It is recommended that monitoring and protective measures to be used during construction, if applicable, be included in the MMRP.

7.3.2.6 Snowy Plover Occurrence Surveys

This measure involves conducting a survey to determine occurrence of breeding/nesting snowy plovers prior to construction, if scheduled between March 1 and September 15, and the project location is within critical habitat. A survey also may be necessary if construction is scheduled in fall-winter (September through February) and the site supports a substantial overwintering population. Survey results may be used determine the need for additional monitoring and/or protective measures during construction.

Relevant Reports:

- Pre-construction surveys to determine snowy plover nesting activity and need for additional protective measures (including coordination with resource agencies) were specified if construction extended beyond March 15 for beach placement associated with maintenance dredging of Channel Islands/Port Hueneme Harbors (USACE 1994a), Ventura Harbor (USACE 1998b), and Marina del Rey (USACE 1999b).

Consideration of Potential Effectiveness:

The mitigation measure recommended in Section 6.3.8 specifies conducting a snowy plover survey within 30 days of a project if the site is within critical habitat and/or is known to support a substantial wintering population. The need for the survey should be determined well in advance of construction based on site location with respect to critical habitat and proximity to known nesting locations. In addition, prior coordination with the USFWS should be conducted to obtain recent information on local snowy plover occurrence in the project vicinity. If a survey is determined to be warranted, the focus should be identification of locations of nesting activity, site use patterns by adults and chicks, and/or site characteristics that limit suitability for occurrence. A MMRP should be prepared and approved by USFWS prior to the survey

Coordination with USFWS is necessary to satisfy ESA requirements for any project that may affect a federal listed species. Informal coordination with these agencies may be effective to review survey results and to identify reasonable measures that may be implemented during construction to avoid and minimize impacts to the species if it has the potential to occur during construction (Section 6.3.8). Informal coordination is recommended because avoidance and minimization measures may vary depending on site-specific conditions. Incorporation of appropriate minimization measures into the project description and/or MMRP should be effective at streamlining formal consultation and permitting processes.

7.3.3 Caulerpa Surveys

Prior to dredging, a survey to determine presence/absence of *Caulerpa* may be required. *Caulerpa* is an invasive, exotic plant species that is regulated in California. *Caulerpa* surveys must be conducted according to approved protocols (http://swr.nmfs.noaa.gov/hcd/caulerad.htm) by certified surveyors. *Caulerpa* surveys are required for any sediment disturbing activity (e.g., dredging) for California nearshore coastal and enclosed bays, estuaries, and harbors from Morro Bay to the U.S./Mexican border. Survey effort varies depending on whether the project location is within a designated *Caulerpa*-free or *Caulerpa*-infected waterbody.

Surveillance level surveys in *Caulerpa*-Free *area* are conducted not earlier than 90 days prior to the disturbing activity and not later than 30 days prior to the disturbing activity and are to be completed, to the extent feasible, during the high growth period of March 1 to October 31 (http://swr.nmfs.noaa.gov/hcd/caulerad.htm). Results are reported on standard survey forms and submitted to CDFG and NOAA according to protocol requirements. If *Caulerpa* is found, CDFG/NOAA must be notified within 24 hours of discovery, and no work is authorized until the area is treated and *Caulerpa* is eradicated.

7.4 Construction Monitoring

Several types of monitoring surveys may be conducted during construction to comply with water quality and/or sensitive species protection permit conditions with respect to:

- Sediment Compatibility Compliance
- Water quality com. pliance.
- Open inlet status
- Grunion.
- Sensitive bird occurrence.
- Marine mammal occurrence.

Two types of monitoring may be conducted during construction: verification of permit compliance, and to ensure no significant impacts to sensitive resources in vicinity. Different types of construction monitoring that have been conducted during California sediment management projects are briefly reviewed below. More detailed description of monitoring is given in Section 7.

7.4.1 Sediment Compatibility Compliance

Relevant Reports:

- Inspection of the beach at the end of construction to determine if undesirable sediment size differences and shell fragment content occur and whether a sand sweeper (or alternative mechanical separation device) should be used to alleviate problem was specified as a mitigation measure in the EIS/EIR for the Imperial Beach Shoreline Protection Project (USACE 2002). This measure also included follow up monitoring at one month intervals, as warranted, until potential impacts are considered less than significant.
- Periodic visual observations and sampling to verify proper quality of source sands is specified in the implementation guidelines for the BEACON South Central Coast Beach Enhancement Program (Moffatt & Nichol 2005a).
- Peterson et al. (2000b) recommended that substrate characteristics be inspected during construction to ensure no substantial change in characteristics than planned. Rehabilitation of substrate after placement was considered impracticable

Monitoring Considerations:

Regular inspection of substrate quality during sand placement should be conducted to ensure substrate characteristics match expectation based on permit requirements. Samples may be collected to verify sand characteristics based on results of visual inspection. Particular attention should be given to shell content, coarse sand, and/or silt/clay.

Final inspection of surface substrate conditions should be conducted to determine potential short-term compaction. Mechanical grading or "tilling" of the surface has been conducted to remedy compaction (NRC 1995, Speybroeck et al. 2006).

7.4.2 Water Quality Compliance

Monitoring of water quality may be conducted to satisfy requirements of the 401 Water Quality Certification and/or WDR for projects involving dredging and/or discharge of sediment into state and federal waters. Generally, compliance is determined by not exceeding Effluent Limitations, Receiving Water Limitations, and/or not exceeding specified thresholds relative to ambient conditions. Monitoring requirements may include visual observations, field measurements using *in situ* instruments, and/or sample collection for laboratory analyses (more detailed review in Section 5.5.1.1, Appendix C).

7.4.3 Turbidity Monitoring

The following questions of interest to the CSMW are addressed in this report section:

- *What level and type of turbidity monitoring before, during, and after sediment management activities is appropriate in order to more directly relate turbidity levels to biological effects?*
- *Can kelp or other species sensitivity to turbidity plumes be used as an indicator species defining limitations on sediment management activities?*

Turbidity will be generated during any sediment management activity that includes dredging and/or discharge in the aquatic environment. However, the magnitude and extent of turbidity will vary depending on project-specific factors such as substrate characteristics, project volume, construction equipment, and construction methods (Section 5.5). The effects of turbidity require consideration of the above project-specific factors, schedule, and site-specific conditions such as hydrodynamics and existing biological resources.

The following types of biological effects related to different aspects of turbidity are of potential concern:

- Light reduction that adversely affects photosynthesis and growth of aquatic vegetation.
- Reduction in water clarity that interferes with foraging success of sensitive, terrestrial species (e.g., California brown pelican, California least tern) that forage in near surface waters aquatic environments. Foraging success requires consideration of both the acquisition of prey as well as the travel distance to obtain food.
- Elevated suspended sediment concentrations that adversely affect foraging, respiration, development, and/or migratory behavior of aquatic invertebrates, fish, and marine mammals.

Turbidity impact concerns generally increase as project volume and duration increase (Clarke and Wilber 2000.). Therefore, it seems reasonable that monitoring requirements

should reflect level of impact concern. Important questions with respect to identification of impact concerns include:

- How large an area will be affected by turbidity?
- What concentrations may be expected?
- How long will elevated turbidity last?
- Will turbidity plumes occur in areas where sensitive habitats and/or resources occur?

Level and type of monitoring relevant to biological impacts of concern are further discussed below followed by a review of considerations with respect to use of indicator species to define sediment management limitations. Several mitigation measures may be employed to reduce turbidity (Section 6.4) and should be considered when answering the above questions. This should help ensure that monitoring data is useful for evaluation of impact of concern as well as effectiveness of mitigation measure.

7.4.3.1 Level of Monitoring

Water quality and turbidity monitoring requirements for sediment management projects in California have varied with respect to constituents, sampling designs (number and distance of sampling locations, frequency of sampling), and compliance criteria (Section 5.5.1.1). These inconsistencies limit the usefulness of resulting data to support science-based evaluations of plume characteristics and ecological consequences of plumes.

It is recommended that level of monitoring should address both spatial and temporal scales of impact. Spatial scale considerations include turbidity plume dimensions, differences in plume characteristics along the near- to far-field gradient from the source, and ambient water characteristics outside the plume. Spatial considerations also include characterization of the plume in the vertical dimension of the water column relevant to the impact issue of concern.

Temporal considerations include differences in plume characteristics associated with environmental conditions during project implementation and verification of plume dissipation after construction is completed. Generally, 401 Water Quality Certification and/or WDR compliance monitoring specifies daily monitoring (Appendix C.1). Daily monitoring is justified as a control strategy to ensure compliance. It also makes sense from an environmental standpoint based on changeable weather conditions.

Depending on receiving environment, it may be appropriate to take measurements more than once a day or at alternate times of day when measurements are taken on consecutive days, if there are substantial changes in plume characteristics due to time-of-day differences in environmental conditions (e.g., winds, currents, tidal stage). Characterizing plume characteristics under different environmental conditions is considered preferable to only obtaining information on maximum plumes. For example, eelgrass response to light limitation depends on the number of hours per day of irradiance-saturated photosynthesis (Zimmerman et al. 1991). Therefore, understanding whether turbidity plumes occur over an eelgrass bed only under maximum plume versus all plume conditions associated with a project is an important distinction with respect to impact evaluation.

7.4.3.2 Types of Monitoring

Different methods of monitoring turbidity plumes and biological relevance of different methodologies have been reviewed by Puckette (1998), Thackston and Palermo (2001), and Davies-Colley and Smith (2001). Puckette (1998) summarized that an effective suspended-sediment plume monitoring program will first identify the locations and dimensions of the plume and then measure the appropriate parameters dependent on the goals of the monitoring.

Plume Dimensions

Information on plume dimensions is needed to address three types of objectives: (1) spatial scale questions relative to permit compliance, (2) spatial scale questions with respect to biological impact concerns, and (3) spatial scale questions with respect to effectiveness of mitigation measures.

Plume dimensions from the source (upcurrent, downcurrent, and offshore if applicable) should be determined. Time of day and environmental conditions at the time plume dimensions are determined should be recorded, such as weather (temperature, wind speed, cloud cover, rain) and surf conditions (wave height, swell). In addition, any operational and/or construction method strategies used to control turbidity should be recorded.

It is recommended that if sensitive habitats are in the vicinity, a determination of whether the plume occurs over SAV or reef habitat should be made. If turbidity plumes occur over sensitive habitats, additional monitoring of plume characteristics may be warranted.

Different methods may be associated with measurement of turbidity plumes. For example, RGP 67 (USACE) specifies that turbidity plumes will be visually estimated by a qualified observer from a high vantage point (e.g., lifeguard tower), and that the daily maximum plume area shall be mapped and documented with digitial photographs. Visual observation and determination of the extent of turbidity plumes is a common monitoring requirement of WDRs and/or 401 Water Quality Certifications (Appendix C.1).

More accurate determination of turbidity plume dimensions outside the surf zone and/or in embayments may be accomplished with a vessel equipped with a standard fathometer that has been adjusted to optimize display of backscatter combined with *in situ* measurements of turbidity and Secchi disk depth (Puckette 1998). Acoustic Doppler sensors (e.g., ADCP, PLUMES) sensors provide detailed information on the structure of the plume (see Figure 5.5-11) and on currents affecting the plume. ADCP may be warranted in areas near sensitive habitats where more detailed plume tracking is desired.

Plume Characteristics

It is well understood that suspended sediment concentrations decrease with increasing distance from the turbidity source (LaSalle et al. 1991, Newell et al. 1998). Most water quality monitoring programs associated with WDRs or 401 Water Quality Certifications specify taking measurements at certain distances from the turbidity source (Appendix C.1). Some monitoring compliance requirements focus on determination of whether turbidity at a certain distance from the source is within 20% of ambient (Appendix C.1). Other requirements may specify obtaining measurements at several locations at increasing

distance from the source with criteria also based on whether turbidity at a specified distance from the source is within 20% of ambient.

Review of collected data from several monitoring programs indicate that near- and far-field differences in plume characteristics often are not adequately described by the sampling designs that have been used to-date, usually because of an insufficient number of sampling locations (Section 5.5.3). In addition, the spatial scale of the plume has not been demonstrated with sampling designs that do not include measurements beyond 500 ft (150 m) downcurrent (Section 6.3.5.1).

Better understanding of near- and far-field differences in plume characteristics is needed to improve evaluations of adequacy of buffer distances and biological impact assessments. Standardizing monitoring requirements with respect to distance upcurrent and downcurrent of the dredge or discharge would facilitate comparisons among projects. This is desired to increase understanding of plume characteristics under different project-specific and environmental conditions.

RGP 67 (USACE 2006) requires mapping of the maximum extent of the plume with compliance criteria based on whether plume dimensions > one-half mile downcoast and offshore persist for more than two days and up to five days. If turbidity plumes exceed that criterion for more than two days, turbidity monitoring is to be conducted at a minimum of four locations: as close to the discharge site as practicable and one-half mile upcoast, downcoast, and offshore. RGP 67 specifies that light transmission is to be measured at mid-depth in the water column.

Monitoring Considerations:

Based on review of monitoring data from several beach nourishment projects, it appears that suspended sediment concentrations may be elevated in the surf zone over distances ranging from < 1,000 ft to 6 mi (10 km) long and 50 to 1,000 ft (15 to 300 m) wide depending on environmental conditions and operational controls (Sections 5.5.3, 6.3.5.1). Therefore the offshore component of the plume criterion for RGP 67 would not be expected to be within the plume. The length component of the monitoring criterion would be expected to be within the plume at least in the downcurrent direction based on persistent mapping of the plume beyond that distance. Limiting the monitoring to a minimum of the four stations specified in RGP 67 will not permit distinction of near-field and far-field plume characteristics associated with beach nourishment projects.

Review of monitoring data collected at several offshore borrow sites and during many harbor dredging projects indicates data gaps with respect to turbidity plume extent and near- and far-field characteristics with many of the WDRs that have been used to-date.

Based on the above considerations, the following monitoring considerations would improve characterization of turbidity plume characteristics.

- Beach nourishment – Two locations within plume: outside breaker zone within main part of plume and near but inside the offshore edge of the plume. Two locations at least 300 ft (150 m) outside the visible plume to serve as references for ambient conditions. Additional measurements at the following distances, if within visible plume (i.e., only would sample distances within visible plume): downcurrent at 100 ft, 300 ft, 500 ft, 1,000 ft, 1,640 ft, 2,500 ft, 3,281 ft, and upcurrent at 100 ft, 300 ft,

500 ft, and 1,000 ft (downcurrent at 30 m, 91 m, 150 m, 300 m, 500 m, and 1000 m; upcurrent at 30 m, 91 m, 150 m, and 300 m). Monitoring would not be necessary at distances that are outside the visible plume.

- Nearshore placement – Within visible plume at the following distances: downcurrent and upcurrent at 100 ft, 300 ft, 500 ft, 1,000 ft, 1,640 ft, and 1,640 ft (30 m, 91 m, 150 m, 300 m, and 500 m). Two locations at least 300 ft (150 m) outside the visible plume to serve as references for ambient conditions.
- Dredging - – Within visible plume at the following distances: downcurrent and upcurrent at 100 ft, 300 ft, 500 ft, 1,000 ft, and 1,640 ft (30 m, 91 m, 150 m, 300 m, and 500 m). Two locations at least 300 ft (150 m) outside the visible plume to serve as references for ambient conditions.

7.4.3.3 Compliance Criteria

Water quality compliance criteria generally specify that turbidity measurements at specified distances from the source to be within 20% of ambient conditions (Appendix C.1). Review of available data suggests that this criterion is protective of biological resources. However, values may exceed that criterion and still be within levels of relatively low turbidity (Section 5.5.3.6). In addition, out of compliance values may be below levels associated with biological effects.

Standard Measurements

Turbidity (NTU) - Measurements by a nephelometer are not directly relevant to biological impact concerns (Section 5.5.2.2). This is because turbidity is an optical property of water caused by the molecules of water, dissolved substances, and organic and inorganic suspended matter. However, there are no standard relationships between turbidity measurements and aspects of turbidity that may result in biological effects, such as light reduction, water clarity reduction, and/or increase in concentration of suspended sediment (Davies-Colley and Smith 2001). However, turbidity measurements are useful for providing useful, real-time data during construction for use as a control strategy (Thackston and Palermo 2000). For example, *in situ* measurements are used to support field assessments of whether water quality compliance requirements are being met and field decisions with respect to need to implement additional turbidity control measures.

Secchi disk – This method provides a relatively reliable measure of water clarity, rough estimate of light extinction, and may be useful under highly turbid conditions that may affect performance of *in situ* instruments (Davies-Colley and Smith 2001). Because of the widespread and historic use of the Secchi disk during water quality compliance monitoring in California, it is recommended that it always be included as part of any water quality monitoring program that includes *in situ* measurements. Secchi disk readings may be affected by lighting conditions; therefore, weather conditions should be reported. Relationships between Secchi disk, light transmission, and TSS must be empirically established during each project and/or when there is a substantial change in substrate characteristics (Davies-Colley and Smith 2001).

Light Reduction

Increased light attenuation due to turbidity may adversely impact photosynthesis, growth, and/or recruitment of kelp and seagrasses (Section 5.5.3.1). Light transmission and/or measurements of PAR provide relevant measures of light attenuation from turbidity effects. Transmissometers are reliable for measuring light transmission when particle concentrations are relatively low, but may become saturated at TSS levels above approximately 150 mg/L (Puckette 1988). PAR may be measured using a variety of sensors (e.g., LI-COR cosine-corrected sensors) (Dean 1985, Moore et al. 1996, Cabello-Pasini et al.. 2002). The Secchi disk provides a rough estimate of light extinction that may be useful under highly turbid conditions (Davies-Colley and Smith 2001).

If light reduction impacts are of concern, it is recommended that relevant measures of light transmission be monitored. Generally, projects spanning ≥ two weeks may be considered as being prolonged with respect to potential light limitation. Light transmission and Secchi disk depth measurements are recommended at several locations within the visible plume at different distances from the turbidity source to document the gradient of light limitation and also outside the visible plume to obtain ambient measurements (see plume characteristics).

Relevant Reports:

- A light level of approximately 1% of surface irradiance (PAR of approximately 0.2 E $m^{-2}d^{-1}$) limits the distribution of giant kelp (Foster and Schiel 1985). Recruitment is limited at 0.4 E $m^{-2}d^{-1}$ and juvenile growth is limited at 0.4 to 0.9 E $m^{-2}d^{-1}$ (Neushul and Haxo 1963, Dean and Dyscher 1983, Dean and Jacobsen 1984, Deysher and Dean 1984, Dean 1985). Saturation levels are 0.8 E $m^{-2}d^{-1}$ for recruitment and 1.8 to 3 E $m^{-2}d^{-1}$ for juvenile growth. Therefore, prolonged light levels < 5% of surface irradiance may reduce recruitment and levels < 10% may adversely affect growth.
- A light level of approximately 10% of surface irradiance is considered a general indicator of eelgrass compensation depth (Dennison 1987, Fonseca 1989). Light levels below 20% surface irradiance may reduce growth and survival (Backman and Barilotti 1976, Burke et al. 1996). Minimum light thresholds vary with environmental conditions, ranging from 3 to 12 hours of photosynthetic-saturating irradiance per day (Dennison and Alberte 1985, Zimmerman 1990, Dennison et al. 1993, Orth et al. 2006). Therefore, critical thresholds may vary depending on site conditions.
- Light levels < 40% surface irradiance limit surfgrass distribution (Williams and McRoy 1982).

Water Clarity for Visual Foragers

Impacts to sensitive, visual foragers that target fish prey in the upper water column (e.g., California least tern, California brown pelican) may be of concern during sediment management projects. Water clarity measurements using a Secchi disk provide a fairly reliable measure of the optical quality of waters (Davies-Colley and Smith 2001).

Relevant Reports

- Davies-Colley and Smith (2001) recommend measuring visual water clarity (measured as Secchi or black disk visibility) instead of turbidity to provide a more

accurate optical quantity with relevance to fish habitat, aesthetics, and contact recreation.

- Secchi disk was specified as the method for measuring reduction in water clarity with relevance to California least tern foraging during the 2001 San Diego Regional Beach Sand Project (USFWS 2000). A Secchi depth of < 3 ft (1 m) was the water depth threshold and 1 hectare (2.47 acres) was spatial threshold for turbidity plumes for that project.

Monitoring Considerations:

A Secchi disk depth of < 3 ft (1 m) was recommended by the USFWS (2000) as a threshold for delineating plume characteristics with the potential to affect least terns and brown pelicans.

Water clarity measurements may be appropriate for sediment management projects conducted within one mile of active nesting sites of least terns. Need for monitoring should consider seasonal breeding period of the species (April 1 to September 15). Monitoring may not be necessary if only for California brown pelican because their breeding sites are located on offshore islands and they have wide foraging range along the mainland.

Total Suspended Solids

TSS is the measure most commonly used during laboratory studies of the effects of suspended sediment on invertebrates and fish (Sections 5.5.3.2, 5.5.3.3). TSS is relevant to effects associated with physical abrasion, respiration, physiological stress, and foraging interference for planktivores, filter-feeders, and suspension-feeders. Therefore, TSS is the most directly comparable measure to the available biological effects data concerning turbidity effects to aquatic animals.

Relevant Reports:

- Thackston and Palermo (2000) reviewed that there is no standard conversion between TSS and turbidity. They recommended measurement of both TSS and turbidity early in the project to develop a project-specific TSS-turbidity correlation, which will enable accurate conversion of subsequent *in situ* turbidity measurements to TSS. Additional water samples for TSS analysis are recommended if substrate conditions change within the project area during construction so that the accuracy of the TSS-turbidity relationship can be updated, as necessary.
- Clarke and Wilber (2000) reviewed that many of the past investigations of suspended sediment effects focused on detrimental effects, but the dosages required to induce them often were well above those likely to occur during dredging. In addition, appropriately designed studies to address dredging impacts associated with sediment resuspension are very limited. They concluded that extrapolations from inappropriate concentrations or exposure durations is a widespread practice and may lead to false conclusions. They strongly recommended that any impact assessment consider not only the concentration aspect of the dosage issue, but also realistic estimates of the likelihood and duration of exposure above that threshold.

Monitoring Considerations:

TSS concentrations in turbidity plumes should be monitored in areas near sensitive spawning grounds and/or nursery areas if the sediment management activity is conducted during peak recruitment and/or productivity periods. Acoustic monitoring is recommended to provide accurate mapping of the plume. Field collected turbidity measurements using a nephelometer and water samples for TSS are recommended to establish site-specific turbidity-TSS-backscatter correlations. The number of TSS samples necessary to adequately establish empirical relationships will vary depending on project- and site-specific conditions (Section 5.5.1.2).

7.4.3.4 Turbidity Indicator Species

Overstory kelp and eelgrass may be effective indicators because of their sensitivity to critical turbidity levels and boundaries are easily mapped However, their suitability may vary seasonally associated with natural periods of annual die-back or thinning.

The USFWS (2000) specified that turbidity plumes with Secchi disk depths < 3 ft (1 m) be used to identify unsuitable water clarity for visual foragers such as California least tern and California brown pelican.

7.4.4 Open Inlet Status

Relevant Reports

- Monitoring to determine if inlet closure occurs due to sedimentation and opening of the lagoon inlets as necessary until the inlet area has stabilized was specified for the BEACON South Central Coast Beach Enhancement Program (Moffatt & Nichol 2005b).
- Monitoring and establishing a fund for increased dredge volume and/or inlet opening of coastal lagoons was specified as a mitigation measure for the 2001 San Diego Regional Beach Sand Project (SANDAG and USDN 2000).
- Monitoring and opening inlet if closure occurs was specified as a mitigation measure for the Goleta Beach Nourishment Demonstration Project (Chambers Group 1992).
- No inlet closure was observed at Goleta Slough during or after beach nourishment at Goleta Beach (Moffatt & Nichol 2005c).

Monitoring Considerations:

Monitoring should be effective for documenting inlet status during and after beach nourishment (Section 6.4.5.3). Because sand level changes may exhibit substantial annual variation, two or more stations along a gradient between the discharge location and inlet should be surveyed before and after project. If other sand sources are of concern with respect to mitigation responsibility, there should be an adequate number of stations along the downcurrent gradient to follow sand movement. Particle tracking also may be used to

measure sand transport (e.g., Black et al. 2004, National Institute of Coastal and Marine Management of the Netherlands 2004).

The overall effectiveness of this measure may depend on the communication and response protocols established during the pre-project phase. Therefore, documentation of responsible party commitment to remove and/or provide funding to remove excess sedimentation should be specified prior to the project. Preparation of an Inlet Monitoring and Response Plan that specifies communication, response protocol, and responsible parties should contribute to the effectiveness of the measure.

7.4.5 Sensitive Species Occurrence

7.4.5.1 California Grunion

Photo credit: Julianne Steers

This measure involves monitoring grunion to determine spawning activity and if observed to implement measures to avoid impacts to spawned eggs, if appropriate. Measures may include a diked buffer (Section 6.4.2.2), redirection of construction activities, and/or halt to construction for 14 days to allow eggs to hatch.

Relevant Reports.

- Sand placement on the beach during March and April has been conducted with grunion monitoring during maintenance dredging projects in southern California; e.g., Oceanside, Point Hueneme, Santa Barbara, and Ventura (USACE 1993, 1994a, 1998a, b, 2000b).
- Monitoring during construction and implementation of protection measures, as necessary, was specified for the 2001 San Diego Regional Beach Sand Project for those beach sites scheduled to be constructed during the spawning season
- Monitoring during construction is specified for the SCOUP project if construction is scheduled during the spawning season and a pre-construction survey determines habitat is potentially suitable for spawning (Moffatt & Nichol 2006).
- RGP 67 specifies monitoring during construction if the project is scheduled between March 1 and August 31 and a pre-construction survey determines habitat is suitable for spawning (USACE 2006).

Monitoring Considerations:

Monitoring for grunion spawning to avoid areas where eggs are laid may be effective for avoiding and/or minimizing physical disturbance of spawning. For the monitoring to be effective, most days of the predicted run must be monitored (K. Martin, 2005 and 2007 personal communications).

The following monitoring recommendation was developed by the senior author in consultation with K. Martin for the SCOUP program (Moffatt & Nichol 2006) and RGP 67.

Monitoring should occur at night from 1 hour before the peak high tide to 2 hours after the peak high tide (i.e., at least 3 hour duration monitoring period) commencing on the second night after a new or full moon and continue for the next two nights (i.e., three nights). If no grunion are observed, no further action would be necessary. If grunion occur within the project area, their location should be mapped and number present estimated (e.g. by Walker Scale). An appropriate protective measure should be implemented and actions communicated to resource agencies in accordance with pre-coordination decisions specified in the MMRP.

7.4.5.2 California Least Tern

Photo credit: Kathy Keane, Keane Biological Consultants

Monitoring of least tern foraging during sediment management projects may be conducted when sediment management projects are scheduled during the breeding season. Monitoring questions of interest, include: Do terns avoid foraging in turbidity plumes or forage less in turbid compared to clear waters, 2) Is the prey capture efficiency impaired in turbidity plumes compared to clear waters, 3) To what extent, if any, do turbidity plumes near tern breeding areas result in reduced reproductive success?

Relevant Reports:

- Permit requirements that water clarity not be < 3 ft (1 m) over an area > 2.47 acre (> 1 hectare) to protect potential least tern foraging were met with few exceedances (and remedied) during the 2001 San Diego Regional Beach Sand Project (AMEC 2002).
- Least terns were observed foraging in turbidity plumes during beach nourishment with diked discharge at Surfside-Sunset Beach (MEC 1997).
- Least terns, Forster's terns, royal terns, and brown pelicans were observed foraging in turbid and non-turbid areas during dredging operations for the NIMITZ Homeporting Project in San Diego Bay (U.S. Navy 1996 cited in USFWS 2000).
- Collins et al. (1979) reported that least terns foraged less consistently in a turbid flood control channel than in clearer waters in the vicinity.

Consideration of Effectiveness

Few studies of least tern foraging during sediment management activities have been conducted. Generally, an environmental window restricted period has been applied to dredging and beach nourishment projects in the vicinity of nesting sites during the breeding season). Available monitoring studies suggest that least terns avoid foraging in turbid waters when given a choice (Collins et al. 1979). However, a turbidity threshold that results in avoidance response has not been established.

Least terns have been observed to forage in the vicinity of beach nourishment (MEC 1997) and dredging (U.S. Navy 1996 cited in USFWS 2000) suggesting that water clarity in turbidity plumes generated by such activities were not depressed beyond visual thresholds of terns. Monitoring also indicates that water clarity reductions during offshore borrow site dredging

and beach nourishment may be sufficiently localized to satisfy the USFWS Biological Opinion conservation measure that surface turbidity (water clarity not < 3 ft) be limited to ≤ 2.47 acre (1 hectare) to avoid potential effects to foraging when least tern nest sites are within two miles of these sediment management activities (USFWS 1-6-01-F-1046). Limited available monitoring studies suggest that impacts may minimized when turbidity is controlled.

Additional monitoring with respect to least tern foraging behavior, water clarity, and turbidity plumes would enable a more rigorous evaluation of potential impacts under different project conditions. That type of information could be useful for establishing science-based guidance thresholds to better regulate turbidity levels during sediment management projects so that breeding season constraints can be applied at the appropriate spatial scale.

7.4.5.3 Western Snowy Plover

Photo credit: Callie Bowdish

Snowy plover monitoring may be conducted if the project location is within critical habitat and project activities are scheduled during the breeding season. Monitoring also may be necessary if the site supports substantial overwintering populations and project activities are scheduled between September through February. Monitoring of snowy plovers during sediment management projects may be conducted if sediment management project schedules extend into the breeding season. Surveys may be used to determine species occurrence and whether additional protective measures may be required during construction.

Relevant Reports:

- Surveys to detect nesting and/or snowy plover behavior have been specified if construction schedules extend into the breeding season for maintenance dredging projects involving beach discharge near Channel Islands/Port Hueneme Harbors, Marina del Rey Harbor, Morro Bay, Oceanside Harbor, Santa Barbara Harbor, and Ventura Harbor (USACE 1994a, 1998a, 1998b, 1999a, 1999b, 2000b).

Monitoring Considerations:

Surveys to determine species occurrence prior to construction appear to be effective for determining need of additional protective measures during construction. Although no reports of injuries or nest damages during beach nourishment activities were identified in reviewed documents, considerable vigilance and contractor coordination may be required to avoid impacts if nesting occurs near the sand delivery pipeline (Hutchinson 1987). The use of qualified biological monitors with authority to halt and/or redirect activities is a primary consideration with the effectiveness of monitoring as an impact avoidance measure. Monitoring methods, protective measures, communication, and reporting should be determined in coordination with and approved by the USFWS as part of required ESA Section 7 coordination. Use of single-point discharge within a restricted corridor has been used to minimize impacts to foraging snowy plovers (Section 6.4.1.3).

7.4.5.4 Marine Mammal Occurrence

Use of environmental monitors on hopper dredges and/or support vessels to determine marine mammal occurrence, behavioral response to sediment management activities, and/or to document adverse impacts (e.g., collisions) have been recommended for some geographic regions.

Relevant Reports:

- The USACE, Los Angeles District specifies monitors are to be used during dredging when sea otters are present (http://el.erdc.usace.army.mil/tessp/info.cfm).
- Protocols developed monitoring borrow sites on the east and Gulf Coasts of the United States recommend use of marine mammal monitors on dredges and/or support vessels during offshore borrow site dredging activities (RPI et al. 2001).
- Monitoring of sea otters has been conducted during dredging at Morro Bay (Bodkin and Rathbun 1988).

Monitoring Considerations:

Sea otters appear to be sensitive to dredging activities (Bodkin and Rathbun 1998), which may be a concern for sediment management activities if conducted in the vicinity of kelp beds used as breeding areas and/or at wintering areas in embayments.

Pinnipeds are more sensitive to disturbance while on land; therefore, sediment management activities may be a concern if conducted near haul-out areas.

Whales appear to be tolerant of vessels when direct approach is avoided, movement is parallel to the animal, and speed is maintained at or slower than the animal.

Available information indicates that risk for collision is higher with fast moving vessels for any of these marine mammals (Laist et al. 2001).

Based on these considerations, monitoring may not be necessary if other mitigation measures are implemented that limit direct approach and control of vessel speed in areas where marine mammals are observed (Section 6.4.1.5).

The need for monitoring should be evaluated on a case-by-case basis for projects that include dredging and/or beach nourishment near sea otter breeding or wintering areas or pinniped haul outs.

7.5 Post-Construction Monitoring and/or Impact Evaluations

7.5.1 Impact Significance Verification and/or Habitat Recovery Rates

Several methods may be used to assess impacts depending on habitat type. Several sources of information with respect to methods commonly employed for assessments of California coastal habitats are listed in the following text box.

Useful Online Sources of Information of Field Sampling Methods

- Rocky Intertidal Habitats and Resources

  http://www.marine.gov/sampling-methods.htm, http://www.piscoweb.org/data/
- Rocky Subtidal Habitats and Resources

  http://www.piscoweb.org/data/
- Offshore borrow sites
  http://www.mms.gov/itd/pubs/2001/2001-089.pdf
  http://www.mms.gov/sandandgravel/MMS2000-054.htm
  http://www.mms.gov/sandandgravel/JCRVolume20MMSstudies.htm
-

Sandy Beach Recovery

Invertebrates

Invertebrates have been sampled using hand-held cores, box samples, and/or standard shovel samples (Parr et al. 1978, Straughan 1981, McLachlan et al. 1984, Nelson 1993, Dugan et al. 2000a, Schoeman et al. 2000, Dugan et al. 2003, SAIC 2006). Cores dimensions often vary among studies; e.g., ranging in diameter from 2 to 8 in (5 to 20.2 cm) and to depths of 4 to 12 in (10 to 30 cm). Collected samples are sieved to separate animals from sediment; sieve sizes of 0.5, 1.0, or 1.5 mm have been used.

Sampling design and method considerations associated with sampling sandy beach invertebrates are reviewed by Straughan (1981) and Nelson (1993). Both indicate that a core size diameter of at least 3-in (7.6 to 7.7 cm) accommodates all sandy beach species and enables efficient collection and processing of multiple samples during a low tide. Straughan (1981) recommends sampling to a minimum depth of 8 in (20 cm). Nelson (1993) recommended sieving with a 0.5 mm screen, although a slower sample processing time was acknowledged than with screens with larger, aperture openings. Straughan (1981) noted that use of a 0.5 mm screen often is difficult under field conditions due to clogging. Most sandy beach sample data collected in California has used 1.0 to 1.5 mm sieves (Straughan 1981, Dugan et al. 2000a, Dugan et al. 2003).

Sandy beach invertebrates exhibit tidal zonation and sampling designs often include collection of samples across the beach from low to high tide. This may be accomplished by sampling at uniform intervals and/or within upper, middle, and lower intertidal stratum (Parr et al. 1978, Straughan 1981, Dugan et al. 2000a, 2003).

Nelson (1983) reviewed that ten, 3-in (7.6 cm) replicate cores from each location and time may provide a sufficient level of replication for sandy beach studies, but recommended carrying out a power analysis to verify sampling design. Parr et al. (1978) determined that a total of 90 samples consisting of 10 samples per 3 intertidal strata times 3 transects enabled estimation of abundance with a precision level of ± 30% at a 95% confidence interval; approximately half that number of samples was required to estimate species number at the same precision level. A total of 49 and 17 samples were required to estimate abundance and species number with a ± 50% precision level.

Invertebrates in the shallow nearshore within the depth of beach closure may be collected by divers using hand-cores and/or a diver-operated suction sampler (Parr et al. 1978, Oliver et al. 1980, McLachlan et al. 1984). Similar to the above discussion, core dimensions have varied from 3- to 6-in diameter by 4- to 6.7-in deep (7.6 to 15-cm diameter by 10- to 17-cm deep). Screen size may vary from 0.5 to 1.0 mm. Apparently, fewer replicate cores are required to estimate abundance and species number than in the intertidal. Parr et al. (1978) determined that the number of replicate cores (3-in diameter by 4-in deep, 8-cm diameter by 10-cm deep) required to estimate invertebrate abundance and species number ranged from 11 to 15 at a ± 30% precision level and from 6 to 7 at a ± 50% precision level at depths of 12 and 20 ft (3.7 and 6.1 m).

Sampling design considerations (number of stations, replicates) for sandy beach and subtidal should be determined based on site conditions and monitoring objective. Simple characterizations of what types of sandy beach invertebrates occur on a beach require less rigorous designs than those addressing recovery of more stable communities.

Fishes

Beach seine sampling has been used to assess beach nourishment effects on surf zone fish. Burlas et al. (2001) used a 50 x 6 ft seine with a 6 by 6 ft bag and ¼ in mesh (15.2 by 1.8 m seine with 1.8 by 1.8 m bag with 6 mm mesh), which was deployed during daylight and hauled perpendicular to shore starting at a depth of approximately 4.1 ft (1.25 m) (also cited in Wilber et al. 2003). Sampling included three samples per station. Sampling was curtailed for safety reasons when wave heights exceeded 4.9 ft (1.5 m). Wilber et al. (2003) reported that although there sample size over a five-year period was 2,190 seines, the sample size was only sufficient to detect a 3-fold difference in abundance. The authors stated that this result suggests that interpretation of meaningful effect size is not simply detection of a 10, 50% or greater change, but realization that reductions in fish abundance (if any are detected) might have no other meaning than the fact that mobile fishes moved beyond the sampling bounds.

Beach seine sampling Batiquitos Lagoon
Photo: SAIC

Versar (2004) used a 150 ft X 6 ft seine with a 6 ft X 6 ft bag and ½ inch square mesh (46 by 1.8 m seine with 1.8 by 1.8 m bag and 13 mm mesh), which was deployed in a semicircle and pulled to shore by hand during daylight hours at or near low tide. Versar (2004) stated that they switched from a ¼ to ½ in (6 to 13 mm) mesh in order to target larger fish and also to reduce haul-back pressure and make sampling more feasible. Fish outside the breaker zone were sampled with a 25 ft (7.6 m) semiballoon, otter trawl equipped with two 3 ft X 1½ ft (1 x 0.45 m) wooden doors, net with a 2-in (50-mm) mesh body and 1½- in (38-mm) stretched mesh cod-end fitted with a 1/8-in (3-mm) cod liner. Replicate tows parallel to shore were conducted for 10 minutes, and trawl collections were standardized to numbers per 1,640 ft (500 m) of tow length.

Birds

Bird observations may be conducted within a standard length of shoreline (e.g., Hubbard and Dugan 2003), standardized transects (CZR 2003), and/or coastline sectors of known length (e.g., Lafferty 2001, SAIC 2006). Generally, birds associated with habitat (e.g., beach) are counted and over-flights by birds either are not counted or noted as such. Counts of birds by species and behavior (foraging, resting) may be conducted.

Sandy Subtidal Recovery

Biological and physical monitoring protocols for evaluating impacts of offshore dredging along the U.S. East and Gulf of Mexico coasts were developed by MMS (RPI et al. 2001, Nairn et al. 2004). The monitoring protocols address the following issues:

Physical

- Bathymetric and substrate surveys.
- Sediment sampling and analysis.
- Wave monitoring and modeling.
- Shoreline monitoring and modeling.

Biological

- Benthic communities and trophic relationships to fish.
- Marine mammals.

The RPI et al. (2001) recommended benthic monitoring involves collection of 0.10 m^2 cores to identify benthic invertebrate species composition, abundance, and biomass. In addition, otter trawls are recommended for collection of demersal fish and macroinvertebrates. The focus of the invertebrate sampling is analysis of recovery processes and rates of the benthic community. Analysis of trawl contents involves identification of species; measurement of length, sexual maturity, and weight of fish; and analysis of stomach contents of commercially and/or recreationally important fish species to assess diets and prey relationships with collected benthic invertebrates. Additional sampling of sediment grain size, total organic carbon, and stable isotope analyses (carbon, nitrogen) to compliment benthic recovery and trophic energy transfer analyses also are recommended. The RPI et al. (2001) biological monitoring protocols recommend surveys prior to dredging and in years 1, 3, 5, and 6 following dredging to assess long-term impacts.

Physical sampling is not addressed in this document. Descriptions of relevant sampling methods are available from several sources (RPI et al. 2001, Hitchcock et al. 2002, Boyd et al. 2004, Cooper 2005).

Invertebrates

RPI et al. (2001) review sampling equipment, sampling design, replication, and sampling processing recommendations for monitoring borrow sites on the East and Gulf Coasts of the United States. Generally, a sampler with a surface area of 0.1 m^2 is used. Other method descriptions for borrow site sampling are available in recent studies conducted off the East Coast (Brynes et al. 2004a,b). Similar methods are described for surveying aggregate mining sites in the United Kingdom (Boyd et al. 2005, Cooper 2005). Similar sampling has been conducted off California during regional, nearshore monitoring, and offshore studies in southern California (e.g., Fauchald and Jones 1983, Thompson et al. 1985). Generally, a box core sampler or Van Veen sampler with a surface area of 0.1 m^2 has been used off California.

Box core sampler
Photo: SAIC

RPI et al. (2001) recommend that the number of replicate samples be determined as part of a baseline or pre-impact survey using a power analysis. Additional recommendations include processing samples with a 0.5 mm, identifying animals to taxonomic categories, and weighing each taxonomic category (e.g., family). That method of analysis focuses on providing information that may be more easily linked to fish gut analyses, which is recommended to provide information on trophic response and recovery of secondary consumers. Off California, offshore samples have been processed with 0.5 and 1.0 mm sieves and animals typically have been identified to the lowest practicable taxon and weighed according to taxonomic categories (e.g., crustaceans, echinoderms, mollusks, polychaetes, other minor phyla). Specific sampling methods should consider comparability with other available data in the vicinity that may be useful as reference information.

The primary question addressed by most monitoring studies after sediment management activities is benthic invertebrate recovery rates (Sections 4.2.6, 4.2.7). Important considerations with respect to recovery relate to species composition, species-abundance relationships, and size distribution (or biomass) (Pearson and Rosenberg 1978, Reilly and Bellis 1983, Newell et al. 1998).

Newell et al. (1998) reviewed that a practical approach to determination of “recovery” is that at least 80% of the species diversity and biomass is restored. Therefore, the question of interest with recovery determinations is whether metrics such as species number and/or biomass are similar (e.g., within 80%) or greater than before impact and at control locations. This type of question has important implications with respect to hypothesis testing and sample size. Generally, fewer samples are required to test a one-tailed hypothesis (e.g., value is ≥ than before or control) than a two-tailed hypothesis (e.g., value is different, < or > than before or control) at the same level of power (Sokal and Rohlf 1969).

Fishes

Methods for trawl sampling are described in several of the above sources referenced under invertebrates (SCCWRP 1985, RPI et al. 2001). Generally, a 25- ft (7.6-m) otter trawl is used, and has been commonly employed for fish sampling off California. RPI et al. (2001) recommend a minimum of three day and three night trawls at each location. Sample analysis typically involves county by species, measurements of standard length, determination of sex, and weight; generally, length and weight is determined on a subsample of collected fish by species.

Marine Mammals

RPI et al. (2001) recommended shipboard monitoring during dredging (on dredge vessel or ancillary craft) and review of marine mammal stranding records. The shipboard monitoring would be conducted by qualified marine wildlife biologists and include observations for presence of marine mammals in the dredge area, documentation of behavior of marine wildlife to dredging activities, and documentation of any collisions or other negative interactions between the dredge vessels and/or support craft with marine wildlife. In addition, review of marine mammal and wildlife stranding data during and for 60 days following dredging events was recommended to check for possible correlation with dredging operation (e.g., body markings).

Rocky Habitats

Methods may include some combination of uniform point contact (UPC) sampling along transects, estimating density within swath transects of specified width and length, counts within quadrats, and/or photoplots (Hill et al. 1998, http://www.marine.gov/sampling-methods.htm, http://www.piscoweb.org/data/ catalog/intertidal_community). The different methods may be used to estimate percent cover of non-mobile invertebrates and vegetation and abundance of mobile invertebrates and fish.

The water column may be divided into near bottom, mid-water, and canopy sections for recording observations of fish. Timed searches sometimes are used to standardize effort with respect to surveys for rare or inconspicuous species (http://www.piscoweb.org/data/ catalog/intertidal_community).

Monitoring of rocky habitats to verify impact significance with respect to beach nourishment projects in California has involved transect- and quadrat-based techniques with assessment of key species (e.g., Chambers Group 2003, AMEC 2005, Engle 2005). Key indicators used during a recent California sediment management project are listed in Table 7.2-3.

Several long-term data sets of rocky intertidal and subtidal monitoring data are available for California that may provide useful reference data for studies conducted in association with sediment management projects (http://www.marine.gov/sampling-methods.htm, http://www. piscoweb.org/data/ catalog/intertidal_community).

SAV Habitats

Techniques employed to map habitat boundaries of vegetated habitats may include aerial photography and/or underwater swims with surface vessel GPS tracking. Time of year is an important consideration with respect to aerial photography due to natural, seasonal die-back

of vegetation. The CDFG posts online GIS shapefiles of kelp canopy along the California coastline based on use of a Digital Multi-Spectral Video system; historical data from 1989, 1999, and annual cover since 2002 are available at http://www.dfg.ca.gov/itbweb/gis/mr_nat_res.htm.

Assessment of habitat changes and/or degradation requires a systematic method such as transects and/or quadrats. For multiple survey sampling, semi-permanent sampling locations should be established with a BACI survey design both in the area of potential impact and at nearby reference areas. Monitoring of SAV habitats to verify impact significance with respect to beach nourishment projects has involved transect--based techniques to assess percent cover of key species such as surfgrass, eelgrass, and kelp and/or quadrat-based techniques to determine densities of indicators within a standardize area (e.g., Chambers Group 2004, AMEC 2005, Engle 2005). Percent sand cover also is measured to examine changes in sand level and relationship with potential sedimentation impacts.

Reef monitoring surveys
Photo credit: Danny Heilprin, SAIC

7.5.2 Burial and Sedimentation

Burial and/or sedimentation of sensitive habitats (reefs, SAV, fishery spawning grounds) may be a site-specific concern with sediment management projects. Several techniques may be employed to examine sand level changes and transport, including:

- Beach profiles.
- Sand level.
- Sediment traps.
- Remote Sensing.

Several of the above methods have developed with recent advances in technology and application may not be widespread. Information from these various methods may be very useful to sediment management planning. Resulting information may be very useful in providing empirical data to support biological impact evaluations that address the following types of questions:

Brief descriptions of the above methods are provided below with references for obtaining additional information.

Sediment profiles

Monitoring of beach profiles provides information useful for model verification; however, profile monitoring in California has been primarily used to document sediment movement, erosion, and/or persistence of beach nourishment projects (e.g., USACE 1991, Coastal Frontiers 2004). It is recommended that data from profile measurements and actual environmental data (wave climate) from the monitoring periods be used to examine model

performance and/or to identify appropriate analytical adjustments that would improve model performance.

Cross-shore beach profile surveys give an indication of trends in beach sand loss or gain for each profile over time. The beach shape also may plotted on a graph to show which section of the beach the sand moves in over the years of survey (e.g., Figure 5.4-2, Coastal Frontiers 2004).

A network of beach profiles is a useful management tool for indicating trends in sand movements at specific locations. Such information is relevant to biological impact evaluations of sedimentation associated with sand transport from beach nourishment locations.

Monitoring of beach profiles provides information useful for model verification; however, profile monitoring in California has been primarily used to document sediment movement, erosion, and/or persistence of beach nourishment projects (e.g., USACE 1991, Coastal Frontiers 2004). Sediment profiles also may be useful for examining cross-shore elevation change between survey periods to evaluate sedimentation. This is of particular interest for beach nourishment projects in areas with hard-bottom substrates downcurrent and/or offshore.

It is recommended that data from profile measurements and actual environmental data (wave climate) from the monitoring periods be used to examine model performance and/or to identify appropriate analytical adjustments that would improve model performance.

Sand Level

Although sand level trends are apparent from beach profile data, direct sand level measurements provide a more precise measure of seabed depth changes. Semi-permanent rods or poles may be used and/or a measuring rod may be used during field surveys depending on question of interest. The following two examples illustrate use of sand level measurements.

SACPB (2000) uses brass sand level rods were installed in 1987 to monitor seabed changes in nearshore areas. The top of the rod is used as a datum to measure seabed height changes. Rods were installed along cross-shore profiles, spaced 82 ft (25 m) apart, for the first 3,281 ft (1000 m), then 164ft (50 m) apart further offshore. The rods have a known position and are located using a GPS by boat, then divers locate the rods underwater by compass and measure the rod heights. The rod lines are measured annually and compared with data from other survey methods to provide precise measures of sand level. This method may be useful in areas where mixed bottom type (e.g., and, hard bottom) occur adjacent to beach nourishment sites.

Measuring rods were used to determine sand depth (to refusal or 4 ft) during surveys examining habitat quality for sandy beach fauna before and after beach nourishment in the City of Encinitas, California (MEC 2000a, SAIC 2006). The primary author found the information useful for examining available sand habitat depth, degree of sediment reworking, sand level change, and sand depth persistence in the context of habitat suitability for invertebrates and grunion spawning.

Remote Sensing

Useful References for Seafloor Mapping

The CSUMB Seafloor Mapping Lab: http://seafloor.csumb.edu

USGS Pacific Seafloor Mapping Images: http://walrus.wr.usgs.gov/pacmaps/site.html

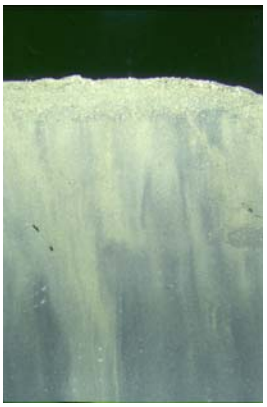
Several technologies involving high-resolution, acoustic remote sensing are being used to provide accurate and highly detailed seafloor maps in California. Technologies include bathymetric LIDAR, hydrographic techniques (multibeam and side-scan sonar), digital elevation models (DEM), and GIS based integration. Statewide seafloor maps with bathymetry, seabed geomorphology (via DEM), and texture (substrate type via acoustic backscatter and reflectance mosaics) are planned for California state waters (http://seafloor.csumb.edu).

Maps provide valuable information on habitat types (rocky versus sandy substrate), relief height, enable quantification of habitat types, and when created at different times can be subtracted from each other to precisely quantify environmental change (e.g. sediment transport, erosion and burial) (Canright 2005).

Acoustic surveys, videos, and underwater still photography have been successfully used to provide high resolution images of the seabed after trailer hopper dredging (e.g., Hitchcock et al. 2002, Boyd et al. 2004, Cooper 2005).

Underwater Photography

Benthic photography using a sediment profile camera may be used to provide images of the sediment profile and sediment-water interface. This methodology has been noted as being useful for examining thin layer, sedimentation (Germano and Cary 2005, Wilber et al. 2005).



Sediment Profile Camera **Sediment profile image**

Photos: SAIC

Modeling

A method of beach surface modeling has been applied in some coastal areas to more closely monitor beach erosion areas and major beach replenishment projects (SACPB 2000). Hydrographic, terrestrial and photogrammetry techniques are combined over the study area to create a dense grid of surface points, each with geographical position and elevation details, which are input into GIS to create the surface model (Fotheringham and Goodwins 1990 cited in SACPB 2000). When the model area is resurveyed, one surface model is subtracted from the other to produce a beach surface difference contour map with gradational shading corresponding to different levels of change.

The map is considered useful for identification of areas of sand loss or gain, supports improved calculations of volume changes, and also has been used to monitor effects of offshore dredging on sites where sand has been removed to replenish other areas of coastline (SACPB 2000).

Integrated GIS

Use of Geographic Information Systems (GIS) can greatly assist integration of different types of monitoring data to increase understanding of coastal change and assist shoreline management. For example, .beach profile data can be overlayed on beach surface difference maps and cross-referenced with sand level measurements for mapping sand movement, checking the accuracy of sand gain and loss volume calculations, examining trends over time, and supporting shoreline management decisions (SACPB 2000).

7.6 Summary and Recommendations

Nelson (1993) summarized that while evidence is beginning to accumulate that there can be minimum biological effects of beach nourishment where projects are properly designed, he considered it premature to decide that biological monitoring is unnecessary. Based on the current document review, his statement is still valid.

Many of the potential impacts associated with sediment management activities may be avoided and minimized when projects are properly designed and implemented (Section 6). However, data gaps and limitations indicate a need for additional information to assist environmental planning and protective design of sediment management projects in areas with sensitive biological resources in the vicinity.

There also is evidence that potential for impact varies depending on project size, proximity to sensitive resources, and natural disturbance regimes of receiving environment. Those factors should be taken into consideration with respect to development of appropriate scale monitoring programs.

Monitoring requirements will differ depending on project- and site-specific conditions. The following monitoring considerations are recommended:

- The objectives of the mitigation and monitoring program, methods, coordination and/or communication protocols, compliance criteria, analysis methods, and schedule should be specified. Monitoring conducted to verify impact significance should specify criteria that will be used to conclude that an impact is significant.
- Standardized monitoring should be conducted to the extent practical to support regional assessments of cumulative impacts.
- Sediment compatibility – Beach nourishment projects that use sediments that substantially differ in physical characteristics from the native beach sediments should require more extensive monitoring unless the change represents an enhancement (e.g., cobble to sand). Testing should verify that sediment characteristics do not become unsuitable for native fauna over time.
- Proximity to sensitive resources – Projects with sensitive resource in the vicinity at potential risk from equipment removal and/or sedimentation impacts should include impact verification monitoring.
- Project size – Larger projects should require more monitoring than small to mid-sized projects. Monitoring should be ecosystem-based.
- Less disturbed habitats – Monitoring of benthic recovery rates is recommended for sediment management projects conducted in less disturbed, nearshore habitats (e.g., borrow sites, nearshore placement). Although projects are unlikely to occur at beaches with persistent sand from a need standpoint, if a project was to occur (e.g., site used as feeder beach), monitoring is recommended to determine recovery rate. Monitoring should be ecosystem-based.
- Frequency of nourishment – Projects that require periodic renourishment should include monitoring that supports an adaptive management approach; i.e., adjustment in procedures and/or volumes to maintain project benefits in balance with environmental impacts.
- A BACI sampling design should be used for monitoring programs that address verification of impact significance or recovery rates so that impact can be detected from natural variability.

8.0 RECOMMENDATIONS

Section Topics:

8.1 Methods to Minimize Impacts

8.2 Methods to Improve Impact Assessment and Streamline Environmental Review and Permitting

8.3 Regional Management of Cumulative Impacts and Ecosystem Benefits

This report section addresses the following question of the CSMW.

- *How can potential impacts from sediment management activities to coastal biota and ecosystems be minimized in order to reduce the concerns of the regulatory community and streamline permitting of sediment management activities?*

Objectives of this study include providing the following types of recommendations:

- Provide recommendations for protecting California's resources during sediment management activities based on current understanding of potential impacts.
- Provide science-based recommendations to address critical information gaps.
- Provide recommendations to reduce environmental concerns and streamline permitting of sediment management activities.

Photo credit: Danny Heilprin, SAIC

The recommendations presented in this section emphasize the following considerations:

- Protective environmental design of sediment management projects.
- Effective monitoring and operational controls during project implementation.
- Focused monitoring to fill critical information gaps on linkages between coastal processes-biological responses and impact management.
- Establishment of thresholds of significance relevant to sediment management projects.
- Effective use of an informal coordination process with resource agencies and interested stakeholders to achieve multiple use objectives at local and regional scales.
- Development of tools, guidelines, and processes to facilitate more effective management of ecosystem and cumulative impacts on a regional basis.
- Recognition and Incorporation of ecosystem benefits into economic cost-benefit formulations so environmentally sound sediment management becomes the preferred alternative.

Section 8.1 recommends methods for minimizing impacts. Section 8.2 suggests methods to improve impact assessment and streamline environmental review and permitting of future projects. Section 8.3 recommends actions to improve management of cumulative impacts and ecosystem benefits associated with regional sediment management.

8.1 Methods to Minimize Impacts

There are several mechanisms to minimize impacts associated with sediment management projects. General recommendations are given below and more detailed descriptions of measures are provided in Section 6.

Pre-construction project design is probably the most important consideration for minimizing adverse ecological impacts from sediment management activities. Opportunities to minimize impacts also are present during project implementation by use of environmentally sensitive construction methods, operational controls, and compliance monitoring. Just as project design is unique to the specific objectives and constraints that shape the definition of each project, so too are the considerations associated with minimizing biological impacts. The recommendations provided below address each of the main components associated with project design and implementation. The applicability of the recommendations to any particular project will depend on the following key factors:

- Project design,
- Construction schedule,
- Construction implementation controls and monitoring, and
- Frequency of activity.

8.1.1 Project Design

The primary objective with environmental project design is to appropriately match design with environmental constraints so that impacts are kept below critical thresholds. An effective feedback loop between project engineers and biologists is recommended to achieve environmentally sensitive project designs.

Important design considerations include environmental constraints, placement location, project size, sediment characteristics, and construction schedule.

8.1.1.1 <u>Environmental Constraints</u>

- Conduct pre-construction surveys and/or environmental review to identify sensitive habitats and sensitive species in area of potential effect and refine design to avoid significant direct and indirect impacts to these resources from project implementation.
- Evaluate beach receiver sites for potential habitat suitability for California grunion spawning based on physical substrate characteristics (sand depth, cobble or other hard substrate cover) and beach width (i.e., available sand habitat above the average neap high tide line associated with the project schedule). Because habitat suitability may vary seasonally; i.e., become more suitable between spring and summer as sand accretion occurs, habitat suitability should be evaluated 30 days before any scheduled placement activity.
- Conduct pre-construction surveys to refine vessel, anchoring, and temporary pipeline locations if sensitive resources occur in the area.

8.1.1.2 Placement Location

- Select beach placement locations for nourishment and shoreline protection objectives that avoid direct impacts to sensitive habitats and species and minimize potential indirect turbidity and sedimentation impacts to sensitive nearshore habitats.

- Select beach placement locations for harbor and lagoon maintenance projects with consideration given to historic use frequency, morphodynamics of beach (if there is choice, select intermediate erosive beach over relatively flat dissipative beach), and potential for occurrence of sensitive species. If sensitive species have potential to occur, include mitigation measures that either restrict construction schedule to outside their occurrence period or implement monitoring and protective measures (e.g., buffers, temporarily halt construction) during construction.

- Select beach and nearshore placement locations that are downcurrent and sufficient distance from inlets to coastal lagoons, creeks, and rivers to minimize increased sedimentation and maintenance requirements for these small water bodies and to avoid interference with migratory runs of salmonids, where applicable.

- Select nearshore placement locations that are sufficient distance from sensitive habitats (kelp beds, surf grass beds, eelgrass beds) to avoid significant turbidity and sedimentation impacts.

- Select locations for sand mining (borrow sites) that are sufficient distance from sensitive habitats (kelp beds, surf grass beds, eelgrass beds) to avoid significant turbidity and sedimentation impacts.

8.1.1.3 Project Size and Configuration

- Appropriately match project size to biological constraints. For example, this may involve placement of a larger volume in an area with little environmental constraints to serve as a feeder beach to downdrift beaches, and/or placement of small to mid size volumes at multiple sites to promote more gradual sediment transport and minimization of potential impacts to sensitive resources.
- Excavate coastal sand mining areas (borrow sites) to relatively shallow depths to avoid creation of deep pits with altered biological resources. Incorporate refuges into design to facilitate rapid recovery.

8.1.2 Construction Schedule

The Corps has concluded that information necessary to formulate technically sound environmental work windows is generally inaccessible or unavailable and has led to restricted project flexibility, cost, and inconsistent application of windows among Corps Districts (Reine et al. 1998). Different work window and schedule restrictions to avoid impacts to threatened and/or endangered and other managed sensitive species are reported

in various environmental documents, permits, sediment management plans, and on-line information sources. This study identified inconsistencies in application of environmental windows within and among different geographic locations in California.

It is recommended that the CSMW coordinate a workshop with resource and regulatory agencies to review existing criteria to guide when environmental work windows for dredging and beach nourishment are appropriate. Review of projects from California and other areas of the United States indicate similarities in turbidity plume and deposition processes that suggest buffers may be effective operational controls. Information on noise levels also permit determination of appropriate buffers to below harassment levels for sensitive wildlife. Other operational controls combined with monitoring appear to be effective at avoiding adverse impacts to sensitive wildlife. Furthermore, project size is an important consideration with respect to impact exposure duration. Nevertheless, there are circumstances when environmental window restricted periods are the most effective protective measures, particularly when proximity controls cannot be satisfied and/or in confined channels and basins where potential risk for impact is higher.

8.1.3 Construction Implementation Controls and Monitoring

The environmental objective during construction should be to control activities to avoid significant impacts and minimize adverse impacts. When possible, projects should be implemented in a way that is analogous to natural events so tolerance responses and recovery following natural processes are maximized. Important considerations during project implementation include pre-construction coordination, operational controls, compliance monitoring, and documentation of mitigation effectiveness.

Mitigation measures and monitoring associated with pre-construction and construction phases of sediment management projects are reviewed in detail in Sections 6 and 7. The following recommendations focus on activities that if implemented could increase consistency and improvement in environmental protection during implementation of sediment management projects.

8.1.3.1 Pre-Construction Coordination

- Conduct early informal coordination with resource agencies to review EFH and sensitive species mitigation measures (see Section 6.6.2)
- If commercial fishing activities occur in the project area, pre-coordination with local commercial fishing organizations is recommended to ensure important fishery grounds are protected and minimal interference to fishing activities. Impact assessments of managed fisheries at a project-specific level may be challenging as a result of limited information on spawning grounds, fishing areas, and use patterns at a local level. Fishing organizations have expressed concerns with beach nourishment projects involving beach and/or nearshore placement of sand in areas with important fisheries. An informal coordination process with local fishing organizations and resource agencies (CDFG, NMFS) is recommended to facilitate exchange of relevant information to improve CEQA/NEPA evaluations by having better understanding of local fishery impact areas of concern, agreement on significance thresholds, and

identification of mitigation measures to minimize interference with local uses while ensuring appropriate resource protection.

8.1.3.2 Standardized Monitoring

Standardize Water Quality Compliance Monitoring to Increase Biological Relevance

There is little standardization among RWQCB water quality monitoring requirements associated with sediment management activities in California. Differences exist in what has been required to be monitored, methods of monitoring, locations of monitoring relative to distance from dredge and/or disposal sites, and frequency of monitoring. These limitations hamper the identification of near field and far field zones of influence and associated measured values, which in turn makes it difficult to develop science-based buffers for protection of sensitive resources from water quality impacts during sediment management operations. It is recommended that the CSMW lead a workshop with resource and regulatory personnel to review and discuss representative water quality data associated with sediment management activities, biological relevance of monitored variables and measured values, and recommendations for standardizing water quality monitoring requirements for future sediment management projects (Section 8.2.3). Standardized monitoring not only would be useful for defining protective buffers, but also could simplify environmental impact analysis of future projects.

Increase Standardization of Methods Used to Monitor Sediment Management Projects

An often cited criticism is that there has been little standardization in the design and methods of environmental studies of beach nourishment projects, and that they have been limited in scope and duration (NRC 1995, Greene 2002, Bishop and Peterson 2005). Consequently, many of the environmental concerns with respect to beach nourishment have not been resolved over the last decade when this deficiency was pointed out. Monitoring guidance recently was prepared to support MMS surveys of potential borrow sites on the East and Gulf Coasts of the United States. Standardized guidelines for monitoring beach nourishment projects of different size would help streamline environmental review. It is recommended that the CSMW lead a workshop with resource agencies to review monitoring guidance and reporting standards (Section 8.2.3). The outcome of the workshop could be used to refine the methods presented in Section 7 of this report and/or to prepare a separate technical guidance document.

8.1.3.3 Monitoring Feedback Loop to Adaptive Management

- Activities undertaken after construction may include monitoring to assess project performance and implementation of additional mitigation measures, if required. Post construction monitoring of project performance may be a permit requirement for certain projects based on considerations of project size and proximity to sensitive habitats. The objective of this type of monitoring is to directly evaluate and verify no significant impacts to sensitive biological resources.

- It is recommended that any post construction biological monitoring be conducted using a BACI (Before-After, Control-Impact) survey design. The need for this type of monitoring should be identified during environmental review and included in the mitigation, monitoring, and reporting program (MMRP) developed for the project. Definition of what constitutes significant impact and how such an impact would be identified (including statistical analysis) by the monitoring program should be specified in the MMRP. In addition, the MMRP should include definition of appropriate compensatory and/or restoration mitigation including success criteria and inclusive costs to implement mitigation including appropriate construction, monitoring, and reporting elements.
- It is recommended that monitoring be conducted to evaluate potential impacts when project designs substantially differ from previously permitted projects within the project area. Considerations may include substantial increases in project volume, use sands that differ by more than 10 percent from receiver site characteristics, substantially modified project location boundaries, and/or use of new equipment and/or technologies. Monitoring should follow a BACI survey design and include specification of how data will be used to evaluate project impacts and/or the effectiveness of new equipment/technologies.

8.1.3.4 Documentation of Mitigation Effectiveness

Different protective measures have been employed to minimize impacts during construction. However, limited monitoring data are available for assessing the effectiveness of protective measures. It is recommended that any permit required monitoring programs include a field on data sheets that identifies what protective measures, if any, were in effect during monitoring, and specification of how data will be used to facilitate evaluations of the effectiveness of protective measures in the monitoring report.

8.1.4 Frequency of Sediment Management Activity

A substantial volume of literature and reports document that benthic community structure is related to frequency of disturbance. Generally, simpler communities dominate frequently disturbed habitats and diversity increases with less disturbance. In the context of sediment management projects, this means that areas subject to regular maintenance dredging generally have a lower habitat quality than less frequently dredged areas in embayments. Along the shore, sandy beach habitats generally support less diverse benthic communities due to the high energetic surf zone than communities in the nearshore and offshore. The biota that use the beach habitat, however, are naturally adapted to the disturbance associated with sand erosion in winter and accretion in summer, displaying seasonal cycles of recruitment and productivity. Fish display seasonal onshore and offshore migration and many of birds that frequent the shores are seasonal migrants. Therefore, frequency of beach nourishment may be less of an issue for sandy beach habitat when projects are scheduled to avoid and/or minimize disturbance of spring-summer benthic recruitment periods. Factors such as project size and disturbance regimes at other beach sites in the region should be considered to avoid and/or minimize the potential for cumulative impacts to wildlife (fish, shorebirds) dependent on a healthy invertebrate forage base if projects schedules extend into spring recruitment periods.

It is recommended that design strategies and/or watershed management be incorporated into project design to decrease the frequency of sediment management activities, where feasible. Design strategies may include avoidance of repetitive disturbance at a frequency that degrades ecosystem function, incorporation of dune restoration and/or rehabilitation into beach nourishment projects to enhance ecological function and longevity of fill performance, and use of sedimentation basins and source control to decrease the frequency of maintenance dredging. ,

Nearshore habitats generally experience substantial disturbance less frequently. Notable exceptions include ENSO events when high wave conditions may result in substantial sand movement and scour much farther offshore than typical under average wave conditions (or hurricane in other parts of the United States). Other exceptions may include areas with strong currents such as where ridge-and-swell topography occurs or near canyons and slope areas. These differences in natural resilience to disturbance should be considered with respect to sediment management projects involving nearshore or profile placement or offshore borrow site dredging. Slow recovery rates (years) to disturbance generally occur unless activities occur in areas naturally subject to frequent disturbance. It is recommended that factors such as project size, area of disturbance, and frequency of disturbance be given careful consideration to avoid cumulative impacts associated with use of nearshore and offshore habitats for sediment management activities.

8.2 Methods to Improve Impact Assessment and Streamlining Environmental Review and Permitting

The recommendations address streamlining throughout impact assessment, environmental review, and permitting. Recommendations address the following elements:

- Establish Standardized CEQA thresholds of significance,
- Incorporate Protective Measures in Project Description,
- Establish guidelines for impact significance thresholds, protective measures, and monitoring, and
- Fill critical information gaps.

8.2.1 Establish Standardized CEQA thresholds of significance

Thresholds of significance are considered a proven method of streamlining the CEQA process; however, few agencies have formally adopted them and limited attention has been given to thresholds for coastal marine habitats and resources. It is recommended that the CSMW coordinate and encourage local municipalities to adopt thresholds of significance applicable to sediment management projects.

8.2.2 Incorporate Protective Measures in Project Description

It is recommended that protective measures to avoid and minimize impacts be incorporated in project descriptions to the maximum extent possible to increase understanding of protective design and resource protection, and to minimize the need for special permit conditions and/or additional mitigation measures.

8.2.3 Establish Guidelines for Impact Significance Thresholds, Protective Measures, and Monitoring

It is recommended that the CSMW coordinate workshop(s) with resource and regulatory agencies to review available technical information and develop interim guidelines to facilitate more standardized environmental assessments and streamlined review of projects proposed in areas with sensitive habitats and species. The interim guidelines should be periodically reviewed and adapted as additional information from technical studies and monitoring become available.

It would be useful if the interim guidelines addressed the following types of information with consideration given to differences in impact concern relative to sediment management activity, project size and duration, placement location, and proximity to sensitive resources.

- Critical impact thresholds.
- Construction mitigation measures (e.g., buffers, construction methods, operational controls, monitoring) that may be acceptable under differing project conditions to satisfy EFH and ESA requirements. Priority should be given to developing guidelines for California grunion, California least tern, Dungeness crab, salmonids, and western snowy plover, which are most commonly regulated by environmental window restricted conditions.
- Process and/or methods to obtain relevant information on sensitive fishery grounds in project area of potential effect.
- Compliance monitoring.
- Impact significance monitoring.

8.2.4 Fill Critical Information Gaps

8.2.4.1 Beach Nourishment Sediment Compatibility

Minimizing the deviation in grain size characteristics between source and receiver sites is the most often recommended measure to minimize biological impacts from beach nourishment projects (Naqvi and Pullen 1982, NRC 1995, Peterson et al. 2000b, Greene 2002, Speybroeck et al. 2006). Similarly, minimizing change in surface substrate characteristics is recommended to minimize recovery rates of invertebrates after offshore dredging (Hurme and Pullen 1988, Kenny and Rees 1996, Newell et al. 1998, Boyd et al. 2004) and to avoid inferring with the ability of shorebirds to probe the sands for invertebrate prey (Peterson et al. 2002). These recommendations are considered precautionary and ecologically sound based

on current understanding of the importance of animal-sediment relationships.

However, limited information is available with respect to critical thresholds of substrate characteristics to protect biological resources and functions. Several available studies suggest some species are substrate generalists and occur on a broad range of beach types with differing environmental conditions (e.g., *Emerita* sand crabs, Dugan and Hubbard 1996), while others may be adversely affected by coarser sediments or increased silt/clay content (Lassuy and Simmons 1989, McLachlan 1996, Nel et al. 2001).

That animals differ in tolerances to broad or narrowly defined substrate conditions is not surprising given the differences in beach morphodynamic types. Many of the sandy beaches in southern California are of the intermediate bar-trough morphology (Dugan et al. 2000a), which are the most dynamic with respect to erosion and accretion and sand mobility (Wright and Short 1984). Based on considerations of beach morphology and wave climate, it seems reasonable that the definition of sediment compatibility from an ecological standpoint may differ between highly dynamic versus less energetic coastlines. For example, sediment grain size characteristics may vary over a smaller range at less energetic, dissipative beach types than at more dynamic intermediate type beaches. However, this is not addressed in current sediment compatibility definitions, which are generally similar among different areas in the United States.

Better understanding of the range of physical conditions (hydrodynamics, substrate characteristics) defining similar invertebrate forage base characteristics may be useful for optimizing sediment compatibility criteria for local and/or regional environmental conditions. This information also may be useful for assessing environmental performance of opportunistic sand programs such as the SCOUP program, which may involve use of less-than-optimum sands in areas, when appropriate. Having a better understanding of sediment compatibility under different project size, hydrodynamic, and physiographic conditions could contribute valuable technical data to support science-based decisions with respect to optimizing the use of a range of potential available sediment sources in an ecologically sound manner.

8.2.4.2 Turbidity and Sedimentation

There is a need for better empirical data on turbidity and sedimentation during sediment management projects. A major gap in understanding relates to the relevance of laboratory-based effects studies and field studies in areas subject to chronic impacts to the turbidity-sedimentation regimes that actually occur during sediment management projects.

Part of the issue may be resolved by improved standardization and biological relevance of water quality monitoring required to satisfy compliance with 401 Water Quality Certification requirements (Section 8.1.3.2).

Another aspect of the issue relates to a need for advancement in the accuracy of model predictions of sediment transport based on local and regional scales of sediment management planning (Section 8.2.4.3).

One of the most difficult challenges of environmental impact analysis of beach nourishment projects is evaluation of the potential for post project sedimentation impact to sensitive resources. Of particular concern are depth and duration of potential sedimentation since

sensitive habitats and species differ in their tolerances and vulnerabilities to sedimentation. It is recommended that the CSMW coordinate a technical workshop with resource and regulatory agencies to review of analytical strengths and weakness of existing sediment transport models, development of an approach for improving the predictive accuracy of analytical models, and approach for obtaining empirical data during representative beach nourishment projects to provide data necessary for model validation and refinement.

Limited information is available on temporal trends in suspended sediment loads discharged from streams. This data gap if filled could be used to examine relationships of differences in quality of sensitive vegetated and/or reef habitats with distance from inlets and/or suspended sediment discharge loads. Better understanding of these relationships could provide a scientific basis for optimizing sediment management planning decisions with respect to beach nourishment receiver site locations and size in areas with sensitive habitats.

8.2.4.3 Validate and Improve Accuracy of Sediment Transport Models

Predictive models (e.g., GENESIS) have been developed to better understand fate and transport of sediments in coastal environments. A number of environmental variables affect model robustness and prediction accuracy. Monitoring of beach profiles provides empirical data of sand movement cross- and alongshore. Beach profiles may be monitored with beach nourishment projects (e.g., Coastal Frontiers 2004). However, post-project validation of model predictions do not appear to be routinely applied in California (R. Boudreau and D. Cannon, 2007 personal communications). This data gap limits adaptive improvement in the accuracy of model predictions under local conditions based on empirical data and lessons learned in California. This is considered particularly relevant in areas with nearshore reefs where model assumptions (i.e., based on sandy seabed) are not met and biological protection issues are of particular concern. There also are concerns that factors such as bathymetry, slope, and hydrodynamics that occur off California are not adequately factored in existing models, which were developed to address transport under east and/or gulf coast conditions (D. Cannon, 2007 personal communication).

Routine monitoring of beach profiles in littoral cells where beach nourishment is planned and/or has been implemented would be useful for developing long-term data sets that may be used in the near-term to validate and improve performance of existing sediment fate-and-transport models using local environmental and physical conditions. Over the long-term, use of beach profiles, local wave data, and seafloor mapping would be useful for developing models more specific to environmental conditions unique to Calfornia.

Biological resource questions that would benefit from improved model prediction performance include:

- Post project sand thickness increase and persistence in areas with sensitive reef and/or SAV habitats (e.g., SANDAG and USDN 2000, CRM 2000, USACE 2005).
- Potential shoaling rates and potential alteration of maintenance dredge frequency of downstream inlets.
- Germano and Cary (2005) consider model refinement to quantify the extent and timing of mixing along the sediment-water interface essential to quantitatively defining biological impacts of dredged-induced sedimentation.

- Germano and Cary (2005) also reviewed that the dynamic energy budget (DEB) model is very useful for specific predictions of impacts and how to link individual effects to population responses, but the models require detailed laboratory results on response of specific organisms to sedimentation.

8.3 Regional Management of Cumulative Impacts and Ecosystem Benefits

8.3.1 Expand Regional Databases and GIS Tools to Facilitate Protection of Biological Resources and Management of Cumulative Impacts

Available studies indicate that cumulative impact detection requires a comprehensive analysis approach. Geographic Information Systems (GIS) have been used to map and overlay fishery resource areas and fishery patterns to support cumulative impact analyses of marine aggregate extraction areas and to more quantitatively assess the potential for impacts from future dredging licenses (Cooper 2005). GIS also has been used to assess the regional sensitivity of fisheries to human impact (Stocks et al. 2001 cited in Cooper 2005). Given that sediment management activities associated with beach nourishment affect broad geographic littoral cells, it makes sense to examine the potential for cumulative impacts from sediment management on a regional scale.

8.3.1.1 Regional Biological Resource Database

It is recommended that regional GIS tools be developed that include mapping of nearshore, sensitive biological resources (including seasonal differences) and fishery resources within the depth range at potential risk to impacts from sediment management activities. These layers would complement the GIS database being developed by the CSMW and facilitate optimizing locations of beach nourishment based on environmental concerns and opportunities.

8.3.1.2 Regional Cumulative Projects Database

It is recommended that regional planning agencies (e.g., SANDAG, BEACON) compile a master list of planned and foreseeable future coastal projects from coastal municipalities within their sphere of influence to facilitate cumulative impact assessments. Relevant information to include on the list include: project location, project size, oincludes littoral cell compile their coastal project lists on a bi-annual basis An information tool that would be beneficial to support cumulative impact analysis.

8.3.2 Minimize Multi-Use Cumulative Impacts

Beach grooming is not a direct activity associated with beach nourishment. However, beach grooming may be undertaken at beaches that receive direct and/or indirect nourishment. Therefore, beach grooming may be indirectly related to sediment management activities that put sand on the beach.

Beach grooming has been demonstrated to impact grunion egg viability and reduce wrack associated forage for shorebirds. Beach maintenance best management practices to protect sensitive grunion habitat have been developed and workshop outreach has been conducted since in 2003 with resource and beach managers. Beach management practices are discussed particularly as they concern sharing the shoreline with humans and wildlife, including avoidance of grunion spawning habitat and minimizing disturbance of the wrack line that provides foraging opportunities for shorebirds such as the threatened snowy plover. Guidance implementation is voluntary and has been adopted by several municipalities from Santa Barbara to San Diego (K. Martin, 2007 personal communication).

It is recommended that CSMW formally recognize and assist this voluntary effort by including beach maintenance BMPs as an information topic on their website, including a link to www.grunion.org. In addition, beach maintenance guidelines should be incorporated into project level planning where beach nourishment is conducted.

8.3.4 Incorporate Ecosystem Benefits into Regional Sediment Management Planning

Regional sediment management (RSM) planning is being conducted by the CSMW to facilitate decision making relative to matching sediment sources to areas of need based on consideration of a variety of factors. The following recommendations are made relative to RSM planning, as follows:

- Incorporate environmental constraints into RSM planning.
- Conduct RSM planning on a littoral cell basis.
- Address cumulative impact concerns on a littoral cell basis.

It is recommended that biological constraints information be compiled for each littoral cell according to sediment management needs. A standardized checklist should be developed to summarize sensitive biological resources within specified distance categories (e.g., within 1,000 feet, 2,000 ft, 1 mile, 2 miles) from historic and candidate beach nourishment sites (e.g., erosion hot spots). The checklist should consider other planning level environmental constraint checklists (e.g., SCOUP) and include identification of environmental issues such as erosion that may place sensitive habitats at risk, habitat degradation, and/or restoration need. Relevant geo-referenced point and/or coverage data on sensitive habitats and species also should be compiled as available for inclusion in GIS, with priority given to data that exhibits limited annual variability.

Conducting RSM planning on a littoral cell basis may facilitate optimization of beach nourishment design (locations, volumes) by consideration of sediment transport budget, locations of erosion hot spots, and locations of environmental constraints. In addition, planning on a littoral cell basis may improve evaluations and effectiveness of planning measures to minimize potential cumulative impacts associated with multiple uses of the coastal zone. This step has the potential to provide an important feedback-loop for appropriate environmental design of sediment management projects to meet shoreline protection needs while protecting biological resources. An important aspect of environmental design and cumulative impact analysis is public recreational use patterns and beach

management practices. Biological resource use patterns, particularly shorebirds, are influenced by recreational use.

8.3.5 Documentation of Environmental Benefits

Beach nourishment often is the result of beneficial reuse of dredged material and may become an increasing beneficial use of sediment associated with coastal development as implementation of opportunistic sand programs (e.g., SCOUP) become more common. The term beneficial use in this context simply means use of the resource in productive ways (http://el.erdc.usace.army.mil/dots/budm/intro.cfm?Topic=Sediment).

Limited available information indicates that beach nourishment, if appropriately applied, may provide beneficial ecosystem functions. Sandy beaches provide habitat for marine invertebrates, which serve as prey for foraging shorebirds and nearshore fish. In addition, beaches provide important resting habitat for migratory shorebirds and far-ranging seabirds. Furthermore, they serve as spawning habitat for managed fishery species such as the California grunion. These habitat functions may become severely limited or eliminated at beaches subject to sand deficit and erosion. A recent study suggests that that these habitat functions were improved at erosive beaches after beach nourishment. Furthermore, limited available information suggests that adverse biological effects may be minimized when beach nourishment projects use are appropriately designed and implemented. Dissimilarities in substrate characteristics from native beaches and/or unfavorable seasonal timing distinguish projects where more pronounced adverse impacts have been reported.

Funding beach nourishment projects provides the opportunity to achieve multiple benefits that include environmental considerations besides the more commonly understood benefits to recreation, protection of property, public safety, and local economies. However, a more substantial body of biological monitoring is needed to better understand how to optimize the design of beach nourishment projects to satisfy both engineering and environmental objectives. Most monitoring programs have focused on documentation of sand transport and beach width performance or evaluations of adverse biological impacts and recovery. Little to no emphasis has been placed on monitoring biological resources to provide information to improve project design relative to resource protection and environmental benefits. It is recommended that a more balanced approach to monitoring be factored into funding allocations to provide information necessary for effective multi-benefit design of future beach nourishment projects.

It also is recommended that ecosystem benefits be included in cost-benefit ratio formulations to help ensure that the environmentally preferred alternative is the most ecologically sound in protecting California coastal biota.

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This document benefited from coordination, discussions, and comments from reviewers.

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Other Acknowledgements

The documented benefited from the primary author's discussions with the following individuals:
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David Cannon, P.E., Everest International Corporation
Tom Dean, Ph.D., Coastal Resources
Jack Engle, Ph.D., University of California, Santa Barbara
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10.0 LITERATURE CITED

Abbott, I.A., and G.J. Hollenberg, 1976. Marine Algae of California. Stanford University Press, Stanford, California. 827 pp.

Alstatt, J.M., R.F. Ambrose, J.M. Engle, P.L. Haaker, K.D. Laffery, and P.T. Raimondi, 1996. Recent declines of black abalone *Haliotis cracherodii* on the mainland coast of central California. *Marine Ecology Progress Series*, 142:185-192.

Anders, F.J. and S.P. Leatherman, 1981. The effects of off-road vehicles on beach and dune systems, Fire Island National Seashore. *University of Massachusetts/ National Park Service Cooperative Research Unit Report.* No. 60, 176 p.

Anders, F.J. and S.P. Leatherman, 1987. Effects of off-road vehicles on coastal foredunes at Fire Island, New York, USA. *Environmental Management*, 11(1):45-52.

Anderson, D. W. 1988. Dose-response relationship between human disturbance and brown pelican breeding success. *Wildland Society Bulletin,* 16:339-345.

Applied Ecology Solutions (AES), 2006. Supplementary Environmental Effects Statement. X12 Underwater Noise – Marine Biota. Final Report. Report prepared for Port of Melbourne Corporation.

Aquatic Bioassay and Consulting, Inc. (ABC), 2002. The Marine Environment of Marina del Rey Harbor, July 2001-June 2002. Prepared for the Department of Beaches and Harbors, County of Los Angeles.

Ainley, D.G. and S.B. Terrill, 1998. Seabirds and Shorebirds in Monterey Bay National Marine Sanctuary Site Characterization. http://www.mbnms.nos.noaa. gov/sitechar/.

Airoldi, L. and F. Cinelli, 1997. Effects of sedimentation on subtidal macroalgae assemblages: an experimental study from a Mediterranean rocky shore. *Journal of Experimental Marine Biology and Ecology*, 215(2):269-288.

Alcoverro, T., R.C. Zimmerman, D.G. Kohrs, and R.S. Alberte, 1999. Resource allocation and sucrose mobilization in light-limited eelgrass *Zostera marina. Marine Ecology Progress Series,* 187:121-131.

Alexander, R.R., R.J. Stanton, and J. Dodd, Jr., 1993. Influence of sediment grain size on the burrowing of bivalves – correlation with distribution and stratigraphic persistence of selected neogene clams. Palaios 8, 289-303.

Allee, R. J., M. Dethier, D. Brown, L. Deegan, R. G. Ford, T. F. Hourigan, J. Maragos, C. Schoch, K. Sealey, R. Twilley, M. P. Weinstein, and M. Yoklavich. 2000. Marine and estuarine ecosystem and habitat classification. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-43. 43 p.

Aleem, A.A. 1973. Ecology of a kelp-bed in southern California. *Botanica Marina.* Vol. XVI, p. 38-95.

Allen, L.G., 1988. Recruitment, distribution, and feeding habits of young-of-the-year California halibut (*Paralichthys californicus*) in the vicinity of Alamitos Bay - Long Beach Harbor, California, 1983-1985. Bull. South. Calif. Acad. Sci. 87:19-30.

Allen, L., 1999. Fisheries Inventory and Utilization of San Diego Bay, San Diego, California. Final Report, Sampling Periods July 1994 to April 1999. Nearshore Marine Fish Research Program, Cal State Northridge.

Allen, M.J. and K. Herbinson, 1990. Settlement of juvenile California halibut, *Paralichthys californicus* along the coasts of Los Angeles, Orange, and San Diego Counties in 1989. *CalCofi Rep.* 31:84-96.

Allen, L.G., A.M. Findlay, and C.M. Phalen, 2002. Structure and standing stock of the fish assemblages of San Diego Bay, California from 1994 to 1999. *Bulletin Southern California Academy of Sciences,* 101(2):49-85.

Allen, S.G., D.G. Ainley, G.W. Page, and C.A. Ribic. 1984. The effect of disturbance on harbor seal haul-out patterns at Bolinas Lagoon, California. Fishery Bulletin 82:493-500.

Ambrose, R. F., 1986. Artificial Reefs, Volume 1: A Review and Analysis. Prepared for Marine Review Committee, Inc.

Ambrose, R.F., D.C. Reed, J.M. Engle, and M.F. Caswell, 1989. California Comprehensive Offshore Resource Study. Submitted to: State Lands Commission. Sacramento, California.

Ambrose, R. F. 1994. Resource Replacement Alternatives Involving Constructed Reefs in Southern California. Unpublished.

AMEC Earth & Environmental, Inc. (AMEC), 2002. Regional Beach Sand Project Preconstruction and Construction Monitoring Report. Prepared for San Diego Association of Governments.

AMEC, 2005. Regional Beach Sand Project, Year 4 (2004-2005) Post-construction Monitoring Report for Intertidal, Shallow Subtidal, and Kelp Forest Resources and Comprehensive Analysis Report (2001-2005). Prepared for San Diego Association of Governments. Available at: http://www.sandag.org/index.asp?subclassid=32&fuseaction=home.subclasshome.

American Trader Trustee Council, 2001. Restoration Plan and Environmental Assessment for Seabirds Injured by the American Trader Oil Spill.

Amsler, C.D. and M. Neushul, 1989. Diel periodicity of spore release from the kelp *Nereocystis luetkeana* (Mertens) Postels *et* Ruprecht. *Journal of Experimental Marine Biology and Ecology,* 134(2):117-127.

Anchor Environmental CA, L.P., 2003. Literature Review of Effects of Resuspended Sediments Due to Dredging Operations. Prepared for Los Angeles Contaminated Sediments Task Force.

Anderson, D.W., J.R. Jehl, Jr., R.W. Risebrough, L.A. Woods, Jr., L.R. Deweese, and W.G. Edgecomb, 1975. Brown Pelicans: Improved Reproduction off the Southern California Coast. *Science* 190: 806-808.

Andrew, R.K., B.M. Howe, and J.A. Mercer, 2002. Ocean ambient sound: comparing the 1960s with the 1990s for a receiver off the California coast. Acoustics Research Letters Online 3:65-70.

Ansell, A.D. and E.R. Trueman, 1973. The energy cost of migration of the bivalve *Donax* on tropical sand beaches. *Marine Behavior and Physiology*, 2:1-21.

Applied Environmental Technologies, Inc. (AET) 2004. Water Quality Monitoring Reports (#s 1-7) Ventura Harbor District Maintenance Dredging (File No. 75-59) Ventura, California, Compliance File No. 6300.

Aquatic Bioassay Consulting Laboratories, Inc. (ABC). 1999a. Laboratory Reports, Santa Barbara Maintenance Dredging, November 1998 to March 1999. Prepared for Coastal Dredging and Marine.

ABC, 1999b. Laboratory Reports, Los Angeles River Estuary Dredging, February 17 to May 12, 1999. Prepared for Coastal Dredging and Marine.

ABC, 2002. The Marine Environment of Marina del Rey Harbor, July 2001-June 2002. Prepared for The Department of Beaches and Harbors, Los Angeles County.

ABC, 2005. Laboratory Reports, Santa Barbara Maintenance Dredging, November 2004 to April 2005. Prepared for Coastal Dredging and Marine.

Applied Biology, Inc. Biological Studies Concerning Dredging and Beach Nourishment at Duval County, Florida, with a Review of Pertinent Literature. U.S. Army Engineer District, Jacksonville, Florida.

Arens, 1994 (see Hesp 2002)

Armonies. W. and K. Reise, 2000. Faunal diversity across a sandy shore. *Marine Ecology Progress Series,* 196:49-57.

Armstrong, D.A., B.G. Stevens, and J.C. Hoeman, 1982. Distribution and abundance of Dungeness crab and *Crangon* shrimp and dredging-related mortality of invertebrates and fish in Grays Harbor, Washington. Report. No. DA-80-86. Washington Department of Fisheries and U.S. Army Engineer District, Seattle, Seattle, WA.

ASR Ltd., 2004. OIL PIERS REEF – PHASE II - Detailed Design of an Offshore Submerged Reef for Erosion Control at Oil Piers, Ventura County, California. Prepared for U.S Army Corp of Engineers (Vicksburg District) under Section 227 of the ERDC/WES Broad Agency Announcement (BAA): National Shoreline Erosion Control Development and Demonstration Program – Ventura County Demonstration Site.

Atkinson, S.F., 1985. Habitat-based methods for biological impact assessment. *The Environmental Professional,* 7:265-282.

Atwood, J.L. and D.E.Minsky, 1983. Least Tern Foraging Ecology at Three Major California Breeding Colonies. Western Birds 14: 57-72.

Atwood, J., J.Fancher and L. Feeney, 1994. California Least Tern in C.G. Thelander ed. Life on the Edge A Guide to California's Endangered Natural Resources Biosystems Books:184-187.

Auld, A.H. and J.R. Schubel, 1978. Effects of suspended sediment on fish eggs and larvae: A laboratory assessment. *Estuarine and Coastal Marine Science*, 6(2):153-164.

Backman, T.W. and D.C. Barilotti, 1976. Irradiance reduction: effects on standing crops of the eelgrass *Zostera marina* in a coastal lagoon. *Marine Biology,* 34:33-40.

Baird, P. H., 1993. Birds, Pages 541-603 In: *Ecology of the Southern California Bight: A Synthesis and Interpretation.* M.D. Dailey, D.J. Reish, and J.W. Anderson (eds.). University of California Press, Berkeley, California.

Bakus, G. J., 1968. Sedimentation and benthic invertebrates of Fanning Island, central Pacific. *Marine Geology*, 6(1):45-51.

Backus, G.J., 1989. The marine biology of southern California. *Occ. Papers Allan Hancock Foundation, New Series* 7, 61 pp.

Baldwin, B. G. (Convening Ed.), in preparation. The Jepson Flora Project. http://ucjeps.berkeley.edu/cguide.html. (Accessed February 2006).

Barnabus, A.D., 1994. Anatomical, histochemical and ultrastructural features of the seagrass *Phyllospadix scouleri* Hook. *Aquatic Botany*, 40:129-143.

Barnard, J.L., 1963. Relationship of benthic amphipoda to invertebrate communities of inshore sublittoral sands of southern California. *Pacific Naturalist,* 3:439-467.

Barnhart, R.A. 1988. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest) - Pacific Herring. U.S. Fish and Wildlife Service Biol. Rep 82(11.79). U.S. Army Corps of Engineers, TR EL-82-4.

Barrett, J.C., G.D. Grossman, and J. Rosenfeld, 1992. Turbidity-Induced Changes in Reactive Distance of Rainbow Trout. Transactions of the American Fisheries Society 121: 437-443.

Bash, J., C. Berman, and S. Bolton, 2001. Effects of Turbidity and Suspended Solids on Salmonids. Center for Streamside Studies, University of Washington.

Bassett Acoustics, 2005. Port of Melbourne Corporation Channel Deepening Project, TDP Underwater Noise Measurements.

Beach, R.A. and R.W. Sternberg, 1988. Suspended sediment transport in the surf zone: Response to cross-shore infragravity motion. *Marine Geology*, 80:61-79.

Beach, R.A. and R.W. Sternberg, 1992. Suspended sediment transport in the surf zone: Response to incident wave and longshore current interaction. *Marine Geology*, 108:275-294.

Bell, J.D. and M. Westoby, 1986a. Importance of local changes in leaf height and density to fish and decapods associated with seagrasses. *Journal of Experimental Marine Biology and Ecology,* 104(1-3):249-274.

Bell, J.D. and M. Westoby, 1986b. Variation in seagrass height and density over a wide spatial scale: Effects on common fish and decapods. *Journal of Experimental Marine Biology and Ecology,* 104(1-3):275-295.

Benedet, L., C.W. Finkl, T. Campbell, and A. Klein, 2004. Predicting the effect of beach nourishment and cross-shore sediment variation on beach morphodynamic assessment. *Coastal Engineering,* 51(8-9): 839-861.

Bence, J.R., S.C. Schroeter, and R.O. Smith, 1989. Technical Report to the California Coastal Commission. F. Kelp Forest Invertebrates. Marine Review Committee.

Beresford, K., 2005. USACE, San Francisco District, personal communication.

Berry, W., N. Rubinstein, B. Melzian, and B. Hill, 2003. The Biological Effects of Suspended and Bedded Sediment (SABS) in Aquatic Systems: A Review. Internal Report. United States Environmental Protection Agency.

Bird, B., L.C. Branch, and D.L. Miller, 2004. Effects of coastal lighting on foraging behavior of beach mice. *Conservation Biology,* 18(5):1435–1439.

Black, R. 1974. Some biological interactions affecting intertidal populations of the kelp *Egregia laevigata*. Marine Biology 28: 189-198.

Blackmon, D., T. Wyllie-Echeverria, and D.J. Shafer, 2006. The role of seagrasses and kelps in marine fish support. *WRAP Technical Notes Collection* (ERDC TN-WRAP-06-1), U.S. Army Engineer Research and Development Center, Vicksburg, MS. http://el.erdc.usace.army.mil/wrap.

Blanchette, C.A., S.E. Worcester, D. Reed, and S.J. Hollbrook, 1999. Algal morphology, flow, and spatially variable recruitment of surfgrass *P. torreyi*. *Mar. Ecol. Prog. Ser., 184:119-128.*

Blaxter, J.H.S. and J.R. Hunter, 1982. The biology of the clupeoid fishes. *Advances. Marine Biology*, 20:1-223.

Blodget, B.G., 1978. The effect of off-road vehicles on Least Terns and other shorebirds. *University of Massachusetts/National Parks Service Cooperative Research Unit Report No. 26.* 79 p.

Blois, J.-C., J.-M. Francaz, M. Gaudichon, S. Gaudichon, and L. Le Bris, 1961. Observations sur les berbiers a *Zosteres* de la region de Roscoff. Cahiers Biol. Mar. 2:223-262.

Bodkin, J.L., 1986. Fish assemblages in *Macrocystis* and *Nereocystis* kelp forests off central California. Fishery Bulletin 84(4):799-808.

Bodkin, J.L. and G.B. Rathbun, 1988. Morro Bay Dredging Project, 1987. Morro Bay Sea Otter Study for U.S. Army Corps of Engineers.

Bodkin, J.L. and G.B. Rathbun, 1989. Morro Bay Dredging Project, 1988. Morro Bay Sea Otter Study for U.S. Army Corps of Engineers.

Boehlert, G.W., 1984. Abrasive effects of Mount Saint Helens ash upon epidermis of yolk sac larvae of Pacific herring *Clupea harengus pallasi*. Marine Environmental Research, 12(2):113-126.

Boehlert, G.W. and J.B. Morgan, 1985. Turbidity enhances feeding abilities of larval Pacific herring *Clupea harengus pallasi*. *Marine Environmental Research,* 12(2):113-126.

Boehlert, G.W., J.B. Morgan, and M.M. Yoklavich, 1983. Effects of volcanic ash and estuarine sediment on early life history stages of the Pacific herring, *Clupea harengus pallasi*. Oregon State University: Corvallis, OR, USA.

Boeing Company, Inc., 2005. Application for Incidental Take Harassment Authorization for Harbor Activities Related to Delta IV/EELV:Table 1.2-1. http://www.nmfs.noaa.govpr/readingrm/mmpa_small_take/boeing_iha_app_2005.doc. cited in Final Environmental Assessment for Issuance of an Incidental Take Harassment Authorization for the Take of Marine Mammals During Dredging Operations at Pier 39, San Francisco, California.

Bolgna, P.A.X., 2005. Assessing within habitat variability in plant demography, faunal density, and secondary production in an eelgrass (*Zostera marina* L.) bed. *Journal of Experimental Marine Biology and Ecology*, 329(1):122-134.

Bollens, S.M. and A.M. Sanders, 2004. Ecology of larval herring in the San Francisco Estuary: Seasonal and interannual abundance, distribution, diet, and condition. Pages 15-36, In: F. Feyer, L.R. Brown, R.L. Brown, J.J. Orsi (eds). *Early History of Fishes in the San Francisco Estuary and Watershed.* American Fisheries Society, Bethesda, MD.

Bonnell, M.L. and M.D. Dailey, 1993. Marine Mammals. Pages 604 to 681 in: *Ecology of the Southern California Bight: A Synthesis and Interpretation.* M.D. Dailey, D.J. Reish, and J.W. Anderson (eds.). University of California Press, Berkeley, California.

Bonsdoff, E. 1983. Recovery potential of macrozoobenthos from dredging in shallow brackish waters. In: *Fluctuations and Succession in Marine Ecosystems*: *Proceedings of the 17th European Symposium on Marine Biology.* L. Cabioch et al. (eds). Brest: *Oceanologica Acta*, pp. 27-32.

Bosnsack, J.A. and D. L. Sutherland, 1985. Artificial reef research: A review with recommendations for future priorities. *Bulletin of Marine Science*, 37(1):11-39.

Bowles, A.E. and B.S. Stewart. 1980. Disturbances to the Pinnipeds and Birds of San Miguel Island, 1979-1980. Technical Report submitted by Hubbs-Sea World Research Institute and San Diego State University to U.S. Air Force. 246 pgs.

Boyd, S.E., K.M. Cooper, D.S. Limpenny, R. Kilbride, H.L. Rees, M.P. Dearnaley, J. Stevenson, W.J. Meadows, and C.D. Morris, 2004. Assessment of the re-habilitation of the seabed following marine aggregate dredging. Science Series Technical Report, CEFAS Lowestoft, 121:154 pp.

Bradley, M.P. and M.H. Stolt, 2006. Landscape-level seagrass-sediment relations in a coastal lagoon. *Aquatic Botany,* 84(2):121-128.

Brandreth, B., 2005. Beach Nourishment and Bird Habitat Restoration in Southern New Jersey. In: The Second Regional Workshop on Dredging, Beach Nourishment, and Bird Conservation: Atlantic Coast from Maine to Virginia, October 25-27, 2005. http://el.erdc.usace.army.mil/training.cfm?Topic=Workshop&List=05oct-dots. Accessed June 2006.

Brinkley, E.S. and A. Humann, 2001. Pelicans, Pages 157-166 In *The Sibley Guide to Bird Life and Behavior*. C. Elphick, J.B. Dunning, Jr., and D.A. Sibley (eds.) Alfred A. Knopf.

Brinson, M.M., 1993. A Hydrogeomorphic Classification of Wetlands. Wetlands Research Program Technical Report WRP-DE-4. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.

Broenkow, W.W., 1996. Physical Oceanography. In: *Monterey Bay National Marine Sanctuaries Site Characterization*. http://bonita.mbnms.nos.noaa.gov/sitechar/phy21.html. Accessed September 2005

Broadhead, J.M. and P.J. Godfrey, 1977. Off road vehicle impact in Cape Cod National Seashore: Disruption and recovery of dune vegetation. *International Journal of Biometeorology,* 21(3):299-306.

Brooks, A. and E. Agate, 2001. *Sand Dunes: A Practical Handbook*. Published by BTCV Ltd., United Kingdom. ISBN 0 946752 32 X. Available online at: http://handbooks.btcv.org.uk/handbooks/index.

Brown, A.C. and A. McLachlan, 2002. Sandy shore ecosystems and the threats facing them: some predictions for the year 2025. *Environmental Conservation, 29(1):62-77.*

Bruce, C., K.Miller, G. Page, L. Stenzel, and W. White, 1994. Western Snowy Plover. Pages 180-182 In *Life on the Edge: A Guide to California's Endangered Natural Resources*. C.G. Thelander (ed.). Biosystems Books:

Brusca, R. C. and G. J. Brusca, 1990. *Invertebrates*. Sinauer Associates, Inc. Publishers, Sunderland, Massachusetts. 922 pp.

Brynes, M.R., R.M. Hammer, T.D. Thibaut, and D.B. Snyder, 2004a. Physical and biological effects of sand mining offshore Alabama, U.S.A. *Journal of Coastal Research*, 20(1):6-24.

Brynes, M.R., R.M. Hammer, T.D. Thibaut, and D.B. Snyder, 2004b. Effects of sand mining on physical processes and biological communities offshore New Jersey, U.S.A. *Journal of Coastal Research*, 20(1):25-43.

Bulthuis, D.A., Effects of temperature on photosynthesis and growth of seagrasses. *Aquatic Botany,* 27(1):27-40.

Buck, E. H., 1995. Acoustic Thermometry of Ocean Climate: Marine Mammal Issues. Congressional Research Service (CRS) Reports for Congress. Available online at: http://www.ncseonline.org/NLE/CRSreports/Marine/mar-2.cfm?&CFID=2242542&CFTOKEN=26598808. Accessed November 2006.

Burger, J., 1991. Foraging behavior and the effect of human disturbance on the Piping Plover (*Chradrius melodus*). *Journal of Coastal Research*, 7(1):39-52.

Buick, A.M. and D.C. Patton, 1989. Impact of off-road vehicles on the nesting success of Hooded Plovers *Charadrius rubricollis* in the Coorong region of South Australia. *Emu*, 89:159-172.

Bull, J.S., D.C. Reed, and S.J. Hollbrook, 2004. An experimental evaluation of different methods of restoring *Phyllospadix torreyi* (Surfgrass). *Restoration Ecology,* 12(1):70-79.

Burger, J. 1994. The Effect of Human Disturbance on Foraging Behavior and Habitat Use in Piping Plover (Charadrius melodus). Estuaries 17:695-701.

Burger, J. and M.Gochfeld, 1991. Human activity influence and diurnal and nocturnal foraging of sanderlings (Caldris alba). The Condor 93: 259-265.

Burlas, M., 2005. Response of Piping Plover to the New Jersey Beach Nourishment Project. In: The Second Regional Workshop on Dredging, Beach Nourishment, and Bird Conservation: Atlantic Coast from Maine to Virginia, October 25-27, 2005. http://el.erdc.usace.army.mil/training.cfm?Topic=Workshop&List=05oct-dots. Accessed June 2006.

Burlas, M., G. Ray, and D. Clarke, 2001. The New York District's Biological Monitoring Program for the Atlantic Coast of New Jersey, Asbury Park to Manasquan Section Beach Erosion Control Project. Final Report. U.S. Army Corps of Engineers, Waterways Experiment Station. Available at www.nan.usace.army.mil/business/prjlinks/coastal/Asbury/index.htm.

Burke, M.K., W.C. Dennison, and K.A. Moore, 1996. Non-structural carbohydrate reserves of eelgrass *Zostera marina*. *Marine Ecology Progress Series,* 137:195-201.

Burrows, E.M., 1971. Assessment of pollution effects of the use of algae. *Proceedings of the Royal Society of London*, *B.* 177: 295-300.

Burton, W., s. Weisberg, and P. Jacobson, 1992. Entrainment Effects of Maintenance Hydraulic Dredging in the Delaware River Estuary on striped bass ichthyoplankton. Report submitted to the Delaware Basin Fish and Wildlife Management Cooperative.

Byrnes, M.R., R.M. Hammer, T.D. Thibaut, and D.B. Snyder, 2004a. Physical and biological effects of sand mining offshore Alabama, U.S.A. *Journal of Coastal Research,* 20(1):6-24.

Byrnes, M.R., R.M. Hammer, T.D. Thibaut, and D.B. Snyder, 2004b. Effects of sand mining on physical processes and biological communities offshore New Jersey, U.S.A. *Journal of Coastal Research,* 20(1):25-43.

Cabello-Pasini, A., C. Lara-Turrent, and R.C. Zimmerman, 2002. Effect of storms on photosynthesis, carbohydrate content and survival of eelgrass populations from a coastal lagoon and the adjacent open ocean. *Aquatic Botany,* 74:149-164.

Cabioch, L., 1968. Contribution à la connaissance des peuplements benthiques de la Manche occidentale. *Cahiers de Biologie Marine*, 9:493S-720S.

Cacchione, D.A. and D.E. Drake, 1990. Shelf Sediment Transport. Pages 729-774 in: The Sea. Volume 9, Ocean Engineering Science. B. LeMehaute and D. M. Hanes (eds.). John Wiley, New York.

CalCoast, 2005. http://www.calcoast.org/restprog/projfund.htm.

CalFlora, 2005. Information on California plants for education, research and conservation. [web application]. 2005. Berkeley, California: The Calflora Database [a non-profit organization]. Available: http://www.calflora.org/. Accessed September 2005 and February 2006.

California Coastal Commission (CCC), 1987. *California Coastal Resource Guide.* University of California Press, Berkeley.

California Coastal Conservancy (Coastal Conservancy), 2001. Southern California Coastal Wetlands Recovery Project Information Station. http:// http://www.wrpinfo.scc.ca.gov/, accessed September 2005.

California Department of Fish and Game (See DFG)

California Environmental Resources Evaluation System (CERES), 2006. California's Coastal Plant Communities. http://ceres.ca.gov/ceres/calweb/coastal /plants/strand.html, Accessed September 2005 and February 2006.

California Exotic Pest Plant Council (Cal EPPC), 1999. The Cal EPPC Lists: Exotic Pest Plants of Greatest Ecological Concern in California. October, 1999. Available online: http://ucce.ucdavis.edu/files/filelibrary/5319/4898.pdf.. Accessed February 2006.

California Native Plant Society (CNPS), 1996. Policy on Invasive Exotic Plants. http://www.cnps.org/archives/exotics.htm. Accessed August 2005.

California Regional Water Quality Control Board (CCRWQCB) and State Water Resources Control Board (SWRCB), 1994. Water Quality Control Plan for the Central Coast Basin.

California Regional Water Quality Control Board, Los Angeles Region (LARWQCB), 1994. Water Quality Control Plan, Los Angeles Region Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties.

California Regional Water Quality Control Board, North Coast Region (NCRWQCB), 2005. Water Quality Control Plan for the North Coast Basin.

California Regional Water Quality Control Board, Santa Ana Region (SARWQCB), 1995. Water Quality Control Plan, Santa Ana River Basin (8).

California Regional Water Quality Control Board, San Diego Region (SDRWQCB), 1994. Water Quality Control Plan for the San Diego Basin (9).

California Regional Water Quality Control Board, San Francisco Bay (SFRWQCB), 2000. Draft Staff Report Beneficial Reuse of Dredged Materials: Sediment Screening and Testing Guidelines. May 2000.

California Regional Water Quality Control Board, San Francisco Bay (SFRWQCB), 2004. Water Quality Control Plan (Basin Plan) for the San Francisco Bay

Calver, S., 2005. Savannah Harbor Navigation Project, Management to Benefit Birds. In: The First Regional Workshop on Dredging, Beach Nourishment, and Birds on the South Atlantic Coast and a Symposium on the Ecology and Conservation of Piping Plovers, February 1-4, 2005. http://el.erdc.usace.army.mil/training.cfm?Topic=Workshop&List=05feb-dots. Accessed June 2006.

Cameron, R. A. and S. C. Schroeter, 1980. Sea urchin recruitment: effect of substrate selection on juvenile distribution. *Marine Ecology Progress Series*, 2:243-247.

Canright, A., 2005. Ocean floor mapping. *California Coast & Ocean*, 21(3). http://coastandocean.org/coast_autumn2005/index.htm

Cardoso, P.G., M. A. Pardal, A. I. Lillebø, S. M. Ferreira, D. Raffaelli, and J. C. Marques. 2004. Dynamic changes in seagrass assemblages under eutrophication and implications for recovery. *Journal of Experimental Marine Biology and Ecology*, 302(2):233-248.

Carlson, T.J., G.R. Ploskey, R.L. Johnson, R.P. Mueller, M.A. Weiland and P.N. Johnson. 2001. Observations of the behavior and distribution of fish in relation to the Columbia River navigation channel and channel maintenance activities. Pacific Northwest National Laboratory, Richland, WA.

Carr, M., 1989. Effects of macroalgal assemblages on the recruitment of temperate zone reef fishes. *Journal of Experimental Marine Biology and Ecology,* 126 (1):59-76.

Carr, M.H., 1994. Effects of macroalgae dynamics on recruitment of a temperate reef fish. *Ecology*, 75(5):1320-1333.

Carr, M.H. and M.A. Hixon, 1997. Artificial reefs: The importance of comparisons with natural reefs. *Fisheries*, 22(4):28-33.

Carretta, J.V., K.A. Forney, M.M. Muto, J. Barlow, J. Baker and M. Lowry, 2004. U.S. Pacific Marine Mammal Stock Assessments: 2003. NOAA Technical memorandum NOAAA-TM-NMFS-SWFSC-358.

Carter, 1988 (see Hesp 2002)

Carter, H.R., G.J.McChesney, D.L. Jaques, C.S. Strong, M.W. Parker, J.E. Takekawa, D. L. Jory, and D.L. Whitworth, 1992. Breeding Populations of Seabirds in California, 1989-1991. Volume I - Population Estimates. For the Minerals Management Service.

Carter, S.K. and G.R. VanBlaricom, 2002.Effects of experimental harvest on red sea urchins (*Strongylocentrotus franciscanus*) in northern Washington. *Fishery Bulletin,* 100:662-673.

CCC see California Coastal Commission

CCRWQCB – See Californian Regional Water Quality Control Board, Central Coast Region.

California Department of Fish and Game (CDFG), 1992. Pacific herring commercial fishing regulations. Draft environmental document. 183 pp. Cited in Tasto 2000.

CDFG see Department of Fish and Game

California Environmental Resources Evaluation System (CERES), 2006. California's Coastal Plan Community. http://ceres.ca.gov/ceres/calweb/coastal/plants.html. Accessed February 2006.

CEQ see Council of Environmental Quality

CERES see California Environmental Resources Evaluation System

Chambers Consultants and Planners, 1982. Biological Monitoring of Pipeline Construction through Kelp Beds Located Offshore Corral Canyon. Prepared for Pacific Offshore Pipeline Company, Los Angeles, California.

Chambers Group, 1980. Marine Biological Study of the Point Arguello Boathouse Area for United States Air Force.

Chambers Group, Inc. 1988. Draft Environmental Impact Report Mobil Exploration and Producing U.S. Inc. Exploration Activities State Oil and Gas Leases PRC 3489 and 3490 for California State Lands Commission.

Chambers Group, Inc. 1992. Final Environmental Impact Report/Environmental Assessment for the BEACON Beach Nourishment Demonstration Project. Prepared for Beach Erosion Authority for Control Operations and Nourishment.

Chambers Group, Inc., 1994. Preconstruction Baseline Report of Biological Monitoring Program for Oceanside Experimental Sand Bypass Program. Prepared for U.S. Army Corps of Engineers Los Angeles District.

Chambers Group, Inc. 2000a. EIR/EIS for the Bolsa Chica Lowlands Restoration Project. Prepared for the California State Lands Commission, United States Fish and Wildlife Service, and United States Army Corps of Engineers.

Chambers Group, Inc., 2000b. Final Addendum to the Environmental Impact Report/Environmental Assessment for the BEACON Beach Nourishment Demonstration Project. Prepared for BEACON.

Chambers Group, Inc., 2001a. Monitoring of Snowy Plovers and Grunion during Dredging and Sand Disposal in Santa Barbara Harbor. Field Notes. For the U.S. Army Corps of Engineers, Los Angeles District.

Chambers Group, Inc. 2001b. Control of Sediment Resuspension During Dredging Projects in Southern California. Prepared for USACE, Los Angeles District.

Chambers Group, Inc. 2001c. BEACON South Central Coast Beach Enhancement Program, Biological Resources Report. Prepared for Moffatt & Nichol Engineers.

Chambers Group, Inc., 2002. Goleta Beach Five-Year Winter Dike Project Construction, Maintenance and Lowering. Prepared for Santa Barbara County Parks.

Chambers Group, Inc. 2004. Biological Monitoring of the BEACON Goleta Beach Nourishment Demonstration Project – 1 Year Report. Prepared for Moffatt & Nichol.

Chambers Group, Inc., 2005. Monitoring Report for Western Snowy Plover at the Talbert Channel. Prepared for County of Orange.

Chang, H. H. 1997. Modeling fluvial processes in tidal inlet. Journal of Hydraulic Engineering, 1161-1165.

Chapman, A.R.O. and J.S. Craigie, 1978. Seasonal growth in *Laminaria longicruris* relations with reserve carbohydrate storage and production. *Marine Biology*, 46:209-1978.

Chasson, A.G., 1993. The effects of suspended sediment on rainbow smelt (Osmerus mordax): a laboratory investigation. Can.J. Zool. 71: 2419-2424.

Chelton, D.B., Bernal, P.A. and J.A. McGowan, 1982. Large-scale interannual physical and biological interactions in the California Current. J. Mar. Res. 40:1095-1125.

Channel Islands National Marine Sanctuary (CINMS), 2000. Draft Affected Environment Chapter. Draft Environmental Impact Statement for Channel Islands National Marine Sanctuary. April 29, 2000.

Christensen, S.W. 1976. Defining and determining the significance of impacts: Concepts and methods. *In.* Proceedings of the Workshop on the Biological Significance of Environmental Impacts. R.K. Sharma, J.D. Buffington, and J.T. McFadden (eds.). Nuclear Regulatory Commission. NR-CONF-002. Washington, D.C.

Christiansen, M.B. and R. Davidson-Arnott, 2004. Rates of landward sand transport over foredune at Skallingen, Denmark and the role of dune ramps. *Geografisk Tidsskrift, Danish Journal of Geography* 104(1):31-43.

City of San Diego, 2007. California Environmental Quality Act Significance Determination Thresholds. City of San Diego Development Services Department. January 2007.

City of Pittsburg, 2005. Draft Environmental Impact Report (EIR) for the Trans Bay Cable (TBC) Project. http://www.ci.pittsburg.ca.us/pittsburg/pdf/4_11Noise and Vibration.htm.

Clarke, D. G., and D.H. Wilber, 2000. Assessment of Potential Impacts of Dredging Operations Due to Sediment Resuspension. DOER Technical Notes Collectioin, ERDC TN-DOER E9, U.S. Army Engineer Research and Development Center, Vicksburg, MS. http://el.erdc.usace.army. mil/dots/doer/ technote.html.

Clarke, D.G., C. Dickerson, and K. Reine, 2003. Characterization of Underwater Sounds Produced by Dredges. (Proceedings Of The Third Specialty Conference On Dredging And Dredged Material Disposal, May 5-8, 2002, Orlando, Florida; Sponsored by Coasts, Oceans, Ports, and Rivers Institute (COPRI) of ASCE).

California Native Plant Society (CNPS), 2001and 2005. web citations

CNPS, 2006. Inventory of Rare and Endangered Plants. Seventh Edition, v7-06a, January 2006. http://cnps.web.aplus.net/cgi-bin/inv/inventory.cgi/.

Coastal Conservancy – see California Coastal Conservancy

Coastal Frontiers Corporation, 2002. SANDAG Regional Beach Monitoring Program, Spring 2002, State of the Coast Report. Prepared for San Diego Association of Governments.

Coastal Frontiers Corporation, 2004. 2004 Regional Beach Monitoring Program, Annual Report. Prepared for San Diego Association of Governments (SANDAG). Available at: http://www.sandag.org/index.asp?subclassid=32&fuseaction=home.subclasshome.

Coastal Planning & Engineering, Inc., 2004a. Anna Maria Island Beach Nourishment Project, Manatee County, Florida. Second Annual Post-Construction Biological Monitoring Report. Submitted to Florida Department of Environmental Protection.

Coastal Planning & Engineering, Inc., 2004b. City of Boca Raton, South Boca Raton Beach Nourishment Project, Two Years Post-Construction, Artificial Reef and Natural Hardbottom Biological Monitoring Results. Prepared for City of Boca Raton.

Coastal Planning & Engineering, Inc., 2004c. City of Boca Raton, Central Boca Raton Beach Nourishment Project, Pre-, Mid and Post-Construction Biological Monitoring. Prepared for City of Boca Raton.

Coastal Resources Management (CRM), 1997. Marine Biological Resources Inventory and Environmental Assessment for the County of Los Angeles Department of Public Works Evaluation of Proposed Malibu Area Sediment Placement Sites Study Los Angeles County, California. Prepared for Owen Group.

CRM, 2000. Marine Biological Impact Assessment, City of San Clemente Beach Replenishment Program. Prepared for Moffatt & Nichol Engineers.

Code of Federal Regulations (CFR). Title 40.

Cogswell, H. 1977. Water Birds of California. University of California Press.

Cohen, A.N., 2005 *Guide to the Exotic Species of San Francisco Bay.* San Francisco Estuary Institute, Oakland, CA, www.exoticsguide.org. Accessed February 2006.

Cohen, J.B., L.M. Houghton, and J.D. Fraser, 2005. Effect of the Westhampton Interim Storm Damage Protection Project on Piping Plover Habitat and Ecology. In: The Second Regional Workshop on Dredging, Beach Nourishment, and Bird Conservation: Atlantic Coast from Maine to Virginia, October 25-27, 2005. http://el.erdc.usace.army.mil/training.cfm?Topic=Workshop&List=05oct-dots. Accessed June 2006.

Colby, D. and D. Hoss, 2004. Larval Fish Feeding Responses to Variable Suspended Sediment and Planktonic Prey Concentrations. *DOER Technical Notes Collection* (ERDC TN-DOER-E16). U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/dot/doer.

Collazo, J.; G. Hammerson, M. Koenen, and D. Mehlman, 1995. Species Management Abstract Brown Pelican *(Pelecanus occidentalis).* The Nature Conservancy. Accessed March 2007. http://www.conserveonline.org/docs/2001/03/brpe.doc.

Collins, C.T., K.E. Bender, and D.D. Rypka, 1979. Report on the Feeding and Nesting Habits of the California Least Tern in the Santa Ana River Marsh Area, Orange County, California. Prepared for the U.S. Army Corps of Engineers, Los Angeles District.

Collins, M.S., 1995. Dredging-Induced Near-Field Resuspended Sediment Concentrations and Source Strengths. Miscellaneous Paper D-95-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Colwell, M.A. and K.D. Sundeen, 2000. Shorebird distributions on ocean beaches of Northern California. *Journal of Field Ornithology* 71(1): 1-15.

Connell, J.H. and W.P. Sousa, 1983. On the evidence needed to judge ecological stability or persistence. *The American Naturalist*, 121(6):789-824.

Converse Consultants Inland Empire (CCIE). 1995. Water Quality Monitoring Data (February to March), Los Angeles River.

Connell, J. H., 1972. Community interactions on marine rocky intertidal shores. *Ann. Rev. Ecol. Sys.,* 3:169-192.

Connor, J. and C. Baxter, 1989. *Kelp Forests*. Monterey Bay Aquarium. Monterey, Ca. 64 pp.

Conover, J.T., 1958. Seasonal growth of benthic marine plants as related to environmental factors in an estuary. *Publ. Inst. Mar. Sci. Univ. Tex.,* 5:97-147.

Cooper, K.M., 2005. Cumulative effects of marine aggregate extraction in an area east of the Isle of Wight – A fishing industry perspective. Science Series Technical Report, CEFAS Lowestoft, 126: 28 pp. Available online at: www.cefas.co.uk.

Cooper, L.W. and C.P. McRoy, 1988. Anatomical adaptations to rocky substrates and surf exposure by the seagrass genus *Phyllospadix*. *Aquatic Botany,* 32:365-381.

Copper, E., 1997. The status of western snowy plover at Naval Amphibious Base, Coronado in 1995. A report for the U.S. Navy, Naval Facilities Engineering Command, San Diego.

Council of Environmental Quality (CEQ), 1997. Considering Cumulative Effects under the National Environmental Policy Act. http://ceq.eh.doe.gov/nepa/ccenepa/ccenepa.htm. Accessed August 2006.

CEQ, 2005. Guidance on the Consideration of Past Actions in Cumulative Effects Analysis. http://ceq.eh.doe.gov/nepa/regs/Guidance_on_CE.pdf. Accessed August 2006.

County of Orange. 2000. Dana Point Harbor Dredging Project, Water Quality Monitoring Data May 2000.

Courtenay, W.R.Jr., D.J. Herrema, M.J. Thompson, W.P. Azzinaro, and J. Van Montfrans, 1972. Ecological monitoring of two beach nourishment projects in Broward County, Florida. *Shore and Beach* 9-13.

Courtenay, W.R.Jr.,B.C. Hartig, and G.R. Loisel, 1980. Ecological Evaluation of a Beach Nourishment Project at Hallandale (Broward County), Florida: Evaluation of Fish Populations Adjacent to Borrow Areas of Beach Nourishment Project, Hallandale (Broward County), Florida, Vol. I. Miscellaneous Report 8-1(I). Fort Belvoir, VA: Coastal Engineering Research Center, U.S. Army Corps of Engineers.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe, 1992. Classification of Wetlands and Deepwater Habitats of the United States. FWS/OBS-79/31, December 1979, Reprinted 1992.

Cox, K.W., 1962. California abalones, Family Haliotidae. *Calif. Dept. of Fish and Game, Fish Bulletin* 118:1-133. Accessed at http://ceo.ucsd.edu/ fishbull/.

Crain, D.A., A. B. Bolten, and K. A. Bjorndal, 1995. Effects of beach nourishment on sea turtles: Review and research initiatives. *Restoration Ecology*, 3:95-104.

Cranford, P.J., C.W. Emerson, B.T. Hargrave, and T.G. Milligan, 1998. In situ feeding and absorption responses of sea scallops *Placopecten magellanicus* (Gmelin) to storm-induced changes in the quantity and composition of seston. *Journal of Experimental Marine Biology and Ecology,* 219(1-2):45-70.

CRM (see Coastal Resources Management)

Cross, J.N., 1982. Intertidal Fishes of Southern California. Pages 11-117 In: Coastal Water Research Project Biennial Report for the Years 1981-1982. W. Bascom (ed.). Southern California Coastal Water Research Project:

Cross, J.N. and L.G. Allen, 1993. Fishes. Pages 459 to 540 Pages 369-458 in: *Ecology of the Southern California Bight: A Synthesis and Interpretation.* M.D. Dailey, D.J. Reish, and J.W. Anderson (eds.). University of California Press, Berkeley, California.

Coastal Science Associates (CSA), 1991. Biological Monitoring Report for Assessemnt of Beach Nourishment Impacts. Tech. Report for Palmetto Dunes Resort, Hilton Head, S.C., 14 pp.

Cyrus, D.P. and S.J.M. Blaber, 1987a. The influence of turbidity on juvenile marine fishes in estuaries. Part 1. field studies at Lake St. Lucia on the southeastern coast of Africa. *Journal of Experimental Marine Biology and Ecology*, 109(1):53-70.

Cyrus, D.P. and S.J.M. Blaber, 1987b. The influence of turbidity on juvenile marine fishes in estuaries. Part 2. Laboratory studies, comparisons with field data and conclusions. *Journal of Experimental Marine Biology and Ecology*, 109(1):71-91.

Culter, J.K. and S. Mahadevan, 1982. Long-Term Effects of Beach Nourishment on the Benthic Fauna of Panama City Beach, Florida. Prepared for U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, VA.

Cummings, V.J., S. Thrush, J. Hewitt, A. Norkko, and S. Pickmere, 2003. Terrestrial deposits on intertidal sandflats: sediment characteristics as indicators of habitat suitability for recolonizing macrofauna. *Marine Ecology Progress Series,* 253:39-54.

Cummings, V.J. and S.F. Thrush, 2004. Behavioural response of juvenile bivalves to terrestrial sediment deposits: implications for post-disturbance recolonization. *Marine Ecology Progress Series,* 278:179-191.

Curtis, M.D., 1991. Establishing Eelgrass Beds in California. Pages 477-489 In: *Coastal Wetlands, Coastal Zone '91 Conference-ASCE Long Beach, CA/July 1991*.

CZR Incorporated, 2003. Waterbird and Shorebird Use at Ocean Isle Beach in Brunswick County, North Carolina, December 2001-November 2002. Prepared for U.S. Army Corps of Engineers Wilmington District.

Dahm, J., G. Jinks, and D. Bergin, 2005. Community-based Dune Management for the Mitigation of Coastal Hazards and Climate Change Effects: A Guide for Local Authorities. Prepared for Climate Change Office, New Zealand. Available at http://www.envbop.govt.nz/media/pdf/Report_Coastalhazardsandclimate.pdf, accessed November 2005.

Daly, M.A. and A.C. Mathieson, 1977. The effects of sand movement on intertidal seaweeds and selected invertebrates at Bound Rock, New Hampshire, USA. *Marine Biology,* 43:45-55.

Dashgardt, S.E. and M.K. Gringras, 2005. The temporal significance of bioturbation in backshore deposits: Waterside beach, New Brunswick, Canada. *Palaios,* 20(6): 589-595.

Dauer, D. M. and J.L. Simon, 1976. Repopulation of the polychaete fauna of an intertidal habitat following natural defaunation: species equilibrium. *Oecologia* (Berl.), 22:99-117.

Davies-Colley, R.J. and D.G. Smith, 2001. Turbidity, suspended sediment, and water clarity: A review. *Journal of the American Water Resources Association*, 37(5):1085-1101.

Davis, H.C., 1960. Effects of turbidity-producing materials ins sea water on eggs and larvae of the clam*(Venus (Mercenaria) mercenaria. Biological Bulletin*, 118(1):48-54.

Davis, H.C. and H. Hidu, 1969. Effects of turbidity-producing substances in sea water on eggs and larvae of three genera of bivalve mollusks. *Veliger,* 11:316-323.

Davis, N., G.R. VanBlaricom, and P.K. Dayton, 1982. Man-made Structures on Marine Sediments: Effects on Adjacent Benthic Communities. *Marine Biology*, 70: 295-303.

Davis, R.C. and F.T. Short, Restoring eelgrass, *Zostera marina* L., habitat using a new transplanting technique: The horizontal rhizome method. *Aquatic Botany*, 59(2):1-15.

Davis, W.E. Jr., 2001. Herons, Egrets, and Bitterns. In *The Sibley Guide to Bird Life and Behavior*. C. Elphick, J.B. Dunning, Jr., and D.A. Sibley (eds.). Alfred A. Knopf: 157-166.

Davies, M. H., N.J. MacDonald, Z. Demirbilek, S.J. Smith, Z.K. Zundel, and R.D. Jones, 2005. Particle Tracking Model (PTM) II: Overview of features and capabilities. *DOER Technical Notes Collection* (ERDC TN-DOER-D5), U.S. Army Engineer Research and Development Center, Vicksburg, MS. http://el.erdc.usace.army.mil/dots/doer.

Dayton, P. K., 1971. Competition, disturbance, and community organization: the provision and subsequent utilization of space in a rocky intertidal community. *Ecological Monographs,* 41(4):351-389.

Dayton, P.K., V. Currie, T. Gerodette, B.D. Keller, R. Rosenthal, and D.V. Tresca. 1984. Patch dynamics and stability of some California kelp communities. *Ecological Monographs*, 54(3): 253-289.

Dayton, P.K. and M.J. Tegner, 1984. Catastrophic storms, El Nino , and patch stability in southern California kelp community. *Science*, 224:283-285.

Dayton, P.K., R.J. Seymour, P.E. Parnell, and M.J. Tegner, 1989. Unusual marine erosion in San Diego County from a single storm. *Estuarine Coastal and Shelf Science*, 29(2):151-160.

DBW See Department of Boating and Waterways

Dean, T.A., 1985. The temporal and spatial distribution of underwater quantum irradiance in a southern California kelp forest. *Estuarine, Coastal and Shelf Science*, 21(6):835-844.

Dean, T.A. and L.E. Deysher, 1983. The effectcs of suspended solids and thermal discharges on kelp *Macrocystis*. Pages 114-135. In. *The Effects of Waste Water Discharges on Kelp in Southern California.* Bascom, W. (ed.). Southern California Coastal Water Research Project, Long Beach, California.

Dean, T.A. and F.R. Jacobsen, 1984. Growth of juvenile *Macrocystis pyrifera* (Laminariales) in relation to enviornmental factors. *Marine Biology,* 83:301-311.

Dean, T.A., S. C. Schroeter, and J.D. Dixon, 1984. Effects of grazing by two species of sea urchins (*Strongylocentrotus franciscanus* and *Lytechinus anamesus*) on recruitment and survival of two species of kelp (*Macrocystis pyrifera* and *Pterygophora californica*). *Marine Biology*, 78:301-313.

Dean, T.A. and F.R. Jacobsen, 1986. Nutrient-limited growth of juvenile kelp, *Macrocystis pyrifera,* during the 1982-1984 "El Niño in southern California. *Marine Biology,* 90:597-601.

Dean, T. A., F. R. Jacobsen, K. Thies, and S. L. Lagos, 1988. Differential effects of grazing by white sea urchins on recruitment of brown algae. *Marine Ecology Progress Series*, 48: 99-102.

Dean, T. A., K. Thies, and S. L. Lagos, 1989. Survival of juvenile giant kelp: the effects of demographic factors, competitors, and grazers. Ecology, 70(2):83-495.

Defeo, O. and A. McLachlan, 2005. Patterns, processes and regulatory mechanisms in sandy beach macrofauna: a multi-scale analysis. *Marine Ecology Progress Series,* 295:1-20.

de Groot, S.J., 1986. Marine sand and gravel extraction in the North Atlantic and its potential environmental impact, with emphasis on the North Sea. *Ocean Management,* 10:21-36.

Department for Environment and Heritage (DEH), 2005. Adelaide's Living Beaches: A Strategy for 2005-2025. Coastline No. 35. www.environment.sa.gove.au.

DeLancey, L. B., 1989. Trophic relationship in the surf zone during the summer at Folly Beach, South Carolina. *Journal of Coastal Research*, 5(3):477-488.

DeMartini, E., 1981.

DeMartini, E.E., A.M. Barnett, T.D. Johnson, and R.F. Ambrose, 1994. Growth and production estimates for biomass-dominant fishes on a southern California artificial reef. *Bulletin of Marine Science,* 55(2-3):484-500.

den Hartog, C., 1987. "Wasting disease" and other dynamic phenomena in *Zostera* beds. *Aquatic Botany,* 27(1): 3-14

Dennison, W.C., 1987. Effects of light on seagrass photosynthesis, growth, and depth distribution. A*quatic Botany,* 27(1):15-26.

Dennison, W.C. and R.S. Alberte, 1986. Photoadaptation and growth of *Zostera marina* L. (eelgrass) transplants along a depth gradient. *Journal of Experimental Marine Biology and Ecology. 98(3):265-282.*

Denny, M.W., B.P. Gaylord, and E.A. Cowen, 1997. Flow and flexibility. II. The roles of size and shape in determining wave forces on the bull kelp *Nereocystis luetkeana*. *The Journal of Experimental Biology,* 200:3165-3183.

Denny, M.W., E.K. Nelson, and K.S. Mead, 2002. Revised estimates of the effects of turbulence on fertilization in the purple sea urchin, *Strongylocentrotus purpuratus*. *Biological Bulletin,* 203:275-277.

Department of Boating and Waterways (DBW) and State Coastal Conservancy (SCC), 2002. California Beach Restoration Study. Sacramento, California.

Department of Fish and Game (DFG), 2001. *California's Living Marine Resources: A Status Report*. The Resources Agency, The California Department of Fish and Game. W.S. Leet, C.M. Dewees, R. Klingbiel, and E.J. Larson (eds.). University of California. www.dfg.ca.gov/mrd/.

Deysher, L.E. and T.A. Dean, 1984. Critical irradiance levels and the interactive effects of quantum irradiance and dose on gametogenesis in the giant kelp, *Macrocystis pyrifera*. *Journal of Phycology,* 20:520-524.

DFG, 2003a. *The Vegetation Classification and Mapping Program.* List of California Terrestrial Natural Communities Recognized by The California Natural Diversity Database. September 2003 Edition. Wildlife & Habitat Data Analysis Branch. http://www.dfg.ca.gov/whdab/pdfs/natcomlist.pdf.

DFG, 2003b. Nearshore Fishery Management Plan (NFMP), Section 2 Environmental Documents. http://www.dfg.ca.gov/mrd/nfmp/section2_chap3.html.

DFG, 2005a. *Ocean Fishing Regulations Book*. http://www.dfg.ca.gov/mrd/ oceanfish2005. Accessed December 2005.

DFG, 2005b. Abalone Recovery and Management Plan (ARMP), Final. http://www.dfg.ca.gov/mrd/armp/index.html. Accessed January 2006.

DFG, 2005c. California Brown Pelican, *Pelecanus occidentalis californicus.* Habitat Conservation Planning Branch. http://www.dfg.ca.gov/hcpb/cgibin/read_one.asp ?specy=birds&idNum=13.

DFG, 2006. State and Federally Listed Endangered, Threatened, and Rare Plants of California. Wildlife & Habitat Data Analysis Branch, California Natural Diversity Database. January 2006. http://www.dfg.ca.gov/whdab/pdfs/TEPlants.pdf.

Department for Environment and Heritage (DEH), 2005. Adelaide's Living Beaches, A Strategy for 2005-2025. Coastline No. 35, Government of South Australia. http://www.environment.sa.gov.au.

De Robertis, A. C.H. Ryer, A. Veloza and R.D. Brodeur, 2003. Differential effects of turbidity on prey consumption of piscivorous and planktivorous fish. *Can .J. Fish. Aquat. Sci.*, 60: 1517-1526.

Dethier, M.N., 1984. Disturbance and recovery in intertidal pools: maintenance of mosaic patterns. *Ecological Monographs,* 54(1):99-118.

Devinny, J.S. and L.A. Volse. 1978. Effects of sediment on the development of *Macrocystis pyrifera* gametophytes. Mar. Biol. 48: 343-348.

deWit, L.A., R. C. Phillips, R. R. Ware, and L.E. Fausak, 1997. Artificial attachment of surf grass (*Phyllospadix* sp.) within a nearshore, rocky habitat in southern California. Chapter 227. Pages 1695-1701 In: *Proceedings of the California and the World Ocean '97*.

Dexter, D.M., 1992. Sandy beach community structure: the role of exposure and latitude. *Journal of Biogeography,* 19:59-66.

Deysher, L.E. and T.A. Dean, 1986. Interactive effects of light and temperature on sporophyte production in the giant kelp *Macrocystis pyrifera*. *Marine Biology*, 93:17-20.

Diaz, R.J. and D.F. Boesch, 1977. Impact of Fluid Mud Dredged Material on Benthic Communities of the Tidal James River, Virginia. Technical Report D-77-45. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Diaz, R.J., G.R. Cutter, Jr., and C.H. Hobbs, III, 2004. Potential impacts of sand mining offshore of Maryland and Delaware: Part 2 – Biological Considerations. *Journal of Coastal Research,* 20(1):61-69.

Dickerson, C., K.J. Reine, and D.G. Clarke, 2001. Characterization of underwater sounds produced by bucket dredging operations. DOER *Technical Notes Collection (*ERDC TN-DOER-E14), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/dots/doer.

Donn, T.E., D.J. Clarke, A. McLachlan, and P. du Toit, 1986. Distribution and abundance of *Donax serra* Röding (Bivalvia: Donacidae) as related to beach morphology. I. Semilunar migrations. *Journal of Experimental Marine Biology and Ecology,* 102(2-3):121-131.

Drysdale, F.R. and M.G. Barbour, 1975. Response of the marine angiosperm *Phyllospadix torreyi* to certain environmental variables: A preliminary study. *Aquatic Botany,* 1:97-106.

Durarte, C.M., J. Terrados, N.S.R. Agawin, M.D. Fortes, S. Bach, and W.J. Kenworthy, 1997. Response of a mixed Philippine seagrass meadow to experimental burial. *Marine Ecology Progress Series,* 147:285-294*.*

Dugan, J.E. and D.M. Hubbard, 1996. Local variation in populations of the sand crab *Emerita analoga* on sandy beaches in southern California. *Revista Chilena de Historia Natural,* 69:579-588.

Dugan, J.E. and A. McLachlan, 1999. An assessment of longshore movement in *Donax serra* Roding (Bivalvia:Donacidae) on the exposed sandy beach. *Journal of Experimental Marine Biology and Ecology*, 234:111-124.

Dugan, J.E., D.M. Hubbard, D.L. Martin, J.M. Engle, D.M. Richards, G.E. Davis, K.D. Lafferty, and R.F. Ambrose, 2000a. Macrofauna communities of exposed sandy beaches on the southern California mainland and Channel Islands. Pages 339-346 In Fifth California Islands Symposium. OCS Study, MMS 99-0038.

Dugan, J.E., D.M. Hubbard, and M. Lastra, 2000b. Burrowing abilities and swash behavior of three crabs, *Emerita analoga* Stimpson, *Blepharopoda occidentalis* Randall, and *Lepidopa californica* Efford (Anomura, Hippoidea), of exposed sandy beaches. *Journal of Experimental Marine Biology and Ecology,* 255:229-245.

Dugan, J.E., D.M. Hubbard, M.D. McCrary, and M.O. Pierson, 2003. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. *Estuarine, Coastal and Shelf Science*, 585:25-40.

Dugan, J.E., E. Jamarillo, D.M. Hubbard, H. Contreras, and C. Duarte, 2004. Competitive interactions in macroinfauna animals of exposed sandy beaches. *Oecologia,* 139:630-640.

Duggins, D.O., J.E. Eckman, and A.T. Sewell, 1990. Ecology of understory kelp environments. II. Effects of kelps on recruitment of benthic invertebrates. Journal of Experimental Marine Biology and Ecology, 143(1-2):27-45. Available online http://www.sciencedirect.com/science. Accessed February 2006.

Ebeling, A.W., D.R. Laur, and R.J. Rowley, 1985. Severe storm disturbances and reversal of community structure in a southern California kelp forest. *Marine Biology,* 287-294..

Ebeling, A.W., R.J. Larson, W.S. Alevizon, and R.N. Bray, 1980. Annual variability of reef-fish assemblages in kelp forests off Santa Barbara, California. *Fishery Bulletin*, 78(2):361-377.

Ebert, T.A., S.C. Schroeter, J.D. Dixon, and P. Kalvass. Settlement patterns of red and purple sea urchins (*Strongylocentrotus franciscanus* and *S. pupuratus*) in California, USA. *Marine Ecology Progress Series*. 111:41-52.

Eckman, J.E., D.O. Duggins, and A.T. Sewell, 1990. Ecology of under story kelp environments. I. Effects of kelps on flow and particle transport near the bottom. *Journal of Experimental Marine Biology and Ecology,* 139(2):173-187.

Eganhouse, R.P. and M. I. Venkatesan, 1993. Chemical Oceanography and Geochemistry. Pages 71-189 in: *Ecology of the Southern California Bight: A Synthesis and Interpretation.* M.D. Dailey, D.J. Reish, and J.W. Anderson (eds.). University of California Press, Berkeley, California.

.

Ehrlich, P.R., D.S. Dobkin and D. Wheye, 1988. The Birder's Handbook. Simon and Schuster.

Eckman, J.E., D.O. Duggins, and A.T. Sewell, 1989. Ecology of under story kelp environments. I. Effects of kelps on flow and particle transport near the bottom. *Journal of Experimental Marine Biology and Ecology*, 139(2):173-187.

Eisma, D., 1993. *Suspended Matter in the Aquatic Environment*. Springer-Verlag, Berlin.

Elphick, C., J.B. Dunning, Jr., and D.A. Sibley (eds.), 2001. *The Sibley Guide to Bird Life and Behavior*. Alfred A. Knopf.

Elwany, H.H.S., W.C. O'Reilly, R.T. Guza, and R.E., Flick, 1995. Effects of Southern California kelp beds on waves. *Jour. Waterw. Port Coast. Ocean Engineer.* 121, 143-150.

Emerson, S.E. and J.B. Zedler, 1978. Recolonization of intertidal algae: an experimental study. Marine Biology, 44:315-324.

Engle, J.M., 1979. Ecology and Growth of Juvenile California Spiny Lobster, *Panulirus interruptus* (Randall). Ph.D. Dissertation, University of Southern California. 273 p.

Engle, J. M., 1994. Perspective on the structure and dynamics of nearshore marine assemblages of the California Channel Islands. Pages 13-26 in: *The fourth California Islands Symposium: Update on the Status of Resources.* W.L. Halvorson and G.J. Maender (eds.). Santa Barbara Museum of Natural History, Santa Barbara, CA.

Engle, J., 1998 personal communication.

Engle, J., 2005. Rocky Intertidal Resource Dynamics in San Diego County: Cardiff, La Jolla, and Point Loma, Final Eight-Year Report (1997/2005). Submitted to AMEC Earth & Environmental, Inc. and U.S. Navy, Southwest Division.

EPA see United States Environmental Protection Agency

Eschmeyer, W.N., E.S. Herald, and H. Hammann, 1983. A Field Guide to Pacific Coast Fishes of North America from the Gulf of Alaska to Baja California Houghton Mifflin Company.

Estes, J.A. and B.B. Hatfield, 1998. Population Status of the California Sea Otter. Appendix D in U.S. Fish and Wildlife Service, 2003. Final Revised Recovery Plan for the Southern Sea Otter (Enhydra lutris nereis). U.S. Fish and Wildlife Service Region 1.

Everts, G.H. and C.D. Eldon, 2000. Beach-retention structures and wide sandy beaches in southern California. *Journal of American Shore & Beach Preservation Association*, 68, No. 3.

Ewing, L., 1997. Procedural Guidance Document: Monitoring. California Coastal Commission. http://www.coastal.ca.gov/pgd/pgd-mon.html.

Fager, E.W., 1968. A sand-bottom epifaunal community of invertebrates in shallow water. *Limnology and Oceanography*, 13:448-464. Remove unless cited

Fancher, J., 2005. USFWS, personal communication.

Fancher, J., K. Foerster, and R. Bransfield, 1988. 1986 and 1987 Nesting Activities and Individual Histories of the California Least Tern at Huntington Beach State Beach, Orange County, California. Prepared by the Fish and Wildlife Service for the Corps of Engineers, Los Angeles District.

Fauchald, K. and P.A. Jumars, 1979. The diet of worms: A study of polychaete feeding guilds. *Oceanography and Marine Biology Annual Review,* 17:193-284.

Fauchald, K. and G. Jones, 1983. Benthic Macrofauna. In: Southern California Baseline Studies and Analysis, 1975-1976. Vol. III. Report 2.4, Science Applications, Inc. (SAI-76-809-LJ).

Faulkes, Z. and D.H. Paul, 1997. Coordination between the legs and tail during digging and swimming in sand crabs. *J. Comp. Physiol.* A – Sensory, Neural, Behav. Physiol. 180(2):161-169.

Federal Register (FR), 1998. National Marine Sanctuary Program Regulations; Florida Keys National Marine Sanctuary Regulations; Anchoring on Tortugas Bank. Rules and Regulations, 63(158):43870-43873, Monday, August 17, 1998.

FR, 2001. Regulations Governing the Approach to Humpback Whales in Alaska. Rules and Regulations, 66 (105): 29502-29509.

FR, 2005. Endangered Fish and Wildlife; Notice to Prepare and Environmental Impact Statement. Vol. 70, No. 7, Tuesday, January 11, 2005.

Federal Register, 2006. Gulf of the Farallones National Marine Sanctuary Regulations. 71(194):59337-59355, October 6, 2006. Available online From the Federal Register Online via GPO Access wais.access.gpo.gov (DOCID:fr06oc06-19).

Feder, H.M., C.H. Turner, and C. Limbaugh, 1974. Observations on fishes associated with kelp beds in southern California. *Fish Bulletin*, 160:1-144. Available online at: http://ceo.ucsd.edu/fishbull.

Ferren, W.R., P.L. Fiedler, and L.A. Leidy, 1995. Wetlands of the Central and Southern California Coast and Coastal Watersheds. A Methodology for their Classification and Description. United States Enviornmental Protection Agency Region IX, San Francisco, CA.

Finneran, J.J., R. Dear, D.A. Carder, and S.H. Ridgway, 2003. Auditory and behavioral responses of California sea lions (*Zalophus californianus*) to underwater impulses from an arc-gap transducer. *Journal Acoustic Society of America*, 114:1667-1677.

Finneran, J.J., D.A. Carder, C.E. Schlundt, and S.H. Ridgway, 2005. Temporary threshold shift in bottlenose dolphins (*Tursiops truncates*) exposed to mid-frequency tones. *Journal Acoustic Society of America*, 118(4):2696-2705.

Fitch, J.E., 1953. Common marine bivalves of California. *Ca. Dept. Fish and Game, Fish Bulletin* 90:1-102.

Fitch, J.E. and R.J. Lavenberg (eds.), 1971. *Marine Food and Game Fishes of California*. Univeristy of California Press, Berkeley, California. 179 pp.

Fritzsche, R.A., R.H. Chamberlain, and R.A. Fisher, 1985. California Grunion. Species Profiles: Life Histories and Enviornmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest). Biological Report 82(11.28). 12 pp.

Florida Department of Environmental Protection (DEP), 2005. Beach Erosion Control Program. http://www.dep.state.fl.us/beaches/programs/bcherosn.htm, accessed November 2005.

Florida Fish and Wildlife Conservation Commission (Florida FWCC), 2005. Comprehensive Wildlife Conservation Strategy for Florida, Habitat Categories. February 7, 2005. http://myfwc.com/wildlifelegacy/pdf/HabitatCategories.pdf. Accessed March 2006.

Fonseca, M.S. 1989, Regional Analysis of the Creation and Restoration of Seagrass Systems. Pages 175-198 In: *Wetland Creation and Restoration: The Status of the Science*. Kusler, J.A. and M.E. Kentula (eds.). EPA/600/3-89/038a. Environmental Research Laboratory, Corvallis, Oregon.

Fonseca, M.S. and J.A. Cahalan, 1992. A preliminary evaluation of wave attenuation by four species of seagrass. *Estuarine, Coastal and Shelf Science,* 35:565-576.

Fonseca, M.S., J.C. Zieman, G.W. Thayer, and J.S. Fisher, 1983. The role of current velocity in structuring eelgrass (*Zostera marina* L.) meadows. *Estuarine, Coastal and Shelf Science, 17:367-380.*

Fonseca, M.S. and W.J. Kenworthy, 1987. Effects of current on photosynthesis and distribution of seagrasses. *Aquatic Botany,* 27:59-78.

Fonseca, M.S., W.J. Kenworthy, D.R. Colby, K.A. Rittmaster, and G.W. Thayer, 1990. Comparisons of fauna among natural and transplanted eelgrass *Zostera marina* meadows: criteria for mitigation. *Marine Ecology Progress Series,* 65:251-264.

Fonseca, M.S., W.J. Kenworthy, and G.W. Thayer, 1992. Surfgrass Beds: Nursery for Coastal Species. Pages 131-147 In: *Stemming the Tide of Coastal Fish Habitat Loss.* Proceedings of the Symposium on Conservation of Coastal Fish Habitat,

Baltimore, Maryland, March 7-9, 1991. Marine Recreational Fisheries 14. Published by the National Coalition for Marine Conservation, Inc., Savannah, CA.

Fonseca, M.S., W.J. Kenworthy, and G.W. Thayer, 1998. Guidelines for the Conservation and Restoration of Seagrasses in the United States and Adjacent Waters. NOAA Coastal Ocean Program Decision Analysis Series, No. 12. NOAA Coastal Ocean Office, Silver Spring, MD.

Foster, M.S., 1975. Regulation of algal community development in a *Macrocystis pyrifera* forest. *Marine Biology* (Berl.) 32:331-342.

Foster, M.S. and D.R. Schiel. 1985. The Ecology of Giant Kelp Forests in California: A Community Profile. U.S. Fish and Wildlife Service Biological Report 85(7.2): 1-152.

Fotheringham D.G. and D.R. Goodwins, 1990. Monitoring the Adelaide Beach System. Proceedings of the 1990 Workshop on Coastal Zone Management, Yeppoon, Queensland.

FR see Federal Register

Fraser, J. and J. Cohen, 2005. Piping Plover Habitat Considerations for Beach Nourishment Designs. In: The First Regional Workshop on Dredging, Beach Nourishment, and Birds on the South Atlantic Coast and a Symposium on the Ecology and Conservation of Piping Plovers, February 1-4, 2005. http://el.erdc.usace.army.mil/training. cfm?Topic=Workshop&List=05feb-dots. Accessed June 2006.

Fritzsche, R.A., R.H. Chamberlain, and R.A. Fischer, 1985. California Grunion. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest). Biological Report 82(11.28). TR EL-82-4.

FWS (see USFWS)

Gajewski and Uscinowicz 1993 cited in Newell et al. 1998).

Gallagher, S.R., 1997. Atlas of Breeding Birds Orange County, California. Sea and Sage Audubon Press

Garcia, S.M., A. Zerbi, C. Aliaume, T. Do Chi, G. Lasserre, 2003. *The Ecosystem Approach to Fisheries: Issues, Terminology, Principles, Institutional Foundations, Implementation and Outlook*. ISSN 0429-9345, FAO Fisheries Technical Paper, 443. Food and Agricultural Organization (FAO) of the United Nations, Rome, 2003..

Gerard, V.A., 1982. Growth and utilization of internal nitrogen reserves by the giant kelp *Macrocystis pyrifera* in a low-nitrogen environment. *Marine Biology*, 66:27-35.

Gerard, V.A., 1984. The Light environment in a giant kelp forest: influence of *Macrocystis pyrifera* on spatial and temporal variability. *Marine Biology,* 84:189-95.

Germano, J.D. and D. Cary, 2005. Rates and effects of sedimentation in the context of dredging and dredged material placement. *DOER Technical Notes Collection (*ERDC TN-DOER-E19), U.S. Army Engineer Research and Development Center, Vicksburg, MS. http://el.erdc.usace.army.mil/dots/doer/doer.html.

Gibbs, R.E., 1902. *Phyllospadix* as a beach builder. *American Naturalist,* 36:101-109.

Gibson, D., 2006. Director, San Elijo Lagoon Foundation, personal communication.

Giesen, W.B.J.T., M.M. van Katwijk, and C. den Hartog, 1990. Eelgrass condition and turbidity in the Dutch Wadden Sea. *Aquatic Botany,* 37(1):71-85.

Golder, W., D. Allen, S. Cameron, and T. Wilder, 2005. Tern Use of Dredged Materials, Designs for Creation and Restoration of Tern Nesting Sites. In: The First Regional Workshop on Dredging, Beach Nourishment, and Birds on the South Atlantic Coast and a Symposium on the Ecology and Conservation of Piping Plovers, February 1-4, 2005. http://el.erdc.usace.army.mil/training.cfm?Topic=_Workshop&List=05feb-dots. Accessed June 2006.

Goreau, T.J. 2001. Reef Protection in Broward County, Florida. Report by Cry of the Water and the Global Coral Reef Alliance. (http://www.cryofthewater.org).

Gorzelany, J.F. and W.G. Nelson, 1987. The effects of beach replenishment on the benthos of a sub-tropical Florida beach. *Marine Environmental Research* 21:75-94.

Government of South Australia, 2005. Adelaide's Living Beaches: A Strategy for 2005-2025. Department for Environment and Heritage. Available online at www.environment.sa.gov.au. Accessed March 2006.

Grant, J. 1981. Sediment transport and disturbance on an intertidal sandflat: Infaunal distribution and recolonization. *Marine Ecology Progress Series*, 6:249-255.

Grant, J. and B. Thorpe, 1991. Effects of suspended-sediment on growth, respiration, and excretion of the soft-shelled clam (*Mya arenaria*). *Canadian Journal of Fisheries and Aquatic Sciences,* 48:1285-1292.

Green, K. 2005. Coastal Beach Habitat Study. PowerPoint presentation at: H20 Conference, Long Beach, California.

Green, K., 2006a. Biological Impact and Resource Protection Issues Associated with Sediment Management Activities. PowerPoint presentation at: California World Ocean Conference, Long Beach, California.

Green, R.H., 1979. *Sampling Design and Statistical Methods for Environmental Biologists*. John Wiley & Sons, New York. 257pp.

Greene, K. 2002. Beach Nourishment: A Review of the Biological and Physical Impacts. ASMFC Habitat Management Series #7. Atlantic States Marine Fisheries Commission.

Gregory, P.A., 2001. Grunion. Pages 246-247, In: *California Department of Fish and Game California's Living Marine Resources: A Status Report*.

Gregory, R.S. and C.D. Levings, 1998. Turbidity Reduces Predation on Migrating Juvenile Pacific Salmon. *Transactions of the American Fisheries Society* 127: 275-285.

Gregory, R.S. and T.G. Northcote, 1993. Surface, planktonic, and benthic foraging by juvenile chinook salmon (*Oncorhynchus tshawytscha*) in turbid laboratory conditions. *Can.J.Fish. Aquat*. Sci.50: 233-240.

Griem, J., 2000. Shorebirds. Interview by NOVA. Available online at: http://www.pbs.org/wgbh/nova/kalahari/shore.html. Accessed January 2007.

Griem, J.N. and K.L.M. Martin, 2000. Wave action: the environmental trigger for hatching in the California grunion *Leuresthes tenuis* (Teleostei: Atherinopsidae). *Marine Biology*, 137:177-181.

Greve, T.M., D. Krause-Jensen, M.B. Rasmussen, and P.B. Christensen, 2005. Means of rapid eelgrass (*Zostera marina* L.) recolonization in former dieback areas. *Aquatic Botany* 82(2): 143-156.

Griffiths, S.P., R.J. West, A.R. Davis, and K.G. Russell, 2004. Fish recolonization in temperatre Australian rockpools: a quantitative experimental approach. *Fishery Bulletin*, 102:634-647.

Griem, J.N. and K.L.M. Martin, 2000. Wave action: the environmental trigger for hatching in the California grunion *Leuresthes tenuis* (Teleosti: Atherinopsidae). *Marine Biology* 137:177-181.

Gress, F., 2001. Breeding Success of Brown Pelicans on West Anacapa Island, in 1999. Appendix A. in American Trader Trustee Council, 2001. Restoration Plan and Environmental Assessment for Seabirds Injured by the American Trader Oil Spill.

Grupo Tortuguero, 2006. Sea turtles of Baja California. http://www.grupotortuguero.org/content/1/2/16.html. Accessed July 2006.

Guidetti, P., 2001. Detecting environmental impacts on Mediterranean seagrass *Posidonia oceanica* (L.) Delile: the use of reconstruction methods in combination with “beyond BACI” designs. *Journal of Experimental Marine Biology and Ecology,* 260(1):27-39.

Guilfoyle, M.P., R.A. Fischer, and M.C. Landin, 2005. A History of Avian Habitat Creation Through Dredged Material Deposition by the U.S. Army Corps of Engineers. In: The First Regional Workshop on Dredging, Beach Nourishment, and Birds on the South Atlantic Coast and a Symposium on the Ecology and Conservation of Piping Plovers, February 1-4, 2005. http://el.erdc.usace.army.mil/training.cfm?Topic=Workshop&List=05feb-dots. Accessed June 2006.

Gunnill, F.C., 1980. Recruitment and standing stocks in populations of one green alga and five brown algae in the intertidal zone near La Jolla, California during 1973-1977. *Marine Ecology Progress Series,* 3: 231-43.

Hackney, C. T., M. H. Posey, S. W. Ross and A. R. Norris. 1996. A review and synthesis of data on surf zone fishes and invertebrates in the South Atlantic Bight and the potential impacts from beach nourishment. Prepared by the University of North Carolina at Wilmington and the North Carolina National Estuarine Research Reserve for the U.S. Army Corps of Engineers, Wilmington, NC.

Hall, S. J., 1994. Physical disturbance and marine benthic communities: life in unconsolidated sediments. *Oceanography and Marine Biology: an Annual Review,* 32:179-239.

Hamm, L., M. Capobianco, H.H. Dette, A. Lechuga, R. Spanhoff, and M.J.F. Stive, 2002. Coastal Engineering 47:237-264.

Hammer, R.M., M.R. Byrnes, D.B. Snyder, T.D. Thibaut, J.L. Baker, S.W. Kelley, J.M. Côté, L.M. Lagera, Jr., S.T. Viada, B.A. Vittor, J.S. Ramsey, and J.D. Wood, 2005. Environmental Surveys of Potential Borrow Areas on the Central East Florida Shelf and the Environmental Implications of Sand Removal for Coastal and Beach Restoration. Prepared by Continental Shelf Associates, Inc. in cooperation with Applied Coastal Research and Engineering, Inc. Barry A. Vittor & Associates, Inc., and the Florida Geological Survey. Prepared for the U.S. Department of the Interior, Minerals Management Service, Leasing Division, Marine Minerals Branch, Herndon, VA. OCS Study MMS 2004-037, 306 pp. + apps.

Hanan, D., J. Sisson, R. Read, and C. Wilson, 2001. Pinnipeds in California Department of Fish and Game California's Living Marine Resources: A Status Report: 523-527.

Hanson, J., M. Helvey, and R. Strach (eds.), 2003. Appendix 14 - Non-Fishing Impacts to Essential Fish Habitat and Recommended Conservation Measures. In: Risk Assessment, Essential Fish Habitat for West Coast Groundfish.

Hardy, J.T., 1993. Phytoplankton. Pages 233-265 in: *Ecology of the Southern California Bight: A Synthesis and Interpretation.* M.D. Dailey, D.J. Reish, and J.W. Anderson (eds.). University of California Press, Berkeley, California.

Harrison, P.G., 1990. Experimental eelgrass transplants in southwestern British Columbia, Canada. Pages 46-57 In: In: *Proceedings of the California Eelgrass Symposium, Chula Vista, California, May 27 and 28, 1988*. Sweetwater River Press, National City, California.

Harrold, C. and D. Reed, 1985. Food availability, sea urchin grazing, and kelp forest community structure. *Ecology,* 66(4):1160-1169.

Hastings, 2002.

Hart Crowser. 2000. Water Quality Measurements – Marina Del Rey Maintenance Dredging. Submitted to USACE, Los Angeles District.

Harvey, J.T., 2004. Potential Impacts to Marine Mammals During Cable-placement Activities for the MARS Project (MBARI) off Monterey Bay, California. Appendix A: Marine Mammal Impacts MARS Cable Route Application of Lease of State Lands.

Harwell, M.C. and R.J. Orth, 2002. Long distance dispersal potential in a marine macrophyte. *Ecology,* 83:3319-3330.

Hastings, M.C. and A.N. Popper, 2005. Effects of Sound on Fish. California Department of Transportation Contract No. 43A0139, Task Order 1. http://www.wsdot.wa.gov/environment/biology/bio_FishWildlife.htm. Accessed November 2006.

Hauxwell, J., J. Cebrian, and I. Valiela, 2006. Light dependence of *Zostera marina* annual growth dynamics in estuaries subject to different degrees of eutrophication. *Aquatic Botany,* 84(1):17-25.

Hays, D.E., 1986. Effects of delayed spawning on viability of eggs and larvae of Pacific herring. *Transactions of the American Fisheries Society*, 115(1):155-161.

Heilprin, D., 2007. SAIC fisheries biologist, personal communication.

Henley, W.F., M.A. Patterson, R.J. Neves, and A.D. Lemly, 2000. Effects of sedimentation and turbidity on lotic food webs: A concise review for natural resource managers. *Reviews in Fisheries Science*, 8(2):125-139.

Herrnkind, W.F., M.J. Butler, IV., and R.A. Tankersley, 1988. The effects of siltation on recruitment of spiny lobsters *Panulirus argus. Fishery Bulletin*, 86:331-338

Herrington, W.C., 1929. The Pismo clam: further studies of the life history and depletion. *California Fish and Game Fish Bulletin*, 18, 58 pp.*.*

Hewitt, J.E., V.J. Cummings, J.I. Ellis, G. Funnell, A. Norkko, T.S. Tally, and S.F. Thrush, 2002. The role of waves in the colonization of terrestrial sediments deposited in the marine environment. *Journal of Experimental Marine Biology and Ecology*, 290(1):19-47.

Hickey, B., 1993. Chemical Oceanography and Geochemistry. Pages 19-70 in: *Ecology of the Southern California Bight: A Synthesis and Interpretation.* M.D. Dailey, D.J. Reish, and J.W. Anderson (eds.). University of California Press, Berkeley, California.

Higgins, R.P. and H. Thiel (eds.), 1988. *Introduction to the Study of Meiofauna*. Smithsonian Institution Press, Washington D.C. 488 pp.

Higgins, C.T., C.I. Downey, and J.P. Clinkenbeard. 2004. Literature Search and Review of Selected Topics Related to Coastal Processes, Features, and Issues in California.

Hill, S., M. T. Burrows, and S.J. Hawkins, 1998. Intertidal Reef Biotypes (Volume VI). An Overview of Dynamic and Sensitivity Characteristics for Conservation Management of

Marine SACs. Scottish Association for marine Science (UK Marine SACs Project). 84 pp.

Hillmann, L.G., 2005. Summary of Regulations for Seaweed Harvesting Along the West Coast of North America (2005). http://egov.oregon.gov/OPRD/NATRES/docs/AlgaeRegulationsSummary.pdf. Accessed February 2006.

Hirsch, N.D., L.H. DiSalvo, and R. Peddicord, 1978. Effects of Dredging and Disposal on Aquatic Organisms. Technical Report DS-78-5, U.S. Army Engineer Waterways Experiment Station, Environmental Laboratory, Vicksburg, Mississippi.

Hiss, J.M., J.L. Schroeder, and S. Lind, 1988. The Effect of Beach Nourishment on Salmonid Prey Resources of Lincoln Park, Seattle, Washington: Pre-project Conditions. Prepared for the U.S. Army Corps of Engineers Seattle District.

Hitchock and Drucker 1996 cited in Newell et al. 1998

Hitchcock, D.R., R.C. Newell, and L.J. Seiderer, 2002 Integrated Report on the Impact of Marine Aggregate Dredging on Physical and Biological Resources of the Sea Bed. U.S. Department of the Interior, Minerals Management Service, International Activities and Marine Minerals Division (INTERMAR), Washington, D.C. OCS Report Number 2000-054.

Hitchcock D.R. and S. Bell, 2004. Physical impacts of marine aggregate dredging on seabed resources in coastal deposits. *Journal of Coastal Research*, 20(1):101-114.

Hodbay, A.J. and M.J. Tegner, 2000. Status review of white abalone (*Haliotis sorenseni*) throughout its range in California and Mexico. NOAA Technical Memorandum NOAA-TM-NMFS-SWR-035. U.S. Department of Commerce.

Hoffman, R.S., 2006 and 2007. NMFS, personal communications.

Hoffman, R.S., 1986. Fishery Utilization of Eelgrass (*Zostera marina*) Beds and Non-Vegetated Shallow Water Areas in San Diego Bay. Southwest Region, National Marine Fisheries Service, NOAA, Administrative Report SWR-86-4.

Hoffman, R. S., 1990. Recovery of Eelgrass Beds in Mission Bay, San Diego, California Following Beach Restoration Work. Pages 21-27 In: *Proceedings of the California Eelgrass Symposium, Chula Vista, California, May 27 and 28, 1988*. Sweetwater River Press, National City, California.

Hoffman, R.S., 1991. Relative Fisheries Values of Natural Versus Transplanted Eelgrass Beds (*Zostera marina*) in Southern California. Pages 16-30 In: *Coastal Wetlands, Coastal Zone '91 Conference-ASCE Long Beach, CA/July 1991*.

Holland, H.T., J.R. Chambers, and R.R. Backman, 1980. Effects of Dredging and Filling for Beach Erosion Control on Fishes in the Vicinity of Lido Key, Florida. Unpublished report. Jacksonville, FL. Jacksonville District, U.S. Army Corps of Engineers.

Hollbrook, S. J., M. H. Carr, R. J. Schmitt, and J. A. Coyer. 1990. Effect of giant kelp on local abundance of reef fishes: the importance of ontogenetic resource requirements. *Bulletin of Marine Science*, 47(1):104-114.

Hollbrook, S.J., D.C. Reed, K. Hansen, and C.A. Blanchette, 2000. Spatial and temporal patterns of predation on seeds of the surfgrass *Phyllospadix torreyi. Marine Biology,* 136:739-747.

Hosier, P.E. and T.E. Eaton, 1980. The impact of vehicles on dune and grassland vegetation on a southeastern North Carolina barrier beach. *Journal of Applied Ecology,* 17:173-182.

Howard, A.E., 1982. The distribution and behaviour of ovigerous edible crabs (*Cancer pagurus*), and consequent sampling bias. *Journal du Conseil Internationale pour l'Exploration de al Mer*, 40:259-261.

Howard, R.K., and F. T. Short, 1986. Seagrass growth and survivorship under the influence of epiphyte grazers. *Aquatic Botany*, 24(3):287-302.

Hubbard, D.M. and J.E. Dugan, 2003. Shorebird use of an exposed sandy beach in southern California. Estuarine, *Coastal and Shelf Sciences,* 58S: 169-182.

Hubbs, C., 1965. Developmental temperature tolerance and rates of four southern California fishes, *Fundulus parvipinnis*, *Atherinops affinis*, *Leuresthes tenuis*, and *Hypsoblennius* sp. *California. Fish and Game*, 51(2):113-122.

Hughes, H., 2005. Encore for eelgrass. *Coast & Ocean*, 21(1&2).

Hunt, G.L. Jr., R.L. Pitman, M. Naughton, K. Winett, A. Newman, P.R. Kelly and K.T. Briggs, 1981. Summary of Marine Mammal and Seabird Surveys of the Southern California Bight Area, 1975-1978. Volume III. Investigators Reports. Part III. Seabirds. Book II. Reproductive Ecology and Foraging Habits of Breeding Seabirds. Bureau of Land Management.

Hunt, G., 1994. Peregrine Falcon Studies on the Channel Islands. Expert Report for the United States vs. Montrose Chemical Corp. et al., September 1994.

Hurme, A.K. and E. Pullen, 1988. Biological effects of marine sand mining and fill placement for beach replenishment: Lessons for other uses. *Marine Mining,* 7:123-136.

Hutchinson, E. S., G.W. Page, and P.E. Persons, 1987. The Nesting of Snowy Plovers on Morro Bay Sand Spit During and After the 1987 Maintenance Dredging of Morro Bay Harbor. A Report of the Point Reyes Bird Observatory. 16 pp.

IMG-Golder, Corporation (IMG), 2004. Review of Potential Effects of Dredging in the Beaufort Sea. Submitted to: Fisheries and Oceans Canada.

Inman, D.L. and P. M. Masters (eds), 2003. *Living with Coastal Change*. Scripps Institution of Oceanography, University of California San Diego. http://coastalchange.ucsd.edu, accessed September 2005.

James, R., J. Tutton, and D. Stadtlander, 1992. A Survey of the Western Snowy Plover on Camp Pendleton San Diego County, California. Fish and Wildlife Service Report of the Marine Corps Base Camp Pendleton, Natural Resources Office. 19 pp.

Jaques, D. and C. Strong, 2000. Post-breeding Brown Pelican Distribution and Roost Habitat Use in California, 1999. Appendix A. in American Trader Trustee Council, 2001. Restoration Plan and Environmental Assessment for Seabirds Injured by the American Trader Oil Spill.

Jackson, G.A., 1977. Nutrients and production of giant kelp, *Macrocystis pyrifera,* off southern California. *Limnology and Oceanography,* 22:979-995.

Jackson, G.a. and C.D. Winant, 1983. Effect of kelp forest on coatal currents. *Continental Shelf Research,* 2:75-80.

Jackson, N.L., K.F. Nordstrom, and D.R. Smith, 2002. Geomorphic-biotic interactions on beach foreshores in estuaries. *Journal of Coastal Research*, 36:414-424.

Jackson, E.L., M.J. Attrill, A.A. Rowden, and M.B. Jones, 2006. Seagrass complexity hierarchies: Influence on fish groups around the coast of Jersey (English Channel). *Journal of Experimental Marine Biology and Ecology*, 330(1):38-54.

Jaques, D.L., C.S. Strong, and T.W. Keeney, 1996. Brown Pelican Roosting Patterns and Responses to Disturbance at Mugu Lagoon and Other Nonbreeding Sites in the Southern California Bight. National Biological Service, Cooperative National Park Resources Studies Unit Technical Report No. 54.

James, M., D. Hubbard, and J. Dugan, 2004. On the Banks of the River of Sand: Restoration of Ecological and Physical Processes in the Coastal Strand Zone. Presented at the

Jannsen, J., 2005. Piping Plover Management on Nourished Beaches in Areas of High Human Use. In: The Second Regional Workshop on Dredging, Beach Nourishment, and Bird Conservation: Atlantic Coast from Maine to Virginia, October 25-27, 2005. http://el.erdc.usace.army.mil/training.cfm?Topic= Workshop&List=05oct-dots. Accessed June 2006.

Jaques, D. and C. Strong, 2002. Disturbance of brown pelicans at communal roosts in southern and central California. Prepared for the American Trader Trustee Council, California Department of Fish and Game, U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration. October 2002.

Jaramillo, E., J. Dugan, and H. Contreras, 2000. Abundance, tidal movement, population structure and burrowing rate of *Emerita analoga* (Stimpson 1857) (Anomura, Hipppidae) at a dissipative and a reflective beach in south central Chile. *Marine Ecology,* 221:113-127.

Jasny, M., J.Reynolds, C. Horowitz, and A. Wetzler, 2005. Sounding the depths II: The rising toll of sonar, shipping, and industrial ocean noise on marine life. National Resources Defense Council. November 2004.

Jedrey, E., 2005. Tern Restoration in Cape Co, Massachusetts: Past, Present, and Future. In: The Second Regional Workshop on Dredging, Beach Nourishment, and Bird Conservation: Atlantic Coast from Maine to Virginia, October 25-27, 2005. http://el.erdc.usace.army.mil/training.cfm?Topic=Workshop&List=05oct-dots. Accessed June 2006.

Jenkins, D. and M. Erwin, 2005. Beach Nourishment and Dredged Material Islands in Relation to Black Skimers and Common Terns Nesting in New Jersey. In: The Second Regional Workshop on Dredging, Beach Nourishment, and Bird Conservation: Atlantic Coast from Maine to Virginia, October 25-27, 2005. http://el.erdc.usace.army.mil/training.cfm?Topic=Workshop&List=05oct-dots. Accessed June 2006.

Johnson, B.H., E. Anderson, T. Isaji, and D.G. Clarke, 2000. Description of the SSFATE numerical modeling system. *DOER Technical Notes Collection (*ERDC TN-DOER-E10). U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/dots/doer.

Johnson, J.E. and R.T.Hines, 1999. Effect of Suspended Sediment on Vulnerability of Young Razorback Suckers to Predation. *Transactions of the American Fisheries Society* 128:648-655.

Johnson, R.O. and W.G. Nelson, 1985. Biological effects of dredging in an offshore borrow area. *Florida Scientist*, 48(3):166-188.

Johnston, D.D. and D.J. Wildish, 1982. Effect of suspended sediment on feeding by larval herring (*Clupea harengus harengus* L.). *Bull. Environm. Contam. Toxicol*. 29:261-267.

Jones, G., 1981. Effects of dredging and reclamation on the sediments of Botany Bay. *Aust. J. Mar. Freshwater Res.,* 32:369-377.

Jutte, P. C., R. F. Van Dolah and M. V. Levisen. 1999a. An environmental monitoring study of the Myrtle Beach Renourishment Project: Intertidal benthic community assessment of Phase I.- Cherry Grove to North Myrtle Beach. Final Report. Prepared by the Marine Resources Division, South Carolina Department of Natural Resources for U. S. Army Corps of Engineers, Charleston, SC.

Jutte, P. C., R. F. Van Dolah and M. V. Levisen. 1999b. An environmental monitoring study of the Myrtle Beach Renourishment Project: Intertidal benthic community assessment of Phase II - Myrtle Beach. Supplemental Report. Prepared by the Marine Resources Division, South Carolina Department of Natural Resources for U. S. Army Corps of Engineers, Charleston, SC.

Jutte, L.E. Zimmerman, and R. Van Dolah, 2001. An environmental monitoring study of the Myrtle Beach Renourishment Project: Physical and biological assessment of offshore sand borrow sites – Phase III. – Surfside Borrow Area. Final Report. Prepared by the

Marine Resources Division, South Carolina Department of Natural Resources for the U.S. Army Corps of Engineers, Charleston, S.C.

Kastak, D., B.L. Southall, R.J. Schusterman, and C.R. Kastak, 2005. Underwater temporary threshold shift in pinnipeds: Effects of noise level and duration. *Acoustic Journal Society of America*, 118(5):3154-3163.

Kastelein, van der Heul, Verboom, Triesscheijn, and Jennings, 2006. The influence of underwater data transmission sounds on the displacement behaviour of captive harbour seals (*Phoca vitulina*). *Marine Environmental Research* 61 (2006) 19–39.

KBC and Aspen See Keane Biological Consulting and Aspen Environmental Group

Keane, K., 1999. California Least Tern Breeding Survey 1998 Season. Prepared for California Department of Fish and Game.

Keane, K., 2001. Final Report. Breeding Biology of the California Least Tern in Los Angeles Harbor 2000 Season. Prepared for Los Angeles Harbor Department, Environmental Management Division.

Keane, K. 2004. California Least Tern Breeding Pairs and Fledgling Production - 2004 Draft.

Keane Biological Consulting and Aspen Environmental Group (KBC and Aspen), 2002. California Least Tern Foraging Surveys Oceanside Harbor Maintenance Dredging Area, 2001. Prepared for U.S. Army Corps of Engineers, Los Angeles District.

Keane, K., 2005 personal communication.

Keeton, W.T., 1972. *Biological Science*. 2nd ed.. W.W. Norton & Company, New York. 888 p.

Keitt, B. S., B.R. Tershy, and D.A. Croll, 2004. Nocturnal behavior effect reduces predation pressure on black-vented shearwaters *Puffinus opistomelas. Marine Ornithology*, 32: 173–178.

Kelly, J.P., 2004. Vague consequences of omnipresence: common raven behavior in heronries. *The Ardeid, pp 1-3.*

Kenworhy, W.J. and M.S. Fonseca, 1992. The use of fertilizer to enhance growth of transplanted seagrasses *Zostera marina* L. and *Halodule wrightii* Aschers. *Journal Experimental Marine Biology and Ecology,* 163:141-161.

Kenny, A.J. and .L. Rees, 1996. The effects of marine gravel extraction on the macrobenthos: Results 2 years post-dredging. *Marine Pollution Bulletin,* 32:615-622.

Kineke G.C. and R.W. Sternberg, 1989. The effect of particle settling velocity on computed sediment concentration profiles. *Marine Geology,* 90:159-174.

Kinnetic Laboratories, Inc. 2003. Santa Cruz Harbor Dredge Demonstration Project – Turbidity and Dye Studies. Letter report to Santa Cruz Port District.

Kiorboe, T., E. Frantsen, C. Jensen, and G. Soreenson, 1981. Effects of suspended sediment on development and hatching of herring (*Clupea harengus*) eggs. *Estuarine Coastal and Shelf Science*, 3(1):107-111.

Komar, P.D., 1997. Erosion of a massive artificial "landslide" on the California coast. *Shore and Beach* 8-14.

Komar, P.D., 1998. *Beach Processes and Sedimentation.* Prentice-Hall, Inc.

Konar, B. and C. Roberts, 1996. Large scale landslide effects on two exposed rocky subtidal areas in California. *Botanica Marina* 39:517-524.

Korschgen, C.E., L.S. George, and W.L. Green, 1985. Disturbance of Diving Ducks by Boaters on a Migrational Staging Area. *Wildl. Soc. Bull*. 13: 290-296.

Kramer, S.H. Growth, mortality, and movements of juvenile California halibut, *Paralichthys californicus* in shallow coastal and bay habitats of San Diego County, California. *Fishery Bulletin*, 89:195-207.

Kraemer, G.P. and R.S. Alberte, 1995. Impact of daily photosynthetic period on protein synthesis and carbohydrate stores in *Zostera marina* L. (eelgrass) roots: implications for survival in light-limited environments. *Journal of Experimental Marine Biology and Ecology,* 185(2):191-202.

Kumer, J., 2005. The Assateague Island Beach Restoration Project. In: The Second Regional Workshop on Dredging, Beach Nourishment, and Bird Conservation: Atlantic Coast from Maine to Virginia, October 25-27, 2005. http://el.erdc.usace.army.mil/training.cfm?Topic=Workshop&List=05oct-dots. Accessed June 2006.

Kuhn, G.G. and F. P. Shepard, 1984. *Sea Cliffs, Beaches, And Coastal Valleys of San Diego County. Some Amazing Histories and Some Horrifying Implications*. University of California Press, Berkeley. 193 pp.

Lafferty, K.D., 2000. Status, Trends and Conservation of the Western Snowy Plover with a Focus on the Devereux Slough Population at Coal Oil Point Reserve, Santa Barbara County, CA. Museum of Systematics and Ecology Environmental Report No. 15, University of California, Santa Barbara.

Lafferty, K.D., 2001a. Disturbance to wintering western snowy plovers. *Biodiversity and Conservation,* 101:315-325.

Lafferty, K.D., 2001b. Birds at a Southern California beach: seasonality, habitat use and disturbance by human activity. *Biodiversity and Conservation*, 10:1949-1962.

Laist, D.W., A.R. Knowlton, J.G. Mead, A.S. Collet, and M. Podesta, 2001. Collisions between ships and whales. *Marine Mammal Science*, 17(1):35–75

Lankford, T.E. and B.J. Baca, 1987. A Biological Study of Macrofaunal and Supratidal Communities in Response to a Proposed Beach Scraping Project at Wild Dunes

Development, Isle of Palms, South Carolina. Tech. Report for Wild Dunes Assoc.: CSE, Columbia, S.C. 20 pp.

Lankford, T.E. and B.J. Baca, and C.E. Nation, 1988. Biological Monitoring of Beach Scraping at Pawleys Island, South Carolina. Tech. Report for Town of Pawleys Island, S.C.: CSE, Columbia, S.C. 31 pp.

Larson, R.J. and E.E. DeMartini, 1984. Abundance and vertical distribution of fishes in a cobble-bottom kelp forest off San Onofre, California. *U.S. National Marine Fisheries Service Fish Bulletin,* 82(1):37-53.

Larson, K.W., and C.E. Moehl. 1990. Entrainment of anadromous fish by hopper dredge at the mouth of the Columbia River. In: *Effects of Dredging on Anadromous Pacific Coast Fishes,* edited by C.A. Simenstad. Washington Sea Grant program, University of Washington, Seattle. 160 pp.

Larson, K. and K. Patterson, 1989. Entrainment of Dungeness crab by hopper dredge at the mouth of the Columbia River, Or. And WA, USA. PP. 268-285 In: *Dredging: Proceedings of WODCON XII.* Orlando, Florida.

LARWQCB – See Californian Regional Water Quality Control Board, Los Angeles Region.

LaSalle, M., D.G. Clarke, J. Homziak, J.D. Lunz, and T.J. Fredette, 1991. A Framework for Assessing the Need for Seasonal Restrictions on Dredging and disposal Operations. Technical Report D-91-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lassuy, D.R., 1989. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest) - Pacific Herring. U.S. Fish and Wildlife Service Biological Report 82 (11.126). TR EL-82-4.

Lassuy, D.R., and D. Simons, 1989. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest) - Pacific Razor Clam. U.S. Fish and Wildlife Service Biological Report 82 (11.89). TR EL-82-4.

Lee, K-S., F.T. Short, and D. M. Burdick, 2004. Development of a nutrient pollution indicator using the seagrass, *Zostera marina*, along nutrient gradients in three New England estuaries. *Aquatic Botany*, 3(3):1 97-216.

Leatherwood, S. and R.R. Reeves, 1983. *The Sierra Club Handbook of Whales and Dolphins.* Sierra Club Books.

Legardè, J. P., 1982. Effects of noise on growth and reproduction of *Crangon crangon* in rearing tanks. *Marine Biology,* 71: 177-185.

Legardère, J. P. and M.R. Régnault, 1980. Influence du niveau sonore de bruit ambient sur la métabolisme de *Crangon crangon* (Decapoda: Natantia) en élevage. *Marine Biology* 57:157-164.

Leighton, D. L., 1971. Grazing activities of benthic invertebrates in Southern California kelp beds. *Nova Hedwigia* (Suppl.), 32:421-453.

Levin, L.A., 1984. Life history and dispersal patterns in a dense infaunal polychaete assemblage: community structure and response to disturbance. *Ecology,* 1185-1200.

Levin, P. S. and M. E. Hay, 2002. Fish-seaweed association on temperate reefs: do small-scale experiments predict large-scale patterns? Marine Ecology Progress Series, 232:239-246.

Lewis, J.R., 1964. *The Ecology of Rocky Shores.* The English Universities Press Ltd., London. 323 pp.

Lewis, R.D. and K. K. McKee, 1989. *A Guide to the Artificial Reefs of Southern California.* Department of Fish and Game. 73 pp.

LFR Levine-Fricke (LFR), 2004. Framework for Assessment of Potential Effects of Dredging on Sensitive Fish Species in San Francisco Bay. Prepared for USACE, San Francisco District.

Leif, P., S. Baden, N. Kautsky, P. Rönnbäck, T. Söderqvist, M. Troell, and H. Wennhage, 2006. Shift in fish assemblage structure due to loss of seagrass *Zostera marina* habitats in Sweden. *Estuarine, Coastal and Shelf Science,* 67(1-2):123-122.

Levisen, M. and R. Van Dolah, 1996. Environmental Evaluation of the Kiawah Island Beach Scraping Project. Final Report, South Carolina Department of Natural Resources, Marine Resources Division, Charleston, South Carolina. 15 pp.

Lindegarth, M., D. Valentinsson, M. Hansson, and M. Ulmestrand, 2000. Interpreting large-scale experiments on effects of trawling on benthic fauna: an empirical test of the potential effects of spatial confounding in experiments without replicated control and trawled areas. *Journal of Experimental Marine Biology and Ecology,* 245:155-169.

Lincoln, R.J., G.A. Boxshall, and P.F. Clark, 1988. *A Dictionary of Ecology, Evolution, and Systematics*. Cambridge University Press, Cambridge.

Lindeman, K.C. and D.B. Snyder, 1999. Nearshore hardbottom fishes of southeast Florida and effects of habitat burial caused by dredging. Fish. Bull. 97: 508-525.

Lindquist, N. and L. Manning, 2001. Impacts of Beach Nourishment and Beach Scraping on Critical Habitat and Productivity of Surf Fishes. Final Report.

Littler, M.M., S. N. Murray, and K.E. Arnold, 1979. Seasonal variations in net photosynthetic performance and cover of intertidal macrophytes. *Aquatic Botany*, 7:35-46.

Littler, M.M., D.R. Martz, and D.S. Littler. 1983. Effects of recurrent sand deposition on rocky intertidal organisms: Importance of substrate heterogeneity in a fluctuating environment. Mar. Ecol. Prog. Ser. 11: 129-139.

Littler, M.M., D.S. Littler, S.N. Murray, and R.R. Seapy, 1991. Southern Caliofrnia Intertidal Ecosystems. Pages 273-296 In: *Ecosystems of the World. Vol. 24. Intertidal and*

Littoral Ecosystems. A.C. Mathieson and P. Nienhuis (eds). Elsevier Scientific Publication, B.V., Amsterdam, The Netherlands.

Lobban, C.S. The growth and death of the *Macrocystis* sporophyte *(Phaeophyceae,* Laminariales)*. Phycologia,* 17(2):196-212.

Lohrer, A.M., S.F. Thrush, J.E. Hewitt, K. Berkenbusch, M. Ahrens, and V.J. Cummings, 2004. Terrestrial derived sediment: response of marine macrobenthic communities to thin terrigenous deposits.

Long, B.G., D.M. Dennis, T.D. Skewes, and I.R. Poiner, 1996. Detecting an environmental impact of dredging on seagrass beds with a BACIR sampling design. *Aquatic Botany*, 53(3-4):235-243.

Love, M., 1996. *Probably More Than You Want to Know About the Fishes of the Pacific Coast*. Really Big Press.

Louisiana Department of Natural Resources (DNR), 2005. Timbalier Island Dune and Marsh Restoration Project (TE-40) Project Profile. http://dnr.louisiana.gov/sec/execdiv/pubinfo/newsr/2005/0321crm-timbalier.ssi. Accessed November 2005.

Luning, K., 1979. Growth strategies of three *Laminaria* species (Phaeophyceae) inhabiting different depth zones in the sublittoral region of Helgoland (North Sea). *Marine Ecology Progress Series*, I:195-207.

Lynch, A.E., 1994. Macrofaunal recolonization of Folly Beach, South Carolina, After Beach Nourishment. Unpublished Master's Thesis, University of Charleston, Charleston, S.C.

MacGinitie, G.E. and N. MacGinitie, 1968. *Natural History of Marine Animals*. McGraw-Hill Book Company, New York. 523 pp.

Madej, M.A., 2004. How Suspended Organic Sediment Affects Turbidity and Fish Feeding Behavior. USGS Soundwaves: http://soundwaves.usgs. gov/2004/11/research2.htm.

Magoon, O.T., S.J. Williams, L.K. Lent, J.A. Richmond, D.D. Treadwell, S.L. Douglass, B.L. Edge, L.C. Ewing, and A. P. Pratt, 2004. Economic impacts of anthropogenic activities on coastlines of the United States. Pages 3-22-3035 In: *Proceedings of the 29th International Conference on Coastal Engineering 2004,* Lisbon, Portugal, September 2004. Published by World Scientific Publishing Company, ISBN:981-256-298-2.

Magoon, O.T. and L. K. Lent, 2005. The costs of sand mining. *California Coast & Ocean*, 21(3). http://coastandocean.org/coast_autumn2005/index.htm

Main, M. B. and W. G. Nelson, 1988. Tolerance of the Sabellariid polychaete *Phragmatopoma lapidosa* Kinberg to burial, turbidity, and hydrogen sulfide. Marine Environmental Research 26:39-55.

Mantua, N.J., S.R. Hare, Y. Zhang, J.M. Wallace, and R.C. Francis, 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. *Bulletin of the American Meteorological Society*, 78, pp. 1069-1079.

Marin-Spiotta, E., 1996. *Phyllospadix* Species. Marine Flora. http://www.mbari.org/staff/conn/botany/seagrass/index.htm. Accessed January 2005.

Marsh, G.A. and D.B. Turbeville, 1981. The environmental impact of beach nourishment: Studies in southeastern Florida. *Shore and Beach*, 40-44.

Marsh, J.A., Jr., W.C. Dennison, and R.S. Alberte, 1986. Effects of temperature on photosynethesis and respiration in eelgrass (*Zostera marina* L.). *Journal of Experimental Marine Biology and Ecology,* 101(3):257-267.

Martin, K., 2006 and 2007. Professor of Biology, Pepperdine University, personal communications.

Martin, K.L.M., 1999. Ready and waiting: delayed hatching and extended incubation of anamniotic vertebrate terrestrial eggs. *American Zoologist*, 39:279-288.

Martin, K., 2002. Does Beach Grooming Harm Grunion Eggs? Sea Grant Coastal Ocean Research. September 2002.

Martin, K., 2006. Introduction to Grunion Biology. Available online at: http://arachnid.pepperdine.edu/grunion/default.htm.

Martin, K.L. and D.L. Swiederski, 2001. Beach spawning in fishes: phlylogenetic tests of hypotheses. *American Zoologist*, 41:526-537.

Maryland Department of Natural Resources (DNR), 2003. The Dune Deal, Assateague State Park. http://www.dnr.state.md.us/naturalresource/inter2003.assateague. html, accessed November 2005.

Masters, P.M., 2005. Holocene sand beaches of southern California: ENSO forcing and coastal processes on millennial scales. *Palaeo, in press.*

Mattison, J.D., J.E. Trent, A.L. Shanks, T.B. Akin, and J.S. Pearse, 1977. Movement and feeding activity of red sea urchins (*Strongylocentrotus franciscanus*) adjacent to a kelp forest. *Marine Biology,* 39:25-30.

Mauer, D., R.T. Keck, J.C. Tinsman, W.A. Leathem, 1981. Vertical migration and mortality of benthos in dredge material: Part I-Mollusca. *Marine Environmental Research,* 4:299-319.

Mauer, D., R.T. Keck, J.C. Tinsman, W.A. Leathem, 1982. Vertical migration and mortality of benthos in dredge material: Part III-Polychaeta. *Marine Environmental Research,* 6:49-68.

Mauer, D., R.T. Keck, J.C. Tinsman, W.A. Leathem, C. Wethe, C. Lord, and T.M. Church, 1986. Vertical migration and mortality of marine benthos in dredged material: A synthesis. *Internationale Revue gesamten Hydrobiologie*, 71:49-63.

Maughan, B.C., 2000. The effects of sedimentation and light on recruitment and development of a temperate, subtidal, epifaunal community. Journal of Experimental Marine Biology and Ecology, 256(1):59-71. Available online http://www.sciencedirect.com/science. Accessed February 2006.

MBNEP See Morro Bay National Estuaries Program

MBC Applied Environmental Sciences (MBC), 2000. Turbidity Issues in Relationship to Dredging. Prepared for The Port of Los Angeles, Los Angeles, California.

McArdle, S.B. and A. McLachlan, 1992. Sand beach ecology: swash features relevant to the macrofauna. *Journal of Coastal Research,* 8(2):398-407.

McBride, S. and F. S. Conte, 1996. California Abalone Aquaculture. Pages 1-5 in: *California Aquaculture*, University of California Davis, Department of Animal Sciences.

McCall, P.L., 1977. Community patterns and adaptive strategies of the infaunal benthos of Long Island Sound. *Journal of Marine Research,* 35:221-266.

McGraw, K. and D. Armstrong, 1990. Fish entrainment by dredges in Grays Harbor, Washington. *Effects of Dredging on Anadromous Pacific Coast Fishes*. C.A. Simenstad (ed.), Washington Sea Grant Program, University of Washington, Seattle.

McGaw, I.J., 2003. Ventilatory and cardiovascular modulation associated with burying behaviour in two sympatric crab species, *Cancer magister* and *Cancer productus*. *Journal of Experimental Marine Biology and Ecology,* 303(1):47-63.

McCrary, M.D. and M.O.Pierson, 1999. Influence of Human activity on Shorebird Beach Use in Ventura County, California. In Minerals Management Service Proceedings of the Fifth California Islands Symposium March 29 - April 1, 1999:424-427.

McCauley, J.E., R.A. Parr, and D.R. Hancock, 1977. Benthic infauna and maintenance dredging: A case study. *Water Research* 11:233-242.

McGorty, S. and C.J. Reading, 1984. The rate of infill and colonization by invertebrates of borrow pits in the Wash (S. E. England). *Estuarine Coastal Shelf Science*, 19:303-319.

McLachlan, A., 1980. Exposed sandy beaches as semi-closed systems. *Marine Environmental Research* 4:59-63.

McLachlan, A., 1990. Dissipative beaches and macrofauna communities on exposed intertidal sands. *Journal of Coastal Research,* 6:57-71.

McLachlan, A., 1996. Physical factors in benthic ecology: effects of changing sand particle size on beach fauna. *Marine Ecology Progress Series,* 121:205-217.

McLachlan, A., A.C. Cockcroft, and D.E. Malan, 1984. Benthic faunal response to a high energy gradient. *Marine Ecology Progress Series*, 16:51-63.

McLachlan, A. and A. Dorvlo, 2005. Global patterns in sandy beach acrobenthic communities. *Journal of Coastal Research,* 21:674-687.

McLachlan, A., T. Erasmus, A.H. Dye, T. Wolldridge, G. Van der Horst, G. Rossouw, T.A. Lasiak, and L. McGwynne, 1981. Sand beach energetics: An ecosystem approach towards a high energy interface.

McLachlan, A, E. Jaramillo, T.E. Donn, and F. Wessels, 1993. Sand beach macrofaunal communities: a geographical comparison. *Journal of Coastal Research*, 15:27-38.

McLachlan, A. and D. Hesp, 1984. Faunal response to morphology and water circulation of a sandy beach with cusp. *Marine Ecology Progress Series*, 19:133-144.

McPeak, R. 1984. Comments on EIS/EIR for EXXON Santa Ynez Unit/Las Flores Canyon Development and Production Plan prepared by Science Applications, Inc. for MMS/SLC/CSB.

MEC Analytical Systems (MEC), 1995a. Evaluaton of Potential Impacts to Marine Biota from the Beach Replenishment Component of the Proposed Lomas Santa Fe Drive Grade Separation Project.

MEC Analytical Systems (MEC), Inc., 1995b. Disturbance of Deep-Water Reef Communities by Exploratory Oil and Gas Operations in the Santa Maria Basin and Santa Barbara Channel for U.S. Department of the Interior Minerals Management Service.

MEC, 1995c. 1994 and 1995 Field Survey Report of the Ecological Resources of Agua Hedionda Lagoon. Prepared for San Diego Gas and Electric Company.

MEC, 1997a. Least Tern and Water Turbidity Monitoring Seal Beach Pier to Warner Avenue. Summary Report. Prepared for U.S. Army Corps of Engineers, Los Angeles District.

MEC, 1997b. Environmental Conditions and Potential Impacts Associated with Dredging the Inner Section of Agua Hedionda Lagoon. Prepared for San Diego Gas and Electric.

MEC, 1998a. Water Quality Monitoring for Dredging Operations, Los Angles Harbor. Submitted to USACE, Los Angeles District.

MEC, 1998b. Water Quality Monitoring for Dredging Operations, Marina Del Rey. Sumbitted to Manson Construction.

MEC, 2000a. Appendix D to the SANDAG Regional Beach Sand Project EIR/EA. Evaluation of Impacts to Marine Resources and Water Quality from Dredging of Sands from Offshore Borrow Sites and Beach Replenishment at Oceanside, Carlsbad, Leucadia, Encinitas, Cardiff, Solana Beach, Del Mar, Torrey Pines, Mission Beach, and Imperial Beach, California. Prepared for KEA Environmental, Inc.

MEC, 2000b. Ports of Long Beach and Los Angeles Year 2000 Biological Baseline Study of San Pedro Bay. Prepared for The Port of Long Beach.

MEC, 2004. Eelgrass monitoring Agua Hedionda Lagoon (in Section 2.2.3, Section 7)

MEC and U.S. Army Engineer Research and Development Center (U.S. Army-ERDC), 2004. Port of Oakland Outer Harbor Maintenance Dredging Operations, Spatial Characterization of Suspended Sediment Plumes During Dredging Operations Through Acoustic Monitoring, Final Report. Submitted to U.S. Army Corps of Engineers, San Francisco District.

MEC-Weston Solutions and U.S. Army-ERDC, 2005. Characterization of Sediment Plumes During Knockdown Operations. PowerPoint Presentation.

Melvin, S., 2005. Design and Permitting of Dredging and Beach Nourishment in Massachusetts to Benefit Piping Plovers and Least Terns. In: The Second Regional Workshop on Dredging, Beach Nourishment, and Bird Conservation: Atlantic Coast from Maine to Virginia, October 25-27, 2005. http://el.erdc.usace.army.mil/training.cfm?Topic=Workshop&List=05oct-dots. Accessed June 2006.

Melvin, S. M., C.R. Griffin, and L.H. MacIvor, 1991. Recovery strategies for piping plovers in managed coastal landscapes. *Coastal Management*, 19:21-34.

Merkel, K.W., 2006, Merkel & Associates, personal communication.

Merkel, K.W., 1990. Growth & survival of transplanted eelgrass: The importance of planting unit size and spacing. Pages 70-78 In: Proceedings of the California Eelgrass Symposium, Chula Vista, California, May 27 and 28, 1988. Sweetwater River Press, National City, California.

Merkel, K.W., 1991a. The use of seagrasses in the enhancement, creation, and restoration of marine habitats along the California coast: Lessons learned from fifteen years of transplants. Technical Advisory Panel Presentation to: Marine Board, National Research Council Committee on the Role of Technology in Marine Habitat Protection and Enhancement, 20 March 1991, San Francisco, CA.

Merkel, K.W., 1991b. Identifying impacts and developing mitigation for eelgrass () meadows within developing and expanding marinas. In: *Marina Research Notebook and Marina Research Reprint Series,* Ross, N.W. (ed.). International Marina Institute, Wichford, Rhode Island.

Merkel, K.W. and R.S. Hoffman, 1990. The use of dredged materials in the restoration of eelgrass meadows: A southern California perspective. Pages 1-12 In: *Proceedings of A Regional Workshop: Beneficial Uses of Dredged Material in the Western U.S., 21-25 May* 1990. Landin, M.S. et al (eds.). U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

Merkel and Associates, 2001. Long-Term Biological Monitoring and Pilot Vegetation Program for the Batiquitos Lagoon Enhancement Project. Prepared for the Port of Los Angeles.

Merkel and Associates, 2005. San Diego Harbor Central Navigation Channel Deepening Project: Final Water Quality Monitoring Report. Prepared for Manson Construction Company.

Mertes, L.A.K., M. Hickman, B. Waltenberger, A.L. Bortman, E. Inlander, C. McKenzie, and J. Dvorsky, 1998. Synoptic views of sediment plumes and coastal geography of the Santa Barbara Basin, California. *Hydrological Processes*, 12:967-979

Messieh, S.N., D.J. Wildish, and R.H. Peterson, 1981. Possible impact of sediment from dredging and spoil disposal on the Miramichi Bay herring fishery. *Canadian Technical Report Fisheries Aquatic Sciences,* No. 1008.

Miles, P.R., C.I. Malme, and W.J. Richardson, 1987. Predictions of drilling site-specific interaction of industrial acoustic stimuli and endangered whales in the Alaskan Beaufort Sea. BBN Report 6509, Outer Continental Shelf Study, MMS 87-0084, Minerals Management Service, Anchorage, AK.

Miles, P.R., C.I. Shepard, G.W. Shepard, W.J. Richardson, and J.E. Bird, 1986. Prediction of drilling site-specific interaction of industrial acoustic stimuli and endangered whales: Beaufort Sea (1985), BBN Report 6185, Outer Continental Shelf Study, MMS 86-0046, Minerals Management Service, Anchorage, AK.

Miller, D.C., C.L. Muir, and O.A. Hauser, 2002. Detrimental effects of sedimentation on marine benthos: what can be learned from natural processes and rates. *Ecological Engineering*, 19:211-232.

Miller,K.J., D. Buford, and H. Mossman, 1999. Designation of Critical Habitat for the Pacific Coast Population of the Western Snowy Plover - Final Rule. Federal Register Vol. 64 No. 234: 68507-68544.

Moffatt & Nichol Engineers (Moffatt & Nichol), 2000a. Technical Report San Clemente Beach Replenishment Program Criteria and Concept Design. Prepared for the City of San Clemente.

Moffatt & Nichol, 2000b. Carlsbad Opportunistic Beach Fill Program Criteria and Concept Design. Prepared for the City of Carlsbad.

Moffatt & Nichol, 2000c. Shoreline morhplogy study, San Diego Regional Beach Sand Project. Prepared for KEA Environmental as Appendix C to the EIR/EA.

Moffatt & Nichol, 2001. Final Technical Report, South Central Coast Beach Enhancement Program Criteria and Concept Design. Prepared for BEACON.

Moffatt & Nichol, 2002. Technical Report San Clemente Beach Replenishment Program Criteria and Concept Design. Prepared for the City of San Clemente.

Moffatt & Nichol, 2003. Goleta Beach Nourishment Demonstration Project Monitoring Report. Prepared for BEACON.

Moffatt & Nichol, 2004. Monitoring Plan for the San Clemente Opportunistic Beach Replenishment Program. Prepared for the City of San Clemente.

Moffatt & Nichol, 2005a. Final Implementation Guidelines and Compliance Protocol, BEACON South Central Coast Beach Enhancement Program. Prepared for BEACON.

Moffatt & Nichol, 2005b. Goleta Beach Nourishment Demonstration Project Monitoring Report One Year Post-Construction. Prepared for BEACON.

Moffatt & Nichol, 2006a. Final Sand Compatibility and Opportunistic Use Program Plan. Prepared for SANDAG. Available online at: http://dbw.ca.gov/CSMW/PDF/Final_SCOUP_Master_Plan.pdf.

Moffat & Nichol, 2006b. Administrative Draft Mitigated Negative Declaration for Implementation of an Opportunistic Beach Fill Program at Four Beaches.

Moore, K.A., H.A. Neckles, and R.J. Orth, 1996. *Zostera marina* (eelgrass) growth and survival along a gradient of nutrients and turbidity in the lower Chesapeake Bay. *Marine Ecology Progress Series,* 142:247-259.

Moore, K.A. and R.J. Orth, 1997. Evidence of Widespread Destruction of Submersed Aquatic Vegetation (SAV) from Clam Dredging in Chincoteague Bay, Virginia. Report to the Virginia Marine Resources Commission.

Moore, K.A., R.L. Wetzel, and R.J. Orth, 1997. Seasonal pulses of turbidity and their relations to eelgrass (*Zostera marina* L.) survival in an estuary. *Journal of Experimental Marine Biology and Ecology*, 215:115-134.

Moore, K.A. and R.L. Wetzel, 1999. Seasonal variations in eelgrass (*Zostera marina*) responses to nutrient enrichment and reduced light availability in experimental ecosystems. *Journal of Experimental Marine Biology and Ecology*, 244(1):1-28.

Moyle, P.B., 1993. Fish: An Enthusiast's Guide. University of California Press.

Moyle, P.B., 2002. *Inland Fishes of California* University of California Press.

Montgomery J.C., A. Jeffs, S.D. Simpson, M. Meekan, and C. Tindle, 2006. Sound as an orientation cue for the pelagic larvae of reef fishes and decapod crustaceans. Advances in Marine Biology, 51:143-96.

Montrose Settlements Restoration Program (MSRP), 2005. Draft restoration plan and programmatic environmental impact statement/environmental impact report. Report of the Montrose Settlements Restoration Program, National Oceanic and Atmospheric Administration, U.S. Fish and Wildlife Service, National Park Service, California Department of Fish and Game, California Department of Parks and Recreation, and California State Lands Commission.

Marcot, B. G., and M. Vander Heyden, 2001. Key ecological functions of wildlife species. Pages 168-186 *in*: D. H. Johnson and T. A. O'Neil (eds). *Wildlife-Habitat Relationships in Oregon and Washington.* Oregon State University Press, Corvallis, Oregon.

Morgan, J.D. and C.D. Levings, 1989. Effects of suspended sediment on eggs and larvae of lincod *Ophiodon elongatus*, Pacific herring *Clupea harengus palllasi*, and surf smelt *Hypomesus pretiosus*. *Canadian Technical Report of Fisheries & Aquatic Sciences*, 1729:I-VII:1-31.

Moring, J.R., 1996. Short-term changes in tidepools following two hurricanes. *Hydrobiologia*, 328:155-160.

Morris, R.H., D. P. Abbott, and E.C. Haderlie (eds.), 1980. *Intertidal Invertebrates of California.* Stanford University Press, California. 690 p.

Morro Bay National Estuaries Program (MBNEP), 2000. Comprehensive Conservation and Management Plan (CCMP). http://www.mbnep.org/publications/#ccmp.

Morro Bay National Estuaries Program (MBNEP), 2004. Question: Does the Bay Support Healthy Eelgrass Beds? http://www.mbnep.org/files/IRC%20Web%20Files/Eelgrass.pdf.

Murray, L. (no date) Sand and gravel extraction for beach recharge – is conflict with fisheries inevitable? MAFF, Fisheries Laboratory. http://www.bmapa.org/ media.htm.

Murray, S.N. and R.N. Bray, 1993. Benthic Macrophtytes. Pages 304-368 in: *Ecology of the Southern California Bight: A Synthesis and Interpretation.* M.D. Dailey, D.J. Reish, and J.W. Anderson (eds.). University of California Press, Berkeley, California.

Naqvi, S.M. and E.J. Pullen, 1982. Effects of Beach Nourishment and Borrowing on Marine Organisms. Prepared for U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, VA.

National Institute of Coastal and Marine Management of the Netherlands, 2004. A Guide to Coastal Erosion Management Practices in Europe: Lessons Learned. EUROSION, "Coastal Erosion – Evaluation of the Needs for Action", Directorate General Environment European Commission. Service Contract B4-3301/2001/329175/MAR/B3. http://www.eurosion.org/reports-online/reports.html.

National Marine Fisheries Service (NMFS), 2002. Endangered Species Act - Section 7 Consultation and Magnuson-Stevens Act Essential Fish Habitat Consultation Biological Opinion Columbia River Federal Navigation Channel Improvements Project. Prepared for U.S. Army Corps of Engineers - Portland District. OHB1999-0270-RI.

NMFS, 2004. Essential Fish Habitat Consultation Guidance, Version 1.1. Office of Habitat Conservation, Silver Spring, Maryland.

National Marine Fisheries Service, National Oceanic and Atmospheric Administration (NMFS-NOAA), 2001. Endangered and Threatened Species; Endangered Status for White Abalone, Final Rule. *Federal Register* 50 CFR Part 224 [Docket No. 990910253–1120–03; ID No. 041300B].

NMFS-NOAA, 2005. Endangered and Threatened Species; Designation of Critical Habitat for Seven Evolutionarily Significant Units of Pacific Salmon and Steelhead in California. *Federal Register* 50 CFR Part 226.

National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), and California Department of Fish and Game (DFG). 2005. Southern California Eelgrass Mitigation Policy (revision 11). (www.http://swr.nmfs.noaa.gov/hcd/ policies/EEPO).

National Oceanic and Atmospheric Administration (NOAA), 1992. Final Environmental Impact Statement and Management Plan for the Proposed Monterey Bay National Marine Sanctuary. Prepared By: Sanctuaries and Reserves Division Office of Ocean and Coastal Resource Management National Ocean Service National Oceanic and Atmospheric Administration, Washington, D.C.

National Oceanic and Atmospheric Administration (NOAA), 2001a. *Glossary of Coastal Terminology*. Washington State Department of Ecology, Coastal Monitoring & Analysis Program, Publication No. 98-105. Updated on April 09, 2001. NOAA Coastal Services Center. http://www.csc.noaa.gov/text/glossary.html.

NOAA, 2001b. *Guide to the Seagrasses of the United States of America (Including U.S. Territories in the Caribbean).* Available on U.S. National Oceanic and Atmospheric Administration. Coastal Services Center. *Submerged Aquatic Vegetation: Data Development and Applied Uses.* (CD-ROM). (NOAA/CSC/20116-CD). Charleston, SC.

National Research Council (NRC), 1985. *Dredging Coastal Ports: An Assessment of the Issues.* National National Academy Press, Washington, D.C. pp. 117-139.

NRC, 1995. *Beach Nourishment and Protection*. National Academy Press, Washington, D.C. 334 pp.

NRC, 2000. *Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution*. National Academy Press, Washington, D.C.

Nelson, W.G., 1989. An Overview of the Effects of Beach Nourishment on the Sand Beach Fauna. Pp. 295-309 In: Proceedings of the 1988 National Conference on Beach Preservation Technology. Tallahassee: Florida Shore and Beach Preservation Association.

Nelson, W.G., 1990. Beach nourishment and Hard-Bottom Habitats: The Case for Caution. Pp. 109-116 In: In: Proceedings of the 1989 National Conference on Beach Preservation Technology. Tallahassee: Florida Shore and Beach Preservation Association.

Nelson, W. G. 1993. Beach restoration in the southeastern U.S.: Environmental effects and biological monitoring. *Ocean and Coastal Management*, 19:157-182

Nelson, W.G. and G.W. Collins, 1987. Effects of Beach Nourishment on the Benthic Macrofauna and Fishes of the Nearshore Zone of Sebastian Inlet State Recreational Area. U.S. Army Corps of Engineers, Jacksonville District.

Neushul, M., 1962. Studies on the giant kelp, *Macrocystis.* II. Reproduction. *American Journal of Botany,* 50:354-359.

Neushul, M. and F.T. Haxo, 1962. Studies on the giant kelp *Macrocystis.* I. Growth of young plants. *American Journal of Botany,* 50:349-353.

Newcombe, C.P. and D.D. MacDonald, 1991. Effects of suspended sediments on aquatic ecosystems. *North American Journal of Fisheries Management*, 11:72-82.

Newcombe, C.P. and J.O.T. Jensen, 1996. Channel suspended sediment and fisheries: A synthesis for quantitative assessment of risk and impact. *North American Journal of Fisheries Management,* 16:693-719.

NCDENR See North Carolina Department of Environment and Natural Resources

NCRWQCB – See Californian Regional Water Quality Control Board, North Coast Region.

Nedeau, E., 2004. Extraordinary eelgrass. *Wildlife Journal*, 9-12.

Nel, R., A. McLachlan, and D. P.E. Winter, 2001. The effect of grain size on the burrowing of two *Donax* species. *Journal of Experimental Marine Biology and Ecology,* 265(2):2219-238.

Nelson, W. G. 1993. Beach restoration in the Southeastern US: Environmental effects and biological monitoring. Ocean & Coastal Management, 19:157-182.

Nemeth, R.S. and J.J. Anderson, 1992. Response of juvenile Coho and Chinook salmon to strobe and mercury vapor lights. *North American Journal of Fisheries Management,* 12(4):684-692.

Newell, R.C., L.J. Seiderer, and D.R. Hitchcock, 1998. The impact of dredging works in coastal waters: A review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. *Oceanography and Marine Biology: An Annual Review*, 36:127-178.

Newell, R.C., L.J. Seiderer, N.M. Simpson, and J.E. Robinson, 2004. Impacts of marine aggregate dredging on benthic macrofauna off the south coast of the United Kingdom. *Journal of Coastal Research,* 20(1):115-125.

New York State Department of Environmental Conservation (NYSDEC), 1998. Rules and Regulations, Part 505 Coastal Erosion Management. http://www.dec.state.ny.us/website/regs/part505.html. Accessed March 2006.

Nickerson, R.B., 1975. A critical analysis of some razor clam (*Siliqua patula* Dixon) populations in Alaska. Alaska Dep. Fish and Game, Juneau. 194 pp.

Niedoroda, A. W., 1979. The geomorphologic effects of off-road vehicles on coastal ecosystems of Cape Cod, Massachusetts. *University of Massachusetts/National Park Service Cooperative Research Unit Report,* No. 17.

Nightengale, B. and C.A. Simenstad, 2002. Artificial Night-Lighting Effects on Salmon and Other Fishes in the Northwest. Ecological Consequences of Artificial Night Lighting conference on February 23-24, 2002, sponsored by The Urban Wildlands Group and the UCLA Institute of the Environment.

Nightengale, B. and C.A. Simenstad, 2001. White Paper. Dredging Activities: Marine Issues. http://wdfw.wa.gov/hab/ahg/dredge.htm. Accessed November 2006.

Nitsos, R., 1990. Morro Bay eelgrass transplant. Pages 43-45 In: *Proceedings of the California Eelgrass Symposium, Chula Vista, California, May 27 and 28, 1988.* Sweetwater River Press, National City, California.

Nittrouer, C.A. and L. D. Wright, 1994. Transport of particles across continental shelves. Reviews of Geophysics, 32 (1):85-113.

NMFS see National Marine Fisheries Service

Nocera, J. J. and S.W. Kress, 1996. Nocturnal predation on common terns by great black-backed gulls. *Colonial Waterbirds,* 19(2): 277-279.

Norkko, A., S.F. Thrush, J.E. Hewitt, V.J. Cummings, J. Norkko, J.I. Ellis, G.A. Funnell, D. Schultz, and I. MacDonald, 2002. Smothering of estuarine sandflats by terrigenous clay: the role of wind-wave disturbance and bioturbation in site-dependent macrofaunal recovery. *Marine Ecology Progress Series,* 234:23-41.

North, W.J., 1957. Kelp investigation program annual report for the period 1 July 1956-30June 1957. University of California Institute of Marine Resources, La Jolly. 60 pp.

North, W.J., 1986. Biology of the Macrocystis resource in North America. In: *Case studies of Seven Commercial Seaweed Resources*. Doty, M.S., J.F. Caddy, and B. Santelices (eds.). FAO Fish. Tech. Pap., (281): 311 p. Accessed at http://www.fao.org/docrep/X5819E/x5819e0a.htm#TopOfPage.

North, W.J., G.A. Jackson, and S.L. Manley, 1986. *Macrocystis* and its environment, knowns and unknowns. *Aquatic Botany*, 26:9-26.

North Carolina Department of Environment and Natural Resources (NCDENR), 2005. Memorandum, Sediment Criteria Recommendations for Nourishment and Dredged Material Disposal on North Carolina Oceanfront Beaches. January 11, 2005.

NRC – See National Research Council

Oakden, J., 1996. Sandy Beaches, In: *Monterey Bay National Marine Sanctuaries Site Characterization*. http://www.mbnms.nos.noaa.gov/sitechar/coast.html. Accessed March 2006.

Obst, B.S. and S.M. Johnson, 1990. California Least tern Breeding Survey 1990 Season. For California Dept. of Fish and Game.

O'Clair, C.E., R.P. Stone, and J.L. Freese, 1990. Movements and habitat use of Dungeness crabs and the Glacier Bay fishery. Pages 74-77 In: *Second Glacier Bay Science*

Symposium, Glacier Bay National Park & Preserve, AK, Sept. 19-22, 1988. A. Milner and J.D. Wood, Jr. (eds.). U.S. National Park Service, Anchorage, AK.

O'Connor, J., 1991. Evaluation of Turbidity and Turbidity-Related Effects on the Biota of the San Francisco Bay-Delta Estuary. Submitted to U.S. Army Corps of Engineers, San Francisco District.

Ogden Environmental and Energy Services. 1996. Monitoring and Reporting for the U.S. Army Corps of Engineers Project DACW-96-C-0011, Emergency Dredging at Marina Del Rey, Los Angeles, California. Prepared for USACE, Los Angles District.

Ogden Environmental and Energy Services. 1998. Oceanside Harbor Maintenance Dredging, Water Quality Reports (January to March 1998). Submitted to USACE, Los Angeles District.

Ogden Environmental and Energy Services. 1999. Oceanside Harbor Maintenance Dredging Project, Water Quality Monitoring Report. Prepared for USACE, Los Angles District.

Ogle, S., 2005. A Review of Scientific Information on the Effects of Suspended Sediments on Pacific Herring (Clupea *pallasi*) Reproductive Success. Pacific EcoRisk. Prepared for U.S. Army Corps of Engineers and Long-Term Management Strategy Science Assessment & Data Gaps Workgroup Herring Sub-Committee.

Ogston, A.S., D. A. Cacchione, R. W. Sternberg, and G. C. Kineke, 2000. Observations of storm and river flood-driven sediment transport on the northern California continental shelf. *Continental Shelf Research*, 20(16):2141-2162.

Ogston, A.S. and R.W. Sternberg, 1995. On the importance of nearbed sediment flux measurements for estimating sediment transport in the surf zone. *Continental Shelf Research,* Vol. 15(13):1515-1524.

Ogston, A.S. and R.W. Sternberg, 1999. Sediment-transport events on the northern California continental shelf, *Marine Geology*, 154, 69-82. Delete unless referenced

Olesen, and Sand-Jensen, 1993.

Oliver, J.S. and P.N. Slattery, 1973. Dredging, Dredge Spoil Disposal and Benthic Invertebrates in Monterey Bay. DACW72-73-0010.

Oliver, J.S., P.N. Slattery, L.W. Hulberg, and J.W. Nybakken, 1977. Patterns of Succession in Benthic Infaunal Communities Following Dredging and Dredged Material Disposal in Monterey Bay. Technical Report D-77-27, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Oliver, J.S., P.N. Slattery, L.W. Hulberg, and J.W. Nybakken, 1980. Relationships between wave disturbance and zonation ob benthic invertebrrated communities along a subtidal high-energy beach in Monterey, Califoria. *U.S. National Marine Fisheries Service Fish Bulletin, 78:437-454.*

Onuf, C.P., 1994. Seagrasses, dredging and light in Laguna Madre, Texas, U.S.A. *Estuarine, Coastal and Shelf Science*, 39:75-91.

Onuf, C.P. and M.L. Quammen, 1983. Fishes in a California coastal lagoon: effects of major storms on distribution and abundance. *Marine Ecology Progress Series*, 12:1-14.

Orr, R.T. and R.C. Helm, 1989. *Marine Mammals of California.* University of California Press.

Orth, R.J., M. Luchenback, and K.A. Moore, 1994. Seed dispersal in a marine macrophyte: Implications for colonization and restoration. *Ecology,* 75(7):1927-1939.

Orth, R.J., M.L. Luchenback, S.R. Marion, K.A. Moore, and D.J. Wilcox, 2006. Seagrass recovery in the Delmarva Coastal Bays, USA. *Aquatic Botany,* 84(1):26-36.

Oviatt, C.A. and S.W. Nixon, 1975. Sediment resuspension and deposition in Narragansett Bay. *Estuarine and Coastal Marine Science*, 3:201-217.

Page, G.W. and L.E. Stenzel, 1981. The breeding status of the snowy plover in California. *Western Birds* 12(1):1-40.

Page, G.W., L.E. Stenzel, and J.E. Kjelmyr, 1999. Overview of shorebird abundance and distribution in wetlands of the Pacific coast of the contiguous United States. The Condor 101: 461-471.

Paine, R. T. and S. A. Levin, 1981. Intertidal landscapes: disturbance and the dynamics of pattern. *Ecological Monographs*, 51(2):145-178.

Palermo, M.R. and V.R. Pankow, 1988. New Bedford Harbor Superfund Project, Acushnet River Estuary Engineering Feasibility Study of Dredging and Dredged Material Disposal Alternatives Report 10 Evaluation of Dredging and Dredging Control Technologies. Department of the Army Waterways Experiment Station Technical Report EL-88-15.

Parr, T., D. Diener, and S. Lacy, 1978. Effects of Beach Replenishment on the Nearshore Sand Fauna at Imperial Beach, California. Prepared for U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, VA.

Patek, S. N., 2001. Spiny lobsters stick and slip to make sound. *Nature* 411: 153-154.

Patten, M.A., G. McCaskie, and P. Unitt, 2003. *Birds of the Salton Sea: Status, Biogeography, and Ecology.* University of California Press, Berkeley, California.

Patton, M.L., R.S. Grove, and R.F. Harman, 1985. What do natural reefs tell us about designing artificial reefs in southern California? *Bulletin of Marine Science,* 37(1):279-298.

Pearson, T.H. and R. Rosenberg, 1978. Macrobenthic succession in relation to organic enrichment and pollution of the environment. *Oceanography and Marine Biology: An Annual Review*, 16:229-311.

Peddicord, R.K., V.A. McFarland, D.P. Belfiori, and T.E. Byrd, 1975. Effects of Suspended Solids on San Francisco Bay organisms, Dredge Disposal Study; Appendix C – Physical Impact. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Peddicord, R.K. and V.A. McFarland, 1978. Effects of Suspended Dredged Material on Aquatic Animals. Technical Report D-78-29, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Pequegnat, W. E. The epifauna of a California siltstone reef. *Ecology*, 45(2):272-283.

Penhale, P.A., 1977. Macrophyte-epiphyte biomass and productivity in an eelgrass (*Zostera marina* L.) community. *Journal of Experimental Marine Biology and Ecology,* 26(2):211-224

Pennak, R.W., 1964. *Collegiate Dictionary of Zoology.* The Ronald Press Company, New York.

Perry, L., 1999. Sediment effects on the behavior and survival of young juvenile *Jasus edwardsii. The Lobster Newsletter*, 12(1):4-5.

Persons, P., 1994. Western Snowy Plover Monitoring in 1993 at Vandenberg Air Force Base, California. Prepared for the U.S. Air Force 30th Space Wing/ET Vandenberg Air Force Base, California. 22 pp.

Petersen, W.R., 2001. Plovers and Lapwings, In *The Sibley Guide to Bird Life and Behavior*. C. Elphick, J.B. Dunning, Jr., and D.A. Sibley (eds.). Alfred A. Knopf.

Peterson, C.H., D.H.M. Hickerson, and G. G. Johnson, 2000a. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of a sandy beach. *Journal of Coastal Research,* 16(2):368-378.

Peterson, C.H., H.C. Summerson, E. Thomson, H.S. Lenihan, J. Grabowski, L. Manning, F. Micheli, and G. Johnson, 2000b. Synthesis of linkages between benthic and fish communities as a key to protecting essential fish habitat. *Bulletin of Marine Science*, 66(3):759-774.

Peterson, C.H., L.M. Manning, J.S. Taylor, G.A. Johnson, 2002. How Beach Nourishment Affects the Habitat Value of Intertidal Beach Prey for Surf Fish and Shorebirds and Why Uncertainty Still Exists. PowerPoint Presentation. Available online at: April 2002 presentation to North Carolina Division of Coastal Management. Available online at: http://dcm2.enr.state.nc.us/sitemap.htm. Accessed March 2006.

Peterson, C.H. and M.J. Bishop, 2005. Assessing the environmental impacts of beach nourishment. *BioScience*, 55(10):857-896.

Phillips, R.C., 1979. Ecological notes on *Phyllospadix* (Potamogetonaceae) in the northeast Pacific. *Aquatic Botany,* 6:159-170.

Phillips, R.C., 1984. The Ecology of Eelgrass Meadows in the Pacific Northwest: A Community Profile. U.S. Fish and Wildlife Service, FWS/OBS-84/24. 85 pp.

Phillips, R.C. and E.G. Menez, 1988. *Seagrasses*. Smithsonian Contribution to the Marine Sciences, Volume 34.

Phillips, R.C., W. S. Grant, and C.P. McRoy, 1983. Reproductive strategies of eelgrass (*Zostera marina* L.). *Aquatic Botany,* 16 (1):1-20.

Pickart, A. J. and J.O. Sawyer, 1998. *Ecology and Restoration of Northern California Coastal Dunes.* CNPS Press. 152 p.

Pickerell, C.H., S. Schott, and S. Wyllie-Echeverria, 2005. Buoy-deployed seeding: Demonstration of a new eelgrass (*Zostera marina* L.) planting method. *Ecological Engineering*, 25(2):127-136.

Pilkey, O.H. et al., 1993. The concept of shoreface profile of equilibrium: A critical review. Journal of Coastal Research, 9(1): 255-278. Available online at: http://psds.wcu.edu/ 1042.asp.

Pilkey, O.H., R.S. Young, D.M. Bush, and E.R. Thieler, 1994. Predicting the behavior of beaches: alternatives to models. Pages 53-60: *In* G.S. DeCarvalho (ed.) *Littoral*, 1994, *Proceeding of the Second International Symposium.* Lisbon. Association-EUROCOAST-Lisbon, Portugal. Available online at: http://psds.wcu.edu/ 1042.asp.

Pilkey, O. and A. Coburn, 2005. The East Coast Nourishment Experience: The Good, Bad, and Ugly. In: The First Regional Workshop on Dredging, Beach Nourishment, and Birds on the South Atlantic Coast and a Symposium on the Ecology and Conservation of Piping Plovers, February 1-4, 2005. http://el.erdc.usace.army.mil/training.cfm?Topic=Workshop&List=05feb-dots. Accessed June 2006.

Podolsky, R., 2002. Artificial Lighting and the Decline of Seabirds. Ecological Consequences of Artificial Night Lighting conference on February 23-24, 2002, sponsored by The Urban Wildlands Group and the UCLA Institute of the Environment.

Poiner, I.R. and R. Kennedy, 1984. Complex patterns of change in the macrobenthos of a large sandbank following dredging. *Marine Biology,* 78:335-352.

Pondella, D. II, P. Morris, J. Stephens, Jr., and N. Davis, 1996. Marine Biological Surveys of the Coastal Zone off the City of Rancho Palos Verdes, Final Report. Prepared for the U.S. Army Corps of Engineers.

Popper, A.N., 2003. Effects of anthropogenic sounds on fishes. *Fisheries*, 28(10):24-31. Available online at: www.fisheries.org. Accessed November 2006.

Popper, A.N., M.E. Smith, P.A. Cott, B.W. Hanna, A.O. MacGillivary, M.E. Austin, and D.A. Mann, 2005. Effects of seismic airgun use on hearing of three fish species. *Journal Acoustic Society of America*, 117:3958-3971.

Popper, A.N., T. J. Carlson, A.D. Hawkins, B.L. Southall, and R.L. Gentry, 2006. *Interim Criteria* for Injury of Fish Exposed to Pile Driving Operations: A White Paper.

Posey, M., 2002. Biological aspects of beach nourishment. April 2002 presentation to North Carolina Division of Coastal Management. Available online at: http://dcm2.enr.state.nc.us/sitemap.htm. Accessed March 2006.

Posey, M. and T. Alphin, 2001. Benthic faunal responses to sediment removal: An example from North Carolina. Proceedings of the Coastal Ecosystems & Federal Activities Technical Training Symposium, August 20-22, 2001. Gulf Shores, Alabama.

Powell, A. and C. Collier, 1994. The Status of Western Snowy Plovers (*Charadrius alexandrinus nivosus*) in San Diego County, 1994. Report to the California Department of Fish and Game and U.S. Fish and Wildlife Service. 23 pp.

Powell, A.N. and C.L. Collier, 2000. Habitat Use and Reproductive success of Western Snowy Plovers at New Nesting Areas Created for California Least Terns. *Journal of Wildlife Management*, 64: 24-33.

Plus, M., J-M. Deslous-Paoli, and F. Dagault, 2003. Seagrass (*Zostera marina* L.) bed recolonization after anoxia-induced full mortality. *Aquatic Botany*, 77(2):121-134.

Pullen, E.J. and S.M. Naqvi, 1983. Biological impacts on beach replenishment and borrowing. *Shore and Beach* 27-31.

Puckette, T.Pl, 1998. Evaluation of dredged material plumes: Physical monitoring techniques. *DOER Technical Notes Collection* (TN DOER-E5). U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/dots/doer.

Quast, J.C., 1968. Fish fauna of the rocky intertidal zone. In: U*tilization of Kelp-Bed Resources in Southern California*. W.J. North and C.L. Hubbs (eds.). California Depart. Fish Game Fish Bulletin, 139:109-142. Available online at: http://ceo.ucsd.edu/fishbull/.

R2 Resource Consultants, 1999. Entrainment of Outmigrating Fish by Hopper Dredge in the Columbia River and Oregon Coastal Sites. Final, unpublished report to the U.S. Army Corps of Engineers, Portland, Oregon. 23 pp.

Rakocinski, C.F., 2006. University of Southern Mississippi, personal communication.

Rakocinski, C.F., R.W. Heard, S.E. LeCroy, J.A. McLelland, and T. Simons, 1996. Responses of Macrobenthos Assemblages to Extensive Beach Restoration at Perdido Key, Florida. *Journal of Coastal Research*, 12(1):326-353.

Rakocinski, C.F., R.W. Heard, S.E. LeCroy, J.A. McLelland, and T. Simons, 2001. Responses of Macrobenthos Assemblages to Extensive Beach Restoration at Perdido Key, Florida. PowerPoint Presentation

Rais, A., 2003. *Cystoseira osmundacea*. Marine Flora. http://www.mbari.org/staff/conn/botany/browns/Cystoseira/index.htm. Accessed February 2006.

Ramirez-Garcia, P., A. Lot, C.M. Duarte, J. Terrados, and N.S.R. Agawin, 1998. Bathymetric distribution, biomass, and growth dynamics of intertidal *Phyllospadix scouleri* and

Phyllospadi torreyi in Baja California (Mexico). *Marine Ecology Progress Series,* 173:13-23.

Reed, D.C., 1990. The effects of variable settlement and early competition on patterns of kelp recruitment. *Ecology,* 71:776-787.

Reed, D.C., 2006. University of California, Santa Barbara, personal communication.

Reed, D. C. and M.S. Foster, 1984. The effects of canopy shading on algal recruitment and growth in a giant kelp forest. *Ecology,* 65:937-948.

Reed, D.C., S.J. Hollbrook, E. Solomon, and M. Anghera, 1998. Studies on germination and root development in the surfgrass *Phyllospadix torreyi*: Implications for habitat restoration*. Aquatic Botany*, 62:71-80.

Reed, D.C. and S.J Hollbrook, 2003. An experimental evaluation of methods of surfgrass (*Phyllospadix torreyi*) restoration using early life history stages. Final Technical Summary, Final Study Report. Prepared for U.S. Department of the Interior Minerals Management Service Pacific OCS Region under MMS Cooperative Agreement No. 14-35-0001-30758.

Reed, D.C., 2005 personal communication.

Reed, D.C., P.T. Raimondi, M.H. Carr, and L. Goldwasser, 2000. The role of dispersal and disturbance in determining spatial heterogeneity in sedentary organisms. *Ecology*, 81(7):2011-2026.

Reed, D.C., S.C. Schroeter, and P.T. Raimondi, 2004. Spore supply and habitat availability as sources of recruitment limitation in the giant kelp *Macrocystis pyrifera* (Phaeophyceae). *Journal of Phycology*, 40:275-284.

Reed, D.C., B.P. Kinlan, P.T. Raimondi, L. Washburn, B. Gaylord and P.T. Drake, *In Press*. A Metapopulation Perspective on Patch Dynamics and Connectivity of Giant Kelp. *In* J.P. Kritzer and P.F. Sale, (eds.) *Marine Metapopulations*. *Academic Press. San Diego*.

Rees, H.L., M.A. Pendle, R. Waldock, D.S. Limpenny, and S.E. Boyd, 1999. A comparison of benthic biodiversity in the North Sea, English Channel, and Celtic Seas. *ICES Journal of Marine Science,* 56:228-246.

Reeves, R.R., B.S. Stewart, and S. Leatherwood, 1992. The Sierra Club Handbook of Seals and Sirenians. Sierra Club Books.

Reilly, F.J, Jr. and V.J. Bellis, 1983. The Ecological Impact of Beach Nourishment with Dredged Materials on the Intertidal Zone at Bogue Banks, North Carolina. Prepared for U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, VA.

Reine, K.J. and D.G. Clarke, 1998. Entrainment by hydraulic dredges: A review of potential impacts. Technical Notes DOER-E1. US Army Engineers Research and Development Center, Vicksburg, MS.

Reine, K.J., D.D. Dickerson, and D.G. Clarke. 1998. Environmental Windows Associated with Dredging Operations. Technical Note DOER-E2. http://el.erdc.usace. army.mil/ dots/doer/technote.html. Accessed January 2005.

Reiser, C.H., 1994. *Rare Plants of San Diego County.* Aquafir Press. 234 p. Available online at: http://sandiego.sierraclub.org/rareplants/.

Reish, D.J., 1982. Benthic survey of the marine invertebrates off Sunset Beach, California. Report to U.S. Army Corps of Engineers, Los Angeles District. 36 pp.

Research Planning, Inc., W.F. Baird & Associates, and Applied Marine Sciences, Inc., 2001. Development and Design of Biological and Physical Monitoring Protocols to Evaluate the Long-Term Impacts of Offshore Dredging Operations on the Marine Environment. OCS Report 2001-089. Prepared for Minerals Management Service, U.S. Department of Interior, Herndon, Virginia.

Reynolds, W.W., D.A. Thompson, and M.E. Casterlin, 1977. Responses of young California grunion, *Leuresthes tenuis*, to gradients of temperature and light. *Copeia*, 1:144-149.

Rice, T.M. and C.H. Peterson, 2005. The effects of beach nourishment projects on coastal ecosystems. Presented at the Second Regional Workshop on Dredging, Beach Nourishment, and Bird Conservation: Atlantic Coast for Maine to Virginia. Accessed online (June 2006) at http://el.erdc.usace.army.mil/training.cfm ?Topic=Workshop&List=05oct-dots.

Richards, S.D., A.D. Heathershaw, and P.D. Thorne, 1996. The effect of suspsended particulate matter on sound attenuation in seawater. *J. Acoust. Soc. Amer.* 100(3):1447-1450.

Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and D.H. Thomson, 1995. *Marine Mammals and Noise*. Academic Press.

Rickard, C.A., a. McLachlan, and G.I.H. Kerley, 1994. The effects of vehicular and pedestrian traffic on dune vegetation in South Africa. *Ocean and Coastal Management,* 23:225-247.

Ricketts, E.F., J. Calvin, and J.W. Hedgpeth, 1968. *Between Pacific Tides.* 4th edition. Stanford University Press, Palo Alto, California. 614 pp.

Rivera, J.A., A. Mager, Jr., R.L. Ferguson, D.W. Field, and F.A. Cross, 1992. Verification of Submerged Aquatic Vegetation Alterations Associated with Corps of Engineers Permit Requests. Pages 781-794 In: First Thematic Conference on Remote Sensing for Marine and Coastal Environments, New Orleans, Louisiana, USA, 15-17 June 1992.

Robinson, W.E., W.E. Wehling, and M.P. Morse, 1984. The effect of suspended clay on feeding and digestive efficiency of the surf clam, *Spisula solidissima* (Dillwyn). *Journal of Experimental Marine Biology and Ecology,* 74(1):1-12.

Rogers-Bennett, L., W.A. Bennett, H.C. Fastenau, and C.M. Dewees, 1998. Recovery of sea urchin beds following experimental harvest. Pages 805-809 In: Echinoderms: San Francisco, Proceedings of the Ninth International Echinoderm Conference, San Francisco, August 5-9, 1996 (R. Mooi and M. Telford, eds.). A. A. Balkema, Roterdam, and Brookfield, VE.

Rosenthal, R.J., W.D. Clarke, and Pl.K. Dayton, 1974. Ecology and natural history of a stand of giant kelp, *Macrocystis pyrifera* (Linnaeus) *Agardh off Del Mar, California. U.S. National Marine Fisheries Service Fish Bulletin*, 72:670-684.

Rossi, F. and A.J. Underwood, 2002. Small-scale disturbance and increased nutrients as influences on intertidal macrobenthic assemblages:experimental burial of wrack in different intertidal environments. *Marine Ecology Progress Series,* 241:29-39.

RWQCB – See California Regional Water Quality Control Board

SAIC see Science Applications International Corporation

Saloman, C.H., 1974. Physical, Chemical, and Biological Characteristics of Nearshore Zone of Sandy Key, Florida, Prior to Beach Restoration. Final Report, U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, VA.

Saloman, C.H., S.P. Naughton, and J.L. Taylor, 1982. Benthic community response to dredging borrow pits, Panama City beach, Florida. M.R. 82-3. U.S. Army Corps of Engineers Research Center. Fort Belvoir, Va.

SANDAG and USDN – see San Diego Association of Governments and U.S. Department of the Navy

Sanders, F., A. Shirey, R. Coller-Socha, T. Murphy, J. Hadden, J. Dozier, and M. Spinks, 2005. Folly River Dredging Project and the Creation of Seabird and Shorebird Habitat on Bird Key Stono Heritage Preserve. In: The First Regional Workshop on Dredging, Beach Nourishment, and Birds on the South Atlantic Coast and a Symposium on the Ecology and Conservation of Piping Plovers, February 1-4, 2005. http://el.erdc.usace.army.mil/training.cfm?Topic=Workshop&List=05feb-dots. Accessed June 2006.

San Diego Association of Governments (SANDAG) and U.S. Department of the Navy (USDN), 2000. San Diego Regional Beach Sand Project, Environmental Impact Report/Environmental Assessment. State Clearinghouse Number 1999041104.

San Dieguito River Park Joint Powers Authority and U.S. Fish and Wildlife Service (SDRP JPA and USFWS). 2000. Final Environmental Impact Report/Environmental Impact Statement (EIR/EIS) for the San Dieguito Wetland Restoration Project. Prepared by Science Applications International Corporation (SAIC) for JPA.

Sand-Jensen, K. 1977. Effect of epiphytes on eelgrass photosynthesis. *Aquatic Botany*, 3:55-63.

Santos, S.L. and J.L. Simon, 1980. Marine soft-bottom community establishment following annual defaunation: Larval or adult recruitment? *Marine Ecology Progress Series*, 2:235-242.

SARWQCB – See Californian Regional Water Quality Control Board, Santa Ana Region.

Sawyer, J. and T. Keeler-Wolf, 1995. *A Manual of California Vegetation*. California Native Plant Society, Sacramento. 471 p.

SCCWRP – See Southern California Coastal Water Research Project

Scheffner, N.W., M.M. Theviot, and J.R. Tallent, Jr., 1995. LTFATE: A model to investigate the long-term fate and stability of dredged material disposal sites; user's guide. Internal Report DRP-95-I, U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.

Schiel, D.R., S.A. Wood, R.A. Dunmore, and D.I. Taylor, 2005. Sediment on rocky intertidal reefs: Effects on early post-settlement stages of habitat forming seaweeds. *Journal of Experimental Marine Biology and Ecology,* article in press, corrected proof.

Schroeter, S. C., J. Dixon, and J. Kastendiek, 1983. Effects of the starfish *Patiria miniata* on the distribution of the sea urchin *Lytechinus anamesus* in a southern California kelp forest. *Oecologia* (Berlin), 56:141-147.

Schroeder, P.R. and M.R. Palermo, 1990. Automated dredging and disposal alternatives management system (ADDAMS), User's Guide. Technical Note EEDP-06-12, U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.

Schroeter, S.C., Dixon, J.D., Kastendiek, J. & Smith, R.O., 1993. Detecting the ecological effects of environmental impacts - a case-study of kelp forest invertebrates. Ecological Applications, 3: 331-350.

Schubel, J.R., H.H. Carter, R.E. Wilson, W.M. Wise, M.G. Heaton, and M.G. Gross, 1978. Field Investigations of the Nature, Degree, and Extent of Turbidity Generated by Open-Water Pipeline Disposal Operations. Dredged Material Disposal Research Program. U.S. Army Engineer Waterways Experiment Station.

Schultze, D. 2001. Nearshore Ecosystem Fish Resources: Overview in *California Department of Fish and Game California's Living Marine Resources: A Status Report*: 149-151.

Sciaudone, E.J., M. A. Pirrello, I. Brotman, M. Crist, J. D. White, and L. Rosenberg, 2005. Post-Isabel Dune Reconstruction, Norfolk, Virginia. Pages 155-165 in: *Solutions to Coastal Disasters 2005*. Proceedings of the Conference, May 8-11, 2005, Charleston,SC. Available at: http://www.pubs.asce.org/WWWdisplaybn.cgi?0784407746. Accessed November 2005.

Science Applications International Corporation (SAIC), 1987. Alcatraz Disposal Site Survey. Phase 1. San Rafael Clamshell/Scow Operation. Technical Report to U.S. Army Corps of Engineers, San Francisco District.

Science Applications International Corporation (SAIC), 2006. Coastal Habitat Study, 2003-2005: Influence of Beach Nourishment on Biological Resources at Beaches in the City of Encinitas, California. Prepared for City of Encinitas.

Science Applications International Corporation and MEC Analytical Systems, 1996. Pier J Expansion Biological Monitoring Study. Submitted to Port of Long Beach.

SCMI see Southern California Marine Institute

Scottish Natural Heritage (SNH), 2000. A Guide to Managing Coastal Erosion in Beach/Dune Systems. Prepared by HR Wallingford. http://www.snh.org.uk/publications/on-line/heritagemanagement/erosion/index.shtml. Accessed November 2005.

Scripps Institute of Oceanography and EDAW, Inc. (Scripps and EDAW), 2002. Summary Report, Cultural Resources Monitoring for the SANDAG Regional Beach Sand Project. Prepared for the San Diego Association of Governments.

SDRWQCB – See Californian Regional Water Quality Control Board, San Diego Region.

Seapy, R.R. and M. M. Littler, 1978. The distribution, abundance, community structure, and primary productivity of macroorganisms from two central California rocky intertidal habitats. *Pacific Science,* 32(3):293-314.

Sebens, K. P., 1980. The regulation of asexual reproduction and indeterinate body size in the sea anemone *Anthopleura elegantissima* and *A. xanthogrammica* (Brandt). *Biological Bulletin* (Woods Hole), 158:370-3382.

Sebens, K. P., 1983. Population dynamics and habitat suitability of the intertidal sea anemones *Anthoplelura elegantissima and A. xanthogrammica*. Ecological Monographs, 53(4):405-433.

Seligsohn, L., 1998. Feds Target Seals. Earth Island Journal, Summer 1998.

Seymour, R.J., M.J. Tegner, P.K. Dayton, and P.E. Parnell, 1989. Storm wave induced mortality of giant kelp, *Macrocystis pyrifera,* in southern California. *Estuarine, Coastal and Shelf Science,* 28:277-292.

SFRWQCB – See Californian Regional Water Quality Control Board, San Francisco Bay.

Shanks, A.L., B.A. Grantham, and M.H. Carr, 2003. Propagule dispersal distance and the size and spacing of marine reserves. *Ecological Applications*, 13(1):S159-S169.

Shaffer, K., 2002. Preliminary Revision to Marine and Estuarine Habitats of the California Wildlife Habitat Relationship System. California Department of Fish and Game. http://www.dfg.ca.gov/whdab/pdfs/Preliminary_Marine_Estuarine._pdf. Accessed February 2006.

Shaw, W.N., 1986. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest), Spiny Lobster. U.S. Fish Wildlife Service Biology Report 82(11.95). U.S. Army Corps of Engineers, TR EL-82-4. (82 11.47) 9 pp.

Shaw, W.N., T.J. Hassler, and D.P. Moran, 1988. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest), California Sea Mussel and Bay Mussel. U.S. Fish Wildlife Service Biology Report 82(11.4). U.S. Army Corps of Engineers, TR EL-82-4. 16 pp.

Shaw, W.N. and T.J. Hassler, 1989. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest), California Pismo Clam. U.S. Fish Wildlife Service Biology Report 82(11.95). U.S. Army Corps of Engineers, TR EL-82-4. 12 pp.

Shepard, F.P. and L.L. Inman, 1951. Sand movement on the shallow inter-canyon shelf at la Jolla, California. Technical Memorandum No. 26, Beach Erosion Board, Corps of Engineers.

Sherk, J.A., J.M. O'Connor, and D.A. Newman, 1975. Effects of suspended and deposited sediment on estuarine environments. *Estuarine Research*, 2: 541-558.

Sherman, D.J., B.H. Jones, E.J. Farrrell, J. Wang, and Z. Zheng, 1998. The Fate of Fine Sediments in a Suspension Plume: Ponto Beach, California. Geomorphology Research Report No. 4. Prepared for the California Department of Boating and Waterways.

Sherwood, C.R., B. Butman, D.A. Cacchione, D.E. Drake, T.F. Cross, R.W. Sternberg, P.L. Wiberg, and A.J. Williams III, 1994. Sediment transport events on the northern California continental shelf during the 1990-1991 STRESS experiment. *Continental Shelf Research*, Vol. 14(10/11):1063-1099.

Shoeman, D.S., A. McLachlan, and J.E. Dugan, 2000. Lessons from a disturbance experiment in the intertidal zone of an exposed sandy beach. *Estuarine Coastal and Shelf Science*, 50:869-884.

Short, F.T., 1987. Effects of sediment nutrients on seagrasses: Literature review and mesocosm experiment. *Aquatic Botany,* 27(1):414-57.

Short, A.D. and P.A. Hesp, 1982. Wave, beach and dune interactions in southeastern Australia. *Marine Geology*, 48:259-284.

Short, F.T., B. W. Ibelings, and C. Den Hartog, 1988. Comparison of a current eelgrass disease to the wasting disease in the 1930s. *Aquatic Botany*, 30(4):295-304.

Short, F.T., R.C. Davis, B.S. Kopp, C.A. Short, and D.M. Burdick, 2002. Site-selection model for optimal transplantation of eelgrass *Zostera marina* in the northeastern US. *Marine Ecology Progress Series,* 227:253-267.

Shroeder, P. C. and C.O. Hermans, 1975. Chapter 1 Annelida: Polychaeta, Pages 1-169 In: *Reproduction of Marine Invertebrates*, *Volume III Annelids and Echiurans*. A.C. Giese and J.S. Pearse (eds.). Academic Press, New York.

Schubel, J.R. and J.C.S. Wang, 1973. The effects of suspended sediment on the hatching success of *Perca flavescens* (yellow perch), *Morone Americana* (white perch), *Morone saxatilis* (striped bass), and *Aloa pseudoharengus*(alewife) eggs. Special Report No. 30, Chesapeake Bay Institute, Johns Hopkins University, Baltimore, MD.

Sigler, J.W., T.C. Bjornn, and F.H. Everest, 1984. Effects of Chronic Turbidity on Density and Growth of Steelheads and Coho Salmon. *Transactions of the American Fisheries Society* 113: 142-150.

Singleton, H., 2001. Water Quality: Ambient Water Quality Guidelines (Criteria) for Turbidity, Suspended and Benthic Sediments, Overview Report. British Columbia Water Management Branch Environment and Resource Division Ministry of Environment and Parks (now called Ministry of Water, Land and Air Protection). Available online at: http://www.env.gov.bc.ca/wat/wq/BCguidelines/ turbidity/turbidity.html.

Slattery, P., 1996. Coastal Dunes. In: *Monterey Bay National Marine Sanctuaries Site Characterization*. http://www.mbnms.nos.noaa.gov/sitechar/coast.html. Accessed September 2005.

Small, A. 1994. *California Birds Their Status and Distribution*. Ibis.

Smyder, E.A. and K.L.M. Martin, 2002. Temperature effects on egg survival and hatching during the extended incubation period of California grunion, *Leuresthes tenuis*. *Copeia*, 2:313-320. Delete if not cited

SNH see Scottish Natural Heritage

Sokal, R.R. and F.J. Rohlf, 1969. Biometry: The Principles and Practice of Statistics in Biological Research. Second Edition. W.H. Freeman and Company, San Francisco. 859 pp.

Sousa, W. P., 1979a. Disturbance in marine intertidal boulder fields: the nonequilibrium maintenance of species diversity. *Ecology*, 60(6):1225-1239.

Sousa, W. P., 1979b. Experimental investigations of disturbance and ecological succession in a rocky intertidal algal community. *Ecological Monographs*, 49(3):227-254.

South Australian Coast Protection Board (SACPD), 2000. Monitoring sand movements along the Adelaide coastline. *Coastline*, 32 June 2000.

Southall, B.L., 2005. Final Report of the National Oceanic and Atmospheric Administration (NOAA) International Symposium: Shipping Noise and Marine Mammals: A Forum for Science, Management, and Technology, 18-19 May 2004, Arlington, Virginia, U.S.A. Primary symposium sponsor: NOAA Fisheries Acoustics Program, Office of Protected Resources (OPR), National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA). Available at: http://www.nmfs.noaa.gov/ pr/acoustics/shipnoise.htm. Accessed November 2006.

Southern California Coastal Water Research Project (SCCWRP), 1994. Volume IV, Benthic Infauna. 1994 Southern California Pilot Project.

SCCWRP, 1998. Volume VIII, Benthic Macrofauna. 1998 Regional Survey.

Southern California Marine Institute (SCMI), 1997. Five-year (1993-1997) Summary Report on Grunion Monitoring Data from Santa Barbara Harbor, California – Final Report. Prepared for the U.S. Army Corps of Engineers, Los Angeles District.

Spadoni, R.H., 1978. Environmental Monitoirn of the Beach Restoration Project for the City of Delray Beach, Florida. *Beach Seminar* 7:38-54.

Spadoni, R.H., 1993. Environmental Impacts of Beach Erosion. Presentation at Florida Shore and Beach Preservation Association Technical Conference on "State of the Art in Beach Nourishment" St. Petersburg, Florida. February 10, 1993.

Speer-Blank, T.M. and K.L.M. Martin, 2004. Hatching events in the California grunion, *Leuresthes tenuis*. *Copeia*, 1:21-27.

Speybroeck, J., D. Bonte, W. Courtens, T. Gheskiere, P. Grootaert, J-P. Maelfait, M.. Mathys, S. Provoost, K. Sabbe, E.W.M. Stienen, V. Van Lancker, M. Vincx, and S. Degraer, 2006. Beach nourishment: an ecologically sound coastal defence alternative? A review. *Aquatic Conservation Marine and Freshwater Ecosystems,* 16:19-435.

Spratt, J.D., 1981. Status of the Pacific herring, *Clupea harengus pallasi,* resource in California 1972 to 1980. Calif. Dept. Fish and Game, Fish. Bull. 171. 107 p.

State Water Resources Control Board (SWRCB), 1979. California marine waters areas of special biological significance reconnaissance survey report: San Diego – La Jolla Ecological Reserve, San Diego County. Water Quality Monitoring Report No. 79-1. viii+85 pp.

SWRCB, 2005. Water Quality Control Plan, Ocean Waters of California, California Ocean Plan. State Water Resources Control Board and California Environmental Protection Agency.

State Water Resources Control Board and California Regional Water Quality Control Board, Central Coast Region (SWRCB and CCRWQCB), 1994. Water Quality Control Plan for the Central Coast Basin.

Stauth, D., 2003. Red sea urchins Discovered to be one of earth's oldest animals. Source: T. Ebert. http://oregonstate.edu/dept/ncs/newsarch/2003/Nov03/ urchin.htm.

Steinitz, M.J., M. Salmon, and J. Wyncken, 1998. Beach renourishment and loggerhead turtle reproduction: A seven year study at Jupiter Island, Florida. *Journal of Coastal Research*, 14(3):1000-1013.

Stern, E.M. and W.B. Stickle, 1978. Effects of Turbidity and Suspended Material in Aquatic Environments. U.S. Army Engineer Waterways Experiment Station Technical Report D-78-21.

Stephenson, G., 1999. Vehicle impacts on the biota of sandy beaches and coastal dunes: A review from a New Zealand perspective. Science for Conservation, 121:5-48.

Stephenson, T.A. and A. Stephenson, 1949. The universal features of zonation between the tidemarks on rocky coasts. *Journal of Ecology,* 38: 289-305.

Stern, E.M. and W.B. Stickle, 1978. Effects of Turbidity and Suspended Matter in Aquatic Environments: Literature Review. Technical Report D-78-21. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Stevens, B.G., 1981. Dredging-Related Mortality of Dungeness Crabs Associated with Four Dredges Operating Grays Harbor, Washington. Report No. DA-79-45, Washington Department of Fisheries and U.S. Army Engineer District, Seattle, Seattle, WA.

Stewart, J., 1989. Maintenance of a balanced, shifting boundary between the seagrass *Phyllospadix* and algal turf. *Aquatic Botany,* 33:223-241.

Stewart, J.G., 1991. *Marine Algae and Seagrass of San Diego County. A Handbook of Benthic Marine Plants from Intertidal and Subtidal Sites Between the U.S.-Mexican Border and Orange County, California.* A Publication of the California Sea Grant College.

Stewart, J. G. and B. Myers, 1980. Assemblages of algae and invertebrates in Southern California *Phyllospadix*-dominated intertidal habitats. *Aquatic Botany*, 9:73-94.

Storlazzi, C.D.. and B.E. Jaffe, 2002. Flow and sediment suspension events on the inner shelf of central California. *Marine Geology,* 181:195-213.

Straughan, D. 1982. Inventory of the Natural Resources of Sandy Beaches in Southern California. Technical Reports of the Allan Hancock Foundation, No. 6.

Strong, C.S., 2005. Marine Birds of the Near Shore Waters of Clatsop Spit: An Assessment of Composition, Abundance, and Potential Effects from Dredge Spoil Deposition Adjacent to the South Jetty of the Columbia River. Prepared for Institute for Natural Resources, Oregon State University.

Suzuki, H., E. Hamadd, K. Saito, Y. Maniwa, and Y. Shirai, 1980. The influence of underwater sound on marine organisms. *J. Navigation*, 35:291-295.

Svejkovsky, J., S. Schroeter, J. Dixon, T. Ebert, 2002. Near-Shore Small-Scale Processes during Upwelling Relaxations along Northern California and Oregon and their Implications on Larvae Settlement: a Remote Sensing Approach. Presented at AGU's 2002 Ocean Sciences Meeting, Honolulu Hawaii, 11-15 February 2002.

Swanson, J.C., T. Isaji, M. Ward, B.H. Johnson, A Teeter, and D.G. Clarke, 2000. Demonstration of the SSFATE numerical modeling system. *DOER Technical Notes*

Collection (ERDC TN-DOER-E12). U.S. Army Engineer Research and Development Center, Vicksburg, MS. Available online at: www.wes.army.mil/el/dots/doer.

SWRCB See State Water Resources Control Board

Szymelfenig, M. L. Kotwicki, and B. Graca, 2006. Benthic re-colonization in post-dredging pits in the Puck Bay (Southern Baltic Sea). *Estuarine, Coastal and Shelf Science*, 68(3-4):489-498.

Taggert, S.J., C.E. O'Clair, T.C. Shirley, and J. Mondragon, 2004. Estimating Dungeness crab (*Cancer magister*) abundance: crab pots and dive transects compared. *Fishery Bulletin*, 102:488-497.

Taylor Biological Company, 1978. Ecological Comparison of Beaches, Offshore Borrow Sites and Adjacent Bottom at Anna Maria Island and Treasure Island, Florida. Contract No. DACW17-78-M-1410, U.S. Army Engineer District, Jacksonville, Florida.

Taylor, P.R. and M.M. Littler, 1982. The roles of compensatory mortality physical disturbance, and substrate retention in the development aand organization of a sand-influenced, rocky-intertidal community. *Ecology*, 63(1):135-146.

Teeter, A. M., 2001. Simulating underflow spreading from a shallow-water pipeline disposal. *DOER Technical Notes Collection* (ERDC TN-DOER-N11), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/dots/doer.

Tegner, M. J. and P. K. Dayton, 1977. Sea urchin recruitment patterns and implications of commercial fishing. *Science,* 196:324-326.

Tegner, M. J. and P. K. Dayton, 1981. Population structure, recruitment and mortality of two sea urchins (*Strongylocentrotus fraciscanus* and *S. purpuratus*) in a kelp forest. *Marine Ecology Progress Series*, 5:255-269.

Tegner, M. J. and P. K. Dayton, 1987. El Niño effects on southern California kelp forest communities. In: A. MacFadyen and E.D. Ford (eds.) *Adv. Ecol. Res.,* 17:243-289.

Tegner, M.J. and P. K. Dayton, 1991. Sea urchins, El Niños, and the long term stability of Southern California kelp forest communities. *Marine Ecology Progress Series,* 77:49-63.

Tekmarine, Inc. and Analytic Planning Service, Inc., 1990. Negative Declaration and Initial Study for the Cabrillo Beach Renourishment Project. Prepared for County of Los Angeles Department of Beaches and Harbors

Terrados, J. and S.L. Williams, 1997. Leaf versus root nitrogen uptake by the surfgrass *Phyllospadix torreyi*. *Marine Ecology Progress Series,*149:267-277.

Terrados, J. C.M. Duarte, M.D. Fortes, J. Borum, N.S.R. Agawin, S. Bach, U. Thampanya, L. Kamp-Nielsen, W.J. Kenworthy, O. Geertz-Hansen, and J. Vermatt, 1998. Changes in community structure and biomass of seagrass communities along gradients of siltation in SE Asia. *Estuarine and Coastal Shelf Science,* 46: 757-768.

Thackston, E.L. and M.R. Palermo, 2000. Improved methods for correlating turbidity and suspended solids for monitoring. *DOER Technical Notes Collection* (ERDC TN-DOER-E8). U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil.el/dots/doer.

Thayer, G.W., M.S. Fonseca, W.J. Kenworthy, 1986. Wetland mitigation and restoration in the southeast United States and two lessons from seagrass mitigation. Page 95-117 In: *Estuarine Management Practices Symposium,* Nov. 12-13, 1985, Baton Rouge, LA. Published 1986, National Sea Grant College Program & National Marine Fisheries Service, NOAA.

Thelander, C. ed. 1994. *Life on the Edge: A Guide to California's Endangered Natural Resources*. BioSystem Books. Santa Cruz, CA. p 132-135.

Thieler, E.R., O. H. Pilkey, Jr., R.S. Young, D.M. Bush, and F. Chai, 2000. The use of mathematical models to predict beach behavior for U.S. coastal engineering: a critical review. *Journal of Coastal Research,* 16(1):48-70.

Thom, R.M. and R.G. Albright, 1990. Dynamics of benthic vegetation standing-stock, irradiance, and water properties in central Puget Sound. *Marine Biology*, 104 (1): 129 – 141.

Thom, R.M., A.B. Borde, G.D. Williams, J.A. Southard, S.L. Blanto, and D.L. Woodruff, 2001. Effects of Multiple Stressors on Eelgrass Restoration Projects. Available online at www.psat.wa.gov/publications/or procceedings/sessions/oral/7b thom.pdf. Accessed September 2005.

Thomas, S. and P.V. Ridd, 2004. Review of methods to measure short time scale sediment accumulation. *Marine Geology,* 207: 95-114.

Thomsen, M.S. and K. McGlathery, 2005. Effects of accumulations of sediments and drift algae on recruitment of sessile organisms associated with oyster reefs. *Journal of Experimental Marine Biology and Ecology,* 328(1):22-34.

Thompson, J.R., 1973. Ecological Effects of Offshore Dredging and Beach Nourishment: A Review. MP 1-73, U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Virginia.

Thompson, B.E., J.D. Laughlin, and D.T. Tsukada, 1987. Reference Site Survey. Technical Report #221. Southern California Coastal Water Research Project.

Thompson, B., J. Dixon, S. Schroeter, and D.J. Reish, 1993. Benthic Invertebrates. Pages 369-458 in: *Ecology of the Southern California Bight: A Synthesis and Interpretation.* M.D. Dailey, D.J. Reish, and J.W. Anderson (eds.). University of California Press, Berkeley, California.

Thompson, B., S. Lowe, and M. Kellogg, 2000. Results of Benthic Pilot Study, 1994-1997, Part 1 – Macrobenthic Assemblages of the San Francisco Bay-Delta, and their Responses to Abiotic Factos. Technical Report 39. San Francisco Estuary Regional Monitoring Program for Trace Substances.

Thornton, S.E., 1981. Suspended sediment transport in surface waters of the California Current off southern California: 1977-1978 floods. *Geo-Marine Letters*, Vol. 1, 23-28.

Thrush, S.F., J.E. Hewitt, A. Norkko, V.J. Cummings, and G.A. Funnell, 2003. Macrobenthic recovery processes following catastrophic sedimentation on estuarine sandflats. *Ecological Applications,* 13(5):1433-1455.

Tomilin, A.G., 1957. Mammals of the U.S.S.R. and adjacent countries. Vol. IX Cetacea V.G. Heptner (ed). Nauk. S.S.S.R, Moscow (English translation, 1967, Israel Program for Scientific Translations, Ltd. Jerusalem).

Trueman, E.R. and R.L. Foster-Smith, 1976. The mechanisms of burrowing of *Sipunculus nudus*. *Journal of Zoology*, London, 179:373-386.

Turbeville, D.B. and G.A. Marsh, 1982. Benthic Fauna of an Offshore Borrow Area in Broward County. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Misc. Report No. 82-1. 42 pp.

Turk, T.R. and M.J. Risk, 1981. Effect of sedimentation on infaunal invertebrate populations of Cobequid Bay, Bay of Fundy. *Can. J. Fish. Aquat. Sci., 38:642-648.*

Turner, T., 1985. Stability of rocky intertidal surfgrass beds: persistence, preemption, and recovery. *Ecology*, 66(1):83-92.

Turner, T. and J. Lucas, 1985. Differences and similarities in the community-roles of three rocky intertidal surfgrasses. *J. Exp. Mar. Biol. Ecol.,* 89:175-189.

Underwood, A.J., 2000. Importance of experimental design in detecting and measuring stresses in marine populations. *Journal of Aquatic Ecosystem Stresses and Recovery,* Vol. 7: pp. Mar-24. http://www.eicc.bio.usyd.edu.au/newsindex html? oct01.html.

Underwood, A.J. and M.G. Chapman, 2006. Early development of subtidal macrofaunal assemblages: relationships to period and timing of colonization. *Journal of Experimental Marine Biology and Ecology*, Vol. 330, pp. 221-233.

University of California, San Diego, 2003. Living with Coastal Change - Coastal Basics - Beaches. Scripps Institution of Oceanography, Coastal Morphology Group. http://coastalchange.ucsd.edu/st3_basics/waves.html, accessed September 2005.

U.S. Army Corps of Engineers Los Angeles District (USACE), 1988a. Sediment Resuspension by Selected Dredges. Environmental Effects of Dredging Technical Notes (EEDP-09-2). U.S. Army Engineer Waterways Experiment Station, Environmental Laboratory, Vicksburg, MS.

USACE, 1988b. Environmental Quality Procedures for Implementing NEPA. Department of the Army ER 200-2-2. U.S. Army Corps of Engineers 33 CFR 230, Washington D.C.

USACE, 1991. Coast of California Storm and Tidal Waves Study (CCSTWS), Final State of the Coast Report, San Diego Region.

USACE, 1993. Final Environmental Assessment Santa Barbara Harbor Maintenance Dredging (FY 94, 95, 96), Santa Barbara County, California.

USACE, 1994a. Environmental Assessment Channel Islands/Port Hueneme Harbors Maintenance Dredging Project. Prepared by USACE, Los Angles District.

USACE, 1994b. Final Environmental Assessment for Oceanside Harbor Maintenance Dredging. Prepared by USACE, Los Angeles District.

USACE, 1995a. Environmental Assessment Surfside-Sunset/West Newport Beach Nourishment Project. Prepared by USACE, Los Angeles District.

USACE, 1995b. Final Supplemental Environmental Assessment Oceanside Harbor Experimental Bypass System. Prepared by USACE, Los Angeles District.

USACE, 1998a. Santa Barbara Harbor Six-Year Maintenance Dredging Program (Santa Barbara County California) Final Environmental Assessment. Prepared by USACE, Los Angeles District.

USACE, 1998b. Final Environmental Assessment for Ventura Harbor Six-Year Maintenance Dredging Program, Ventura County, Ventura. Prepared by USACE, Los Angeles District.

USACE, 1998c. Final Environmental Assessment for Fiscal Year (FY 1998) Operations & Maintenance Dredging of the Crescent City Harbor Federal Channels, Del Norte County California. Prepared by USACE, San Francisco District.

USACE, 1999a. Final Environmental Assessment for Morro Bay Harbor Three-Year Maintenance Dredging Program. Prepared by USACE, Los Angeles District.

USACE, 1999b. Final Environmental Assessment for Marina Del Rey Harbor Maintenance. Prepared by USACE, Los Angeles District.

USACE, 2000a. Environmental Assessment for Channel Islands/Port Hueneme Harbors Maintenance Dredging Project. Prepared by USACE, Los Angeles District.

USACE, 2000b. Final Environmental Assessment Oceanside Harbor Maintenance Dredging. Prepared by USACE, Los Angeles District.

USACE, 2001. Final Environmental Assessment for Morro Bay Harbor Six-Year Maintenance Dredging Program, San Luis Obispo County, California.

USACE,. 2002a. Coastal Engineering Manual. Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, D.C. (in 6 volumes).

USACE, 2002b. Biological Evaluation for Beach Re-nourishment at Lincoln Park, Seattle Washington. Prepared by USACE, Seattle District, July , 2002.

USACE, 2002c. Environmental Assessment for Operations and Maintenance Dredging of the Moss Landing Harbor Federal Channels, Monterey County, California.

USACE, 2002d. Bolinas Lagoon Ecosystem Restoration Project Draft Feasibility Report and Draft EIR/EIS. http://www.marinopenspace.org/os_bolinaslagoonmgt plan.asp

USACE, 2002e. Imperial Beach Shore Protection Project Final Environmental Impact Statement (EIS)/Final Environmental Impact Report (EIR). Prepared by USACE, Los Angeles District.

USACE, 2003a. Morro Bay Estuary City of Morro Bay, San Luis Obispo County, CA Ecosystem Restoration Feasibility Study, F3 Conference Report Without-Project Conditions Analysis. Prepared July 2003.

USACE, 2005a. Encinitas-Solana

USACE, 2005b. The Gateway, Summer 2004 Issue. U.S. Army Corps of Engineers, San Francisco District. http://www.spn.usace.army.mil/gateway/summer2004/bodegabay.html.

USACE, 2005c. Project fact sheets. U.S. Army Corps of Engineers, San Francisco District. http://www.spn.usace.army.mil/projects2005/om/CrescentCityHarbor/ factsheet.pdf; http://www.spn.usace.army.mil/projects2005/om/HumboldtHarbor andBay/factsheet.pdf; http://www.spn.usace.army.mil/projects2005/om/Noyo RiverandHarbor/factsheet.pdf; http://www.spn.usace.army.mil/projects2005/om/BodegaBay/factsheet.pdf; http://www.spn.usace.army.mil/projects2005/civ/BolinasLagoonEcosystemRestoration/factsheet.pdf.

USACE, 2006. Regional General Permit Number 67, Discharges of Dredged or Upland Derived Fill Materials for Beach Nourishment. USACE Los Angeles District, September 25, 2006.

USACE and Los Angeles Harbor Department (LAHD), 1992. Deep Draft Navigation Improvements, Los Angeles and Long Beach Harbors, San Pedro Bay, California.

USACE and County of Orange, 2000. Upper Newport Bay Ecosystem Restoration Feasibility Study F4/AFB Main Report, Draft Environmental Impact Statement/Report. January 2000.

USACE and San Diego Unified Port District (SDUPD), 2003. Environmental Impact Statement/Environmental Impact Report for San Diego Harbor Deepening (Central Navigational Channel).

U.S. Army Corps of Engineers and U.S. Environmental Protection Agency (USACE and EPA), 2004. Evaluating Environmental Effects Of Dredged Material Management Alternatives -- A Technical Framework. Prepared 1992 and revised 2004.

U.S. Army Corps of Engineers (USACE), U.S. Environmental Protection Agency (EPA), San Francisco Bay Conservation and Development Commission (BCDC), and San Francisco Bay Regional Water Quality Control Board (SFBRWQCB), 2001. Long Term Management Strategy (LTMS) For the Placement of Dredged Material in San Francisco Bay Region, Management Plan 2001. .

U.S. Code of Federal Regulations, 2003. Title 40, Chapter 1, Part 227-230 – Criteria for the evaluation of permit applications for ocean dumping of materials and 404(b)(1) Guidelines for Specification of Disposal Sites for Dredge or Fill Material. http://www.access.gpo.gov/nara/cfr/waisidx_0/040cfr227_00/40cfr230__00.htm.

U.S. Department of Interior/Minerals Management Service (USDOI/MMS), 1999. Environmental Report: Use of Federal Offshore Sand Resources for Beach and Coastal Restoration in New Jersey, Maryland, Delaware, and Virginia. Office of International Activities and Marine Minerals. OCS Study. MMS 99-0036.

U.S. Department of the Navy, Southwest Division (USDN), 1996. Turbidity/Waterfowl Monitoring Report for Nimitz Class CVN Naval Air Station North Island Coronado, 6 Sept. to 28 Oct. 1996. Naval Facilities Engineering Command.

U.S. Department of the Navy, Southwest Division (USDN), 1997a. Environmental Assessment for Beach Replenishment at South Oceanside and Cardiff/Solana Beach, California.

USDN, 1997b. Environmental assessment for Beach Replenishment at North Carlsbad, South Carlsbad, Encinitas, and Torrey Pines, California.

U.S. Environmental Protection Agency (USEPA). 1971. Noise from Construction Equipment and Operations, Building Equipment and Home Appliances. (Prepared under contract by Bolt, et al., Bolt, Beranek & Newman, Boston, Massachusetts.) Washington, D.C.

USEPA, 1992. Environmental effects of dredged material management alternatives. A Technical Framework. EPA842-B-92-008.

USEPA, 2002. Total Maximum Daily Loads for Nutrients Malibu Creek Watershed. http://www.epa.gov/region09/water/tmdl/ final.html.

U.S. Environmental Protection Agency and U.S. Army Corps of Engineers (USEPA and USACE), 1991. Evaluation of Dredged Material Proposed for Ocean Disposal (Testing Manual).

U.S. Environmental Protection Agency and U.S. Army Corps of Engineers (USEPA and USACE), 1998. Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. – Testing Manual (Inland Testing Manual).

USEPA and USACE, 2004. Evaluating Environmental Effects of Dredged Material Management Alternatives - A Technical Framework. United States Environmental Protection Agency Office of Water (4504F)Department of The Army U.S. Army Corps of EngineersEPA842-B-92-008. November 1992Revised May 2004. Available online at: http://www.epa.gov/owow/oceans/ regulatory/dumpdredged/framework/techframeork. pdf.

U.S. Fish and Wildlife Service (USFWS), 2000. Biological Opinion on San Diego Regional Beaches Sand Replenishment Project, Coastal Zone of San Diego County, California: FWS Log No. 1-6-01-F-1046; Corps Public Notice No. 1999-15076-RLK.

USFWS, 2001. Amendment to Biological Opinion on San Diego Beaches Sand Replenishment Project, Coastal Zone of San Diego County, California; FWS Log. No. 1-6-01-F-1046.1; Corps Public Notice No. 1999-15076-RLK.

USFWS, 2003. Final Revised Recovery Plan for the Southern Sea Otter (*Enhydra lutris nereis*). U.S. Fish and Wildlife Service Region 1.

USFWS, 2005a. Dune Restoration. http://www.fws.gov/hoppermountain/Guadalupe/dunerest.html. Accessed November 2005.

USFWS, 2005b. Endangered and Threatened Wildlife and Plants; Addition of White Abalone and the United States Distinct Vertebrate Population Segment of the Smalltooth Sawfish to the List of Endangered and Threatened Wildlife. *Federal Register* 70(220): 69464-69466.

USFWS and NMFS, 1998. Endangered Species Consultation Handbook: Procedures for Conducting Consultation and Conference Activities Under Section 7 of the Endangered Species Act. Available online: http://www.fws.gov/endangered/consultations/s7hndbk/s7hndbk.htm.

Utne, A.C.W., 1997. The effect of turbidity and illumination on the reaction distance and search time of the marine planktivore *Gobiusculus flavescens*. Journal of Fish Biology 50: 926 938.

Utne-Palm, A.C., 2004. Effects of larvae ontogeny, turbidity, and turbulence on prey attack rate and swimming activity of Atlantic herring larvae. *Journal Experimental Marine Biology Ecology*, 310(2):147-161.

Valle, C.F., J.W. O'Brien, and K.B. Wiese, 1998. Differential habitat use by California halibut, *Paralichthys californicus,* barred sand bass, *Paralabrax nebulifer,* and other juvenile fishes in Alamitos Bay, California. *Fish. Bull.* 97:646-660.

Vanaverbeke, J., M. Steyaert, A. Vanreusel, and M. Vincx, 2003. Nematode biomass spectra as descriptors of functional change due to human and natural impact. *Marine Ecology Progress Series*, 249:157-170.

VanBlaricom, G.R., J.A. Ames, M.D. Harris, and R.A. Hardy, 2001. Sea Otter in California Department of Fish and Game California's Living Marine Resources: A Status Report: 536-540.

Van Dalfsen, J.A. and K. Essink, 2001. Benthic community response to sand dredging and shorefae nourishment in Dutch coastal waters. *Senckenbergiana mariitima* 31(2):329-332.

van der Merwe, D. and D. van der Merwe, 1991. Effects of off-road vehicles on the macrofauna of a sandy beach. *South African Journal of Science,* 87:210-213.

Van der Veer, H.W., M.J.N. Bergman, and J.J. Beukema, 1985. Dredging activities in the Dutch Wadden Sea: effects on macrobenthic infauna. *Netherlands Journal of Sea Research*, 19:183-190.

Van der Wal, d., 2000. Modeling Aeolian sand transport and morphological development in two beach nourishment areas. *Earth Surface Processes and Landforms,* 5:77-92.

Van Dolah, R.F., D.R. Calder, and D.M. Knott, 1984. Effects of dredging and open-water disposal on benthic macroinvertebrates in a South Carolina Estuary. *Estuaries,* 7(1):28-37.

Van Dolah, R. F., R. M. Martore, A. E. Lynch, P. A. Wendt, M V. Levisen, D. J. Whitaker, and W. D. Anderson, 1994. Final Report. Environmental Evaluation oof the Folly Beach Nourishment Project. Prepared by the Marine Resources Division, South Carolina Department of Natural Resources for U. S. Army Corps of Engineers, Charleston, SC. 101 p.p. & appendices.

van Gils J.A., T. Piersma, A. Dekinga, B. Spaans, and C. Kraan, 2006. Shellfish dredging pushes a flexible avian top predator out of a marine protected area. PLoS Biol 4(12): e376. DOI: 10.1371/journal.pmed.0030376. Available online at: http://biology.plosjournals.org/perlserv/?request=get-document&doi=10.1371/journal.pbio.0040376.

van Lent, F. and J. M. Verschuure, 1994a. Intraspecific variability of *Zostera marina* L. (eelgrass) in the estuaries and lagoons of the southwestern Netherlands. I. Population dynamics. Aquatic Botany, 48(1):31-58.

van Lent, F. and J. M. Verschuure, 1994b. Intraspecific variability of *Zostera marina* L. (eelgrass) in the estuaries and lagoons of the southwestern Netherlands. II. Relation with environmental factors. *Aquatic Botany*, 48(1):59-75.

Varanus Biological Services (Varanus), 1999. California Brown Pelican Night Roost Monitoring During Maintenance Dredging of Marina del Rey Harbor, Los Angeles, California, October 14-28 and November 10-14, 1999. Prepared for Hart Crowser.

Valle, C.F., J.W. O'Brien, and K.B. Wiese, 1998. Differential habitat use by California halibut, *Paralichthys californicus,* barred sand bass, *Paralabrax nebulifer*, and other juvenile fishes in Alamitos Bay, California. *Fishery Bulletin,* 97:646-660.

Versar, Inc. 2004. Year 2 Recovery from Impacts of Beach Nourishment of Surfzone and Nearshore Fish and Benthic Resources on Bald Head Island, Caswell Beach, Oak Island, and Holden Beach, North Carolina. Final Study Findings. For the U.S. Army Corps of Engineers, Wilmington District.

Visser, E. P., P. S. McDonald and D. A. Armstrong. 2004. The impact of yellow shore crabs, *Hemigrapsus oregonensis*, on early benthic phase Dungeness crabs, *Cancer magister*, in intertidal oyster shell mitigation habitat. Estuaries 27(4): 699-715. http://www.erf.org/cesn/vol27n4.html. Accessed January 2006.

Vogel, J.L. and D.A. Beauchamp, 1999. Effects of light, prey size, and turbidity on reaction distances of lake trout (*Salvelinus namaycush*). Can. J.Fish. Aquat. Sci. 56: 1293-1297.

Voigt, B., 1998. *Glossary of Coastal Terminology*. Washington State Department of Ecology, Coastal Monitoring & Analysis Program, Publication No. 98-105. Updated on April 09, 2001. NOAA Coastal Services Center. http://www.csc.noaa.gov/text/glossary.html.

Walker, B., S. Carpenter, J. Anderies, N. Abel, G.S. Cumming, M. Janssen, L. Lebel, J. Norberg, G.D. Peterson, and R. Pritchard, 2002. Resilience management in social-ecological systems: a working hypothesis for a participatory approach. *Conservation Ecology* 6(1): 14. [online] http://www.consecol.org/vol6/iss1/art14/.

Wang, J.C.S., 1986. Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories. A cooperative study by the California Department of Water Resources, California Department of Fish and Game, U. S. Bureau of Reclamation and U. S. Fish and Wildlife Service. Technical Report 9 (FS/B10-4ATR 86-9). Available online at: http://elib.cs.berkeley.edu/kopec/tr9/html/home.html. Accessed January 2007.

Wardle, C.S., T.J. Carter, G.G Urquhart, A.D.F. Johnstone, A.M. Ziolkowski, G. Hampson, and D. Mackie, 2001. Effects of seismic air guns on marine fish. *Continental Shelf Research,* 21:1005-1027.

Ware, R., 1993. Eelgrass (*Zostera marina*) in southern California bays and wetlands with emphasis on Orange County, California. *Shore and Beach*, 20-30.

Warriner, J.S., J.C. Warriner, G.W. Page, and L.E. Stenzel, 1986. Mating systems and reproductive success of a small population of polygamous Snowy Plovers. *Wilson Bulletin,* 98:15-37.

Warnock, N. and S. Warnock, 2001. Sandpipers, Phalaropes, and Allies in C. Elphick, J.B. Dunning, Jr., and D.A. Sibley eds. The Sibley Guide to Bird Life and Behavior. Alfred A. Knopf: 273-287.

Warrick, J.A. and J.D. Milliman, 2003. Hyperpycnal sediment discharge from semiarid southern California rivers: implications for coastal sediment budgets. *Geology*. 31(9):781-784.

Warrick, J.A., L.A.K. Mertes, L. Washburn, and D.A. Siegel, 2004. Dispersal forcing of southern California river plumes, based on field and remote sensing observations. *Geo-Marine Letters*, 24: 46-52.

Washington State Department of Transportation (WSDOT), 2006. Advanced Training Manual: Biological Assessment Preparation for Transportation Projects. Part 2, Guidance on Specific BA Topics. http://www.wsdot.wa.gov/Environment/Biology/BA/default.htm#BAManual. Accessed December 2006.

Washburn, L., K.A. McClure, B.H. Jones, and S.M. Bay, 2003. Spatial scales and evolution of stormwater plumes in Santa Monica Bay. *Marine Environmental Research,* 56:103-125.

Watson, J.J, 1992. Dune breeding birds and off-road vehicles. *The Naturalist,* 36(3):8-12.

Watt, S.G. and H.G. Greene, 2002. Monitoring of Dredged Upper Santa Cruz Harbor Mixed Sand and Mud Sediment Released into the Nearshore Area of Santa Cruz, California. Center for Habitat Studies Moss Landing Marine Laboratories.

Watters, D.L., K.T. Oda and J. Mello, 2001. Pacific Herring in California Department of Fish and Game California's Living Marine Resources: A Status Report: 456-459.

Webb, C., 2006. Moffatt & Nichol Engineers, personal communication.

Wells, J.T. and J. McNinch, 1991. Beach scraping in North Carolina with special reference to its effectiveness during Hurricane Hugo. *Journal of Coastal Research,* SI 8 II, 249-261.

Weston Solutions and U.S. Army Engineer Research and Development Center (U.S. Army-ERDC), 2006. Assessment of Sediment Resuspension by Vessel Traffic. PowerPoint Presentation. Accessed 2006.

Weymouth, F.W., 1922. The life-history and growth of the Pismo clam (*Tivela stultorum* Mawe). *Ca. Dept. of Fish and Game Fish Bulletin* 7:1-103.

Wheeler, P.A.. and W.J. North, 1981. Nitrogen supply, tissue composition and frond growth rates for *Macrocystis pyrifera* off the coast of Southern California. *Marine Biology*, 64:59-69.

Wilber, D. H. and D. G. Clarke. 2001. Biological effects of suspended sediments: A review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. *North American Journal of Fisheries Management*, 21:855-875.

Wilber, D.H., D.G. Clarke, G.L. Ray and M. Burlas, 2003. Response of surf zone fish to beach nourishment operations on the northern coast of New Jersey, USA. *Marine Ecology Progress Series,* 250: 231-246.

Wilber, D.H., W. Brostoff, D.G. Clarke, and G.L. Ray, 2005. Sedimentation: Potential biological effects from dredging operations in estuarine and marine environments. *DOER Technical Notes Collection (*ERDC TN-DOER-E20), U.S. Army Engineer Research and Development Center, Vicksburg, MS. http://el.erdc.usace.army.mil/dots/doer/doer.html.

Wilber, D.H., D.G. Clarke, and M.H. Burlas, 2006. Suspended sediment concentrations associated with a beach nourishment project on the northern coast of New Jersey. *Journal of Coastal Research,* 22:1035-1042.

Wild, P.W. and R.N. Tasto, 1983. Life history, environment, and mariculture studies of the Dungeness crab, *Cancer Magister,* with emphasis on the Central California fishery resource. *Calif. Dept. of Fish and Game, Fish Bulletin* 172:1-339. Accessed at http://ceo.ucsd.edu/ fishbull/.

Williams, J., 1962. *Oceanography: An Introduction to the Marine Sciences*. Little, Brown and Company. Boston, Massachusetts. 242 pp.

Williams, G.L., 1998. Planning Considerations for Nearshore Placement of Mixed Dredged Sediments. Technical Note DOER-N3. U.S. Army Engineer Waterways Experiment Station. Vicksburg, Mississippi.

Williams, S.L. and C.P. McRoy, 1982. Seagrass productivity: The effect of light on carbon uptake. *Aquatic Botany,* 12:321-344.

Williams, S.L. and M.H. Ruckelshaus, 1993. Effects of nitrogen availability and herbivory on eelgrass (*Zostera marina*) and epiphytes. *Ecology,* 74(3):904-918.

Williams, S., 1995. Surfgrass (*Phyllospadix torreyi*) reproduction: reproductive phenology, resource allocation, and male rarity. *Ecology*, 76(6):1953-1970.

Williams, G., W. Pearson, J., Skalski, and K. Larson, 2004. Dredge entrainment of Dungeness crab in the Columbia River Estuary. Paper presented at 2004 SETAC, www.allenpress.com.

Wilson, W.B., 1950. The effects of sedimentation due to dredging operations on oysters in Copano Bay, Texas, M.S. thesis, Texas A&M, College Station, TX.

Wilson, B., R.S. Batty, and L.M. Dill, 2004. Pacific and Atlantic herring produce burst pulse sounds. Proceedings Royal Society of Longdon B (Suppl.). O3b10262.S3.

Wolcott, T.G. and D.I. Wolcott, 1984. Impact of off-road vehicles on macroinvertebrates of a mid-Atlantic beach. *Biological Conservation,* 29:217-240.

Worden, J.B., and R.V. Smith, 2004. Ventura Harbor U.S. Army Corps of Engineers Dredging Western Snowy Plover Monitoring Report. Prepared for Ventura Port District.

Worden, J.B.., R.V. Smith, and A. Cope, 2002. Ventura Harbor California Least Tern and Western Snowy Plover 2001 Monitoring Report. Prepared for Ventura Port District.

Wright, L.D. and A.D. Short, 1984. Morphodynamic variability of surf zones and beaches: A synthesis. *Marine Geology,* 56:93-118.

Wright, L.D., S.-C. Kim, and C. T. Friedrichs, 1999. Across-shelf variations in bed roughness, bed stress and sediment suspension on the northern California shelf. *Marine Geology*, 154(1-4):99-115.

Wright, T.D., D.B. Mathis, and J.M. Brannon, 1978. Aquatic Disposal Field Investigations, Galveston, Texas, Offshore Disposal Site; Evaluative Summary. Technical Report D-77-20, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Yannicelli, B., R. Palacios, and L. Gimenez, 2002. Swimming ability and burrowing time of two cirolanid isopods from different levels of exposed sandy beaches. *Journal of Experimental Marine Biology and Ecology,* 273(1):73-88.

Zieman, J.C. and R.T. Zieman, 1989. The ecology of seagrass meadows of West Florida: A community profile. *U.S. Fish and Wildlife Service Biological Report,* 85 (7.25). 155 pp.

Zeiner, D.C., W. F. Laudenslayer Jr., K.E. Mayer and M.White, 1990. California's Wildlife Volume II Birds California Dept. of Fish and Game.

Zimmermann, R.C. and J.N. Kremer, 1984. Episodic nutrient supply to a kelp forest ecosystem in southern California. *Journal of Marine Research,* 42:591-604.

Zimmerman, R.C., R.D. Smith, and R.S. Alberte, 1989. Thermal acclimation and whole-plant carbon balance in *Zostera marina* L. (eelgrass). *Journal of Experimental Marine Biology and Ecology,* 130:93-109.

Zimmerman, R.C., R.D. Smith, and R.S. Alberte, 1990. Seagrass Revegetation: Developing A Predictive Model Of Light Requirements. Pages 6-12 In: In: *Proceedings of the California Eelgrass Symposium, Chula Vista, California, May 27 and 28, 1988.* Sweetwater River Press, National City, California.

Zimmerman, R.C., J.L. Reguzzoni, S. Wyllie-Echeverria, M. Josselyn, and R.S. Alberte, 1991. Assessment of environmental suitability for growth of *Zostera marina* L. (eelgrass) in San Francisco Bay. *Aquatic Botany, 39:353-366.*

Zimmerman, R.C., J.L. Reguzzoni, and R.S. Alberte, 1995. Eelgrass (*Zostera marina* L.) transplants in San Francisco Bay; role of light availability on metabolism, growth and survival. *Aquatic Botany*, 51:67-86.

APPENDIX A

LIST OF REVIEWED PERMITS

Table A. List of Reviewed Permits.

Project	Discharge Location	Year(s)	Volume (cy)	Applicant	CCC	RWQCB	USACE
Northern California							
Crescent City Harbor Maintenance Dredging	Whaler Island Disposal Site	1998-1999	65,000	USACE	August 20, 1998 Concurrence with CD-80-98	WDR Order No. 92-103	USACE 1998c EA & FONSI
Santa Cruz Harbor Maintenance Dredging	Twin Lakes State Beach	2000-2010		Santa Cruz Port District	CD 3-00-034-A2	Letters of Certification Dec. 13, 2000, Nov. 8, 2004	25179S
Moss Landing Harbor Maintenance Dredging	South Sandspit Disposal Site	2002	20,227	USACE	Aug 15, 2002 Concurrence with ND-056-02	WDR Order Number 01-007	USACE 2002c EA & FONSI
Moss Landing Harbor Maintenance Dredging	Offshore Aquatic Sites (SF-12, SF-14)	2002-2007 CCC; 2003-2013 USACE	100,000 per year with maximum 1,000,000r	Moss Landing Harbor District	CD 3-01-049	WDR Order Number 01-007	26356S
Central California							
Morro Bay Harbor Maintenance Dredging	Surf zone or nearshore disposal off Morro Strand State Beach and off Montana de Oro State Park	1999-2001	Up to 1,308,000 cubic meters	USACE	Apr 15, 1999 Concurrence with ND-028-99		USACE 1999a EA and 404(b)1 certification
Morro Bay Harbor Maintenance Dredging	Surf zone or nearshore disposal off Morro Strand State Beach and off Montana de Oro State Park	2001-2007	Up to 1,127,100 per year	USACE	Aug 16, 2001 Concurrence with ND-064-01		Chambers Group 2001 (EA) and 404(b)1 certification

Table A.(Continued)

Project	Discharge Location	Year(s)	Volume (cy)	Applicant	CCC	RWQCB	USACE
Southern California							
BEACON Demonstration Project	Goleta Beach	2003-2008	100,000 to 150,000	BEACON	2003, 4-02-054	Jun 18, 2003 (no file number)	Sep 9, 2003, 200200666-JCM
South Coast Beach Enhancement Program	Beaches at Ash Avenue, Goleta Beach, Hueneme Beach, Oil Piers, Surfer's Point	2005-2010	Up to 100,000 to 275,000 depending upon beach	BEACON	Apr 4, 2005 NOI to Issue Permit	Jun 28, 2005 Technically Conditioned 401 certification	Not Issued?
Santa Barbara Harbor Maintenance Dredging	East Beach, Surf Zone, Nearshore	FY 1994-1996	Up to 600,000 per year	USACE	Jun 9, 1993 CD-32-93	Sep 5, 1986 Order No. 86-149	USACE 1993 EA and 404(b)1 Evaluation
Santa Barbara Harbor Maintenance Dredging	East Beach, Surf Zone	1999-2005	Up to 600,000 per year	USACE	May 13, 1998 CD-48-98	Sep 5, 1986 Order No. 86-149	USACE1998a EA and 404(b)1 Evaluation
Ventura Harbor Maintenance Dredging	Surf and/or nearshore (McGrath State Beach	1998-2004	Up to 1,000,000/ dredge cycle	USACE	Jul 10, 1998 CD-64-98		USACE 1998b EA and 404(b)1 Evaluation
Channel Islands/Port Hueneme Harbors Maintenance Dredging	Hueneme and/or Silver Strand Beaches	2000-2005	Up to 2,000,000/ dredge cycle with total of 6,900,000	USACE	May 2, 2000 CD-52-94		USACE 2000a EA and 404(b)1 Evaluation

Table A. (Continued)

Project	Discharge Location	Year(s)	Volume (cy)	Applicant	CCC	RWQCB	USACE
Channel Islands/Port Hueneme Harbors Maintenance Dredging	Hueneme and/or Silver Strand Beaches	1994-2000	Up to 2,200,000/ dredge cycle	USACE	Jul 15, 1994 CD-52-94	Jul 21, 1975 Order No. 75-2 and 75-63	USACE 1994a EA and 404(b)1 Evaluation
Marina Del Rey Harbor Maintenance Dredging	Dockweiler Beach and Redondo Beach	1999-2000	Up to 1,263,528	USACE	Jun 1999 CD-022-99	Sep 5, 1986 Order No. 86-149	USACE 1999b EA and 404(b)1 Evaluation
Cabrillo Beach Renourishment Project	Cabrillo Beach	1991	300,000	County of Los Angeles Department of Beaches		1991 WDR waived	Aug 20, 1991 91-047-SS
Alamitos Bay Peninsula Oceanfront Beach Nourishment Program	Beach between 59th and 72nd Place	1994-1999	Up to 300,000	City of Long Beach	Aug 16, 1994 CDP 5-94-102	Oct 25, 1994 401 certification waiver	1994 RGP 32 (No. 94-01516-FT)
Surfside-Sunset/West Newport Beach Nourishment Project	Surfside-Sunset Beach, West Newport Beach	1995-1996	1.6 million on Surfside-Sunset Beach, 140,000 to west Newport Beach	USACE	Jun 29, 1995 Concurrence with ND-58-95		USACE 1995a EA and 404(b)1 evaluation
San Gabriel River to Newport Bay Beach Replenishment Project	Surfside-Sunset Beach	1989-1990	2,000,000	USACE	1989 CCD	No letter received RWQCB	USACE 1989 EA and 404(b)1 evaluation

Table A. (Continued)

Project	Discharge Location	Year(s)	Volume (cy)	Applicant	CCC	RWQCB	USACE
Santa Ana River Mainstem Project	Newport Beach or in nearshore	1991-?	Up to 3,000,000			Apr 19, 1991 Order No. 91-34	
Santa Ana River Mainstem Project	East Beach, south of Seal Beach Pier (from Main Street to Neptune Avenue)	1995-1997	60,000	City of Seal Beach	Apr 22, 1994 CDP No. 5-94-084		Nov 21, 1994 94-008-00-RRS
Bolsa Chica Lowlands Restoration	Seal Beach	2002-2011	Up to 1,300,000 to ebb shoal and 190,000 to beach, and 250,000 to 300,000 to beach every two years	USFWS		Apr 23, 2002 Technically Conditioned Certification	Aug 14, 2002 9700-19300-RLK
Dana Point Harbor Maintenance Dredging	Swim Beach in Dana Point Harbor and San Juan Capistrano Beach	1997-2001	50,500	County of Orange	Mar 11, 1998 CDP No. 5-97-232	Aug 25, 1997 P 260 996 986, Order No. 96-32	97-00088-RRS
City of San Clemente Beach Replenishment Project	Beaches at North Beach, Linda Lane, T-Street	2005-2010	Up to 300,000 per year	City of San Clemente	2004, CDP No. 5-02-142	2004, File No. 02C-059	2005, RGP 66 (File No. 200400838-DPS)
Oceanside Harbor Maintenance Dredging	Oceanside Beach	2000-2010	Up to 400,000 per year	USACE	Aug 22, 2000 CCD	Aug 23, 1995 Order No. 96-32	USACE 2000b EA and 404(b)1 evaluation

Table A. (Continued)

Project	Discharge Location	Year(s)	Volume (cy)	Applicant	CCC	RWQCB	USACE
Oceanside Harbor Maintenance Dredging	Oceanside Beach	1994-2000	Up to 400,000 per year	USACE		Sep 12, 1994 Order No. 94-124, Aug 23, 1995 Order No. 96-32	USACE 1994b EA, USACE 1995b Supplemental EA and 404(b)1 evaluation
Agua Hedionda Lagoon Maintenance Dredging	Carlsbad Beaches	1992-2001	Up to 500,000	Cabrillo Power		Aug 23, 1995 Order No. 96-32	87-171-SK (Extended)
Agua Hedionda Lagoon Maintenance Dredging	Carlsbad State Beach	1988-1992	Up to 500,000	SDG&E		May 5, 1986 Order No. 86-44	Mar 3, 1988 87-171-SK
Batiquitos Lagoon Enhancement Project	Batiquitos	1993-1994		City of Carlsbad	Mar 4, 1994 CDP No. 6-90-219A	May 17, 1993 Order No. 93-50	April 1992 88-217-EW
Moonlight Beach Park	Moonlight Beach	1990	300	City of Encinitas	May 16, 1990 Administrative Permit No. 6-90-105/PW		
San Elijo Lagoon Inlet Maintenance	Cardiff Beach	2005		San Elijo Lagoon Conservancy	CDP No. 6-05-007		

Table A. (Continued)

Project	Discharge Location	Year(s)	Volume (cy)	Applicant	CCC	RWQCB	USACE
San Diego Harbor Deepening Project	Imperial Beach	2004-2005	1,700,000	USACE and SDUPD		Mar 2, 2004 03C-139	USACE and SDUPD 2003 EIS/EIR
San Diego Regional Beach Sand Project	Beaches at Oceanside, North Carlsbad, South Carlsbad, Batiquitos, Leucadia, Moonlight Beach, Cardiff, Solana Beach, Del Mar, Torrey Pines, Mission Beach, Imperial Beach	2001-2002	2,100,000	SANDAG	Nov 13, 2000 NOI Application No. 6-00-38	Jun 15, 2001, File No. 00C-063	Dec 4, 2000 Provisional 1999-15076-RLK
Silver Strand	Silver Strand in front of U.S. Navy Amphibious Base	1985	1,100,000	USACE	1985 CCD		USACE 1985 EA
Pier 2 (P-332S) Dredging San Diego Bay	Nearshore off Imperial Beach	1995	233,000	U.S. Navy		1994 Order No. 94-22	1994 94-177-DZ

Abbreviations:
CCC = California Coastal Commission
CCD = Coastal Consistency Determination
CD = Consistency Determination
CDP = Coastal Development Permit
EA = Environmental Assessment
FONSI = Finding of No Significant Impact
ND = Negative Determination
RWQCB = Regional Water Quality Control Board
SANDAG = San Diego Association of Governments
USACE = U.S. Army Corps of Engineers

APPENDIX B

ANNOTATED SUMMARIES OF REPORTED IMPACTS FROM SEDIMENT MANAGEMENT ACTIVITIES

B.1 Impacts to Reef Habitats
B.2 Impacts to SAV Habitats
B.3 Impacts to Invertebrates
B.4 Impacts to Fish
B.5 Impacts to Birds

APPENDIX B.1

Representative Reports of Impacts to Reef Habitat from Sediment Management Activities

Table B.1. Reported responses of reef habitats to beach nourishment.

Project	Volume (cy) and Sediment Character	Survey Period	Rocky Intertidal	Subtidal Reefs	Reference
Beach Nourishment					
San Diego Regional Beach Project Apr-Jun, Aug 2001 Borrow site dredging (hopper) offshore and pumped to beach, dikes used to limit turbidity	2,104,000 receiver sites 101,000 to 421,000 Source materials 0.12-0.87 mm , 0.05-13.8% fines	Spring 2001-Spring 2004 Five years Before and After Sand Placement Surveyed sites r in areas of predicted sedimentation (generally no more than 3,281 ft (1,000 m) distant from receiver site.	Changes in sand cover similar at treatment (Cardiff) and control (Scripps) reefs. Seasonal sand levels within typical seasonal variation. *Project – No apparent adverse impacts.*	No indication that substantial sand migration from project affected any monitored reefs with exception of one location off Batiquitos (BL-SS-3) and one location off Solana Beach (SB-SS-2). Post-project percent cover of surfgrass, feather boa kelp, and sea palms similar to higher than pre-project at BL-SS-3. Surfgrass, feather kelp, and sea palms variable at SB-SS-2 with no clear relationship to sand cover. No strong correlation between percent sand cover, substrate relief , and lobster. *Impact – Localized adverse.*	AMEC 2005
Goleta Beach Nourishment Demonstration Project: 2003	79,000 in 2003, 18,600 in 2004	2003 to 2004	Temporary partial burial	NA	Chambers Group, 2003,2004
Beach placement at Carlin Park in Southeast Florida March and April 1995	457,800	1994-1996		About 12 to 14 acres of nearshore hard bottom were buried. Approximately 4 acres were constructed to mitigation for burial impacts. (See fish table for response of reef fish) *Impact – Significant.*	Lindeman and Snyder 1999

Table B.1. Reported responses of reef habitats to beach nourishment.

Project	Volume (cy) and Sediment Character	Survey Period	Rocky Intertidal	Subtidal Reefs	Reference
Ana Maria Island, Mantee County, Florida	2.2 million	1992/1993		Seven acres of reef were buried. Two artificial reefs were constructed to mitigate for direct burial impacts. *Impact – Significant.*	Coastal Planning & Engineering 2004a
Ana Maria Island, Mantee County, Florida	1.9 million	2002		Ephemeral, low relief reefs (< 2 ft, 0.6 m). Similar macroalgae, invertebrates, and fish before and 1 year after construction. *Impact – Minimal, if any.*	Coastal Planning & Engineering 2004a
Central Boca Raton, Florida Borrow site and beach placement	500,000			Patch reefs ranged from low (~ 1 ft) to moderate (~ 3 ft) relief. No apparent trend relative to project activities. *Impact – Not apparent.*	Coastal Planning and Engineering 2004c
Boca Raton, Florida Beach nourishment	343,000			Sand burial effects documented. Effects at artificial reef location attributed to natural sand movement from ebb bar. It was suggested artificial reef was placed too close to inlet. Natural low relief reef also experienced sand inundation. *Impact – Substantial adverse, but not all project related.*	Coastal Planning and Engineering 2004b

Table B.1. Reported responses of reef habitats to beach nourishment.

Project	Volume (cy) and Sediment Character	Survey Period	Rocky Intertidal	Subtidal Reefs	Reference
Borrow Site Dredging					
Pompano Beach and Lauderdale-by-the-Sea, Florida Completed 1970	Not specified Sandy	Aug 1970 to Jul 1972 (11 months) Post project 10 quadrats for algae and invertebrates		Negligible to no impacts observed to inshore and offshore coral reefs. (See fish table for response of reef fish)	Courtenay et al. 1972
Hallandale Beach, Florida Jul-Sep 1971 Borrow site dredging between inshore and offshore reefs and beach fill	Not specified (268,000 cited in Marsh and Turbeville 1981) Sandy	Aug 1971 to Aug 1972 (1 year) During and after project Qualitative observations algae, invertebrates, fish at treatment and unaffected sites		No indication of damage reported for inshore coral patch reef communities. Damage to offshore coral patch reefs within approximately 1,300 to 2,600 ft (400 to 800 m) of the dredged borrow area that included loss of algae, hard corals, and attached mollusks from turbidity /sedimentation. Evidence of physical damage to patch reef formations from dredge (overturned, cut marks). Movement of motile invertebrates (lobsters, crabs, shrimp) and fishes from area (some invertebrates absent for 9 months). *Impact: Substantial Adverse.*	Courtenay et al. 1972
Hallandale Beach, Florida Jul-Sep 1971 Offshore borrow site dredging	268,000 Sandy Five years post project	Nov to Dec 1977 (1 month) 1.0 m^2 quadrats (3 per station), 4 stations per treatment and unaffected areas		Physical damage to some corals near Hallandale similar to unaffected site were attributed to anchor scars from recreational boaters and divers, no evidence of substantial damage reported by Courtenay et al. 1972. *Impact: Dredge damage not observed.*	Marsh et al. 1981
Delray Beach, Florida 1978 Dredging and beach fill		5 stations before, during, and after Water, sedimentation samples, diver observations		Turbidity and sedimentation caused no observable effects. Damage from dredge anchor and cable dragging across reef uprooting soft corals, fragmenting sponges, overturning and/or scarring coral heads. *Impact: Substantial adverse.*	Spadoni 1978 cited in Naqvi and Pullen 1982

APPENDIX B.2

Representative Reports of Impacts to SAV Habitats Sediment Management Activities

Table B.2. Reported responses of kelp bed habitats to beach nourishment.

Project	Volume (cy) and Sediment Character	Survey Period	Giant Kelp	Associated Biota	Reference
Beach Nourishment					
Goleta Beach Demonstration Project Oct 2003 (sand excavated offshore and pumped to beach, swale used to limit turbidity)	79,000 Additional 18,600 in 2004	2003-2004 Before and After Project	No increase in sand cover. Changes in kelp density related to impact and subsequent recovery to winter storm. *Project: No adverse impact.*		Moffat & Nichol 2005
San Diego Regional Beach Project Apr-Jun, Aug 2001 (sand dredged from offshore borrow sites and pumped to beach, dikes used to limit turbidity)	2,104,000 Receiver sites from 101,000 to 421,000 cy Source materials 0.12-0.87 mm , 0.05-13.8% fines	Spring 2001-Spring 2004 Three years Before and After Sand Placement	Sand cover less than values observed prior to project. Giant kelp persistence and recruitment has increased throughout region since project implementation, probably in response to oceanographic conditions. *Project: No adverse impacts.*	Abundance of key indicator species (ascideans, *Chaceia, Diopatra, Kelletia, Lithopoma, Pisaster, Strongylocentrotus pururatus and S. franciscanus)* within range of natural variation with no apparent loss of habitat associated with sand burial. *Project: No adverse impacts to kelp bed invertebrate biota.*	AMEC 2004

Table B.2. Reported responses of seagrass habitats to beach nourishment.

Project	Volume (cy) and Sediment Character	Survey Period	Eelgrass	Surfgrass	Reference
Beach Nourishment					
Goleta Beach Demonstration Project Oct 2003 (sand excavated offshore and pumped to beach, swale used to limit turbidity)	79,000 in 2003, 18,600 in 2004	2003-2004 1 year Before and After Project	Seasonal variation in eelgrass cover observed. Percent cover similar or greater than pre-project condition at all three transects. *Project: No adverse impact.*	Percent cover of surfgrass exhibited greater variation in vicinity of beach nourishment than upcoast sites. Some variability related to seasonal decline, other variation related to increased sand cover. Sand cover not persistent and variability in percent cover of surfgrass within variation observed prior to project. *Project: Temporary burial, but no impacts beyond natural variability for sites.*	Chambers 2004
San Diego Regional Beach Project Apr-Jun, Aug 2001 (sand dredged from offshore borrow sites and pumped to beach, dikes used to limit turbidity)	2,104,000 Receiver sites from 101,000 to 421,000 cy Source materials 0.12-0.87 mm, 0.05-13.8% fines	2001-2004 Three years Before and After Project		No substantial change in sand cover documented at any monitored subtidal reefs with exception of one location off Batiquitos (BL-SS-3) and one location off Solana Beach (SB-SS-2). Surfgrass percent cover in spring 04 similar to higher than pre-project at BL-SS-3. Surfgrass in spring 04 within range of pre-project observations at SB-SS-2. Decline in shoot density at SB-SS-2 as well as some other sites with no substantial change in sand cover. *Project – No obvious adverse impacts.*	AMEC 2004

APPENDIX B.3

Representative Reports of Impacts to Invertebrates from Sediment Management Activities

Table B.3. Reported responses of invertebrates to sediment management activities.

Project (Locations, Year)	Volume (cy) and Sediment Character	Survey Period and Methods	Results (Listed Separately for Intertidal, Subtidal, and Borrow Sites, as Appropriate)	Reference
Beach Placement				
San Diego Regional Beach Project, California (Offshore borrow sites – sand pumped to beach, dikes used to limit turbidity, Encinitas beaches, Jun & Aug 2001)	455,000 Source materials 0.12-0.87 mm , 0.05-9.7% fines Native cobble to sand 0.16 to 0.46 mm	May 1999 (Before) 2003 -2005 (After) Receiver and non receiver sites 3-4 years after project Shovel samples, 1 mm sieve	Number of species and abundance with similar seasonal trends among receiver and non receiver sites. Two sites changed from cobble (with no fauna) to sandy beach (with fauna) after nourishment. Invertebrate community developed earlier in season at receiver sites with deeper sand depths across season than non receiver sites with shallow depths in winter-early spring. *Impact: No long term adverse, sandy habitat created or enhanced.*	SAIC 2006
Imperial Beach, California (material dredged from San Diego Bay, pumped to beach, Mar-Jun 1977)	1,000,620 Source materials 0.12 mm, 5-15 % fines Native 0.21-0.27 mm on beach, 0.08-0.16 mm offshore	1976-1978 15 months, before and after project Cores, 0.5 mm sieve	<u>Intertidal</u> *Construction Phase*- No survival of invertebrates in dredge materials pumped through discharge pipe. Burial of fauna, possibly some motile species escaped (not documented). *Post Construction Phase* - Similar number of species and abundance and/or variability among nourished and control sites without relationship to nourishment. Number of species, abundance, biomass without obvious pattern related to nourishment among sites within, adjacent, and nearby but farther away from project within 5 weeks of sand placement. *Impact: Short term.* <u>Subtidal</u> Offshore sedimentation of 3 to 9 cm at 3.7 m (12 t) and 6.1 m (20 ft) stations. Changes in number of species and abundance at nearshore sites variable without relationship to project. Seasonal and storm related changes considered more influential than projectt. Some burial, but no mortality of sand dollars observed. *Impact: Not obvious.*	Parr et al. 1978

Table B.3 (Continued)

Project (Locations, Year)	Volume (cy) and Sediment Character	Survey Period and Methods	Results (Listed Separately for Intertidal, Subtidal, and Borrow Sites, as Appropriate)	Reference
Asbury Park to Manasquan Section Beach Erosion Control Project, New Jersey (Phase 1 1997 completed Oct (Phase 2 1999-2000 completed mid-Dec) (Dredged from offshore borrow areas, pumped to beach)	8,083,440 (6,180,000 cm) Source materials: mainly < 10% silt/clay Native sediments: Intertidal 0.27-1.78 mm, - 3.3 ft (- 1m) 0.18-1.16 mm, 16 to 20 ft (5-6.5 m) 0.05-0.22 mm	1994-2000 7 & 13 months after phase 1 and 2 projects Before and After Project Cores & grabs, 0.5 mm sieve	<u>Intertidal</u> 1997 - Temporary decrease in abundance, number of species, biomass. 1997 intertidal recovery estimated within 2 months. 1999-2000 - Abundance and number of species within natural variation within 5 months, biomass lower but within natural variation. 1999-2000 phase recovery nearly but not complete 5 months after placement, author's estimated 6.5 months to full recovery based on trend analysis. *Impact: Short term with rapid recovery during seasonal high, slower recover during seasonal low.* <u>Subtidal</u> 1999-2000 – 3.3 (*1 m) water depths* Five months after placement, abundance similar, number of species reduced at low end of natural variation, biomass reduced but within natural variation. *16 to 20 ft (5-6.6 m) water depths* Five months after placement, number of species and abundance reduced at low end of natural variation, biomass reduced but within natural variation Longer recovery during 1999-2000 thought to relate to timing of fill placement relative to population seasonality (i.e., recovery after Oct 1997 in time of seasonal high, recovery after Dec 1999 during time of seasonal low). *Impact: Recovery incomplete 5 months after placement.*	Burlas et al. 2001

Table B.3. (Continued)

Project (Locations, Year)	Volume (cy) and Sediment Character	Survey Period and Methods	Results (Listed Separately for Intertidal, Subtidal, and Borrow Sites, as Appropriate)	Reference
Bald Head Island, Caswell Beach, Oak Island, Holden Beach, North Carolina March 2001- May 2002	5,600,000 14 miles of beach 4 sites Bald Head (spring 2001) Caswell Beach (summer 2001) Oak Island (Fall 2001) Holden Beach (winter 2002)	Generally quarterly Wrack area – ghost crabs, Swash zone – *Donax* and *Emerita* (Cores 1 mm) Shallow and deep nearshore – (Cores 0.5 mm)	<u>Wrack Area</u> Impacts to ghost crabs localized, not evident 1 year later. <u>Swash Zone</u> *Donax* and *Emerita* abundance lower 1 year later at Bald Head (spring) and Caswell Beach (summer). <u>Shallow Nearshore</u> Biomass significantly lower (spring) 1 year later Bald Head. Abundance and taxa significantly lower (summer) 1 year later at Caswell beach, site was reconstructed twice in summer 2001. Biomass significantly lower 1 year later Holden Beach. <u>Deeper Nearshore</u> Taxa, abundance, biomass significantly lower (spring) 1 year later Bald Head. Increase in silt/clay noted after nourishment, but not substantially different 1 year later *Impact: Incomplete recovery within 1 year*	Versar 2004
Bogue Banks, North Carolina Mar-May 1990 (material dredged from Bogue Sound, pumped to beach)	278,000 Source materials 0.06-0.08 mm with shell hash and mud balls Native sands 0.20 mm	June-July 1990 2 months, After Project (Cores, 3 mm sieve, *Donax and Emerita*)	<u>Intertidal</u> 86% fewer *Donax* and 99% fewer *Emerita* at nourished beaches compared to controls. Dissimilar sands (finer, mud balls, increase in shell debris, harder feel) suggested as explanation. Fining of sediments resulted in median phi change from 2.3 (0.2 mm) to 3.7 (0.08 mm). *Impact: Not recovered within 2 months.*	Petersen et al. 2000

Table B..3. (Continued)

Project (Locations, Year)	Volume (cy) and Sediment Character	Survey Period and Methods	Results (Listed Separately for Intertidal, Subtidal, and Borrow Sites, as Appropriate)	Reference
Bogue Banks, North Carolina Morehead City State Port Harbor dredged, material placed on beach at Fort Macon State Park (cutterhead dredge, hydraulic pipeline discharge) Dec1977-Jun 1978	1,180,000 Source materials included clay balls, shell hash, and average grain size slightly larger than native beach	Sampling every two weeks, Jan 1977 to Sep Aug 1978 at nourished and comparison beach 20 months (post discharge period of 2 months) Cores, 1 mm sieve	<u>Intertidal</u> Surf zone turbidity measured twice, TSS at comparison beach ranged from 0.086 to 0.096 g/L; Nourished beach ranged from 1.76 to 4.70 g/L in surf zone and 15.03 to 34.18 at pipeline effluent. No living invertebrates on beach during nourishment. Ghost crab abundance lower in upper intertidal lower during and for 2 months after nourishment, migration to search for food rather than mortality suspected. Recovery of density of *Emerita* sand crabs within 1 month of nourishment by new recruits but no overwintering adults, different age classes at comparison beach. Recruitment after nourishment (and turbidity) ceased. Initial recovery by *Donax* from longshore migration, not larval recruitment; density significantly lower at receiver site 2 months after nourishment. High turbidity during recruitment period considered detrimental to recovery. Lower diversity during and 2 months after nourishment. Beach not recovered 2 months after project. Reductions in invertebrate density observed at adjacent beach during nourishment, turbidity suspected. Authors suggested adult *Emerita* and *Donax* killed in overwintering grounds by turbidity. *Impact: Not recovered within 2 months.*	Reilly and Bellis 1983

Table B.3. (Continued)

Project (Locations, Year)	Volume (cy) and Sediment Character	Survey Period and Methods	Results (Listed Separately for Intertidal, Subtidal, and Borrow Sites, as Appropriate)	Reference
Indialantic and Melbourne Beach, Florida Oct-Feb 1980-1981 (Material trucked to site)	540,204 (413,000 cm) Source materials 1.31 Native 1.7 phi on beach and 2.75 phi subtidal	1980-1981 1 year Before and After Project (Cores, 0.6 mm sieve)	<u>Intertidal</u> Post Construction–Similar trends in number of species and abundance at nourished and control sites. *Impact: No obvious negative impact to number of species or abundance.* <u>Subtidal</u> Offshore – Little evidence of offshore sand movement. Similar trends in number of species and abundance at shallow subtidal sites (≤ 3 m, ≤ 10 ft water depths). Distance from high tide line and seasonal differences more influential than beach nourishment. Sediment profile data indicated downcoast, but not upcoast control, affected by sediment transport, but no obvious difference in biology. *Impact: No obvious negative impact to number of species or abundance*	Gorzelany & Nelson 1987
Hallandale Beach, Florida Jul-Sep 1971 Borrow site dredging between inshore and offshore reefs and beach fill	Not specified (268,000 cited in Marsh and Turbeville 1981) Sandy	Aug 1971 to Aug 1972 1 year During and after project Qualitative observations invertebrates at treatment and unaffected sites	<u>Subtidal</u> Temporary movement of invertebrates (lobsters, crabs, shrimp) from project area (some species absent from area for 9 months)	Courtenay et al. 1972

Table B.3. (Continued)

Project (Locations, Year)	Volume (cy) and Sediment Character	Survey Period and Methods	Results (Listed Separately for Intertidal, Subtidal, and Borrow Sites, as Appropriate)	Reference
Hallandale Beach, Florida Jul-Sep 1971 Borrow site dredging between inshore and offshore reefs and beach fill	268,000 Sandy	Nov to Dec 1977 (6 years after project) 1 month PVC cores at 5 treatment and at 5 control sites along transects from intertidal to offshore reef, 24 samples/ station, 1 mm sieve, grain size.	Intertidal Significant difference between sites, fewer polychaetes and crustaceans at Hallandale, attributed to coarser sediments. Subtidal No significant difference among stations, except for shallowest nearshore site that had similar result as intertidal. Borrow Site – see borrow site part of table	Marsh and Turbeville 1981
Panama City, Florida Offshore borrow sites hydraulically dredged and sands placed in nearshore in 1976 Study in 1979-1980 designed to examine long-term effects of beach placement and offshore dredging	Not specified, (8.24 million citied in Saloman et al. 1982) Sandy	Nov-Dec 1979, May1980 Three-four years after project 49 stations along transects (swash zone, first sandbar < 5 ft (1.5 m), between first and second sandbar, second sandbar, 10-13 ft (3-4 m) depth 2 stations inside (6.1 m) and 2 stations outside borrow sites (9-10 m) cores, 0.7 mm sieve Compared to data collected in 1974-1975 (Saloman 1976)	Intertidal Mean grain size 1.71 phi with 0.02% silt/clay in 1979 similar to 1.64 phi with 0.07% silt/clay in 1974-1974. Greater variety of species and higher densities in Nov 1979 compared to Nov 1974, and similar number of species and lower densities in May 1980 compared to May1975. *Impact: No obvious long term effect.* Subtidal Mean grain size 2.05-2.34 phi with 0.01-0.05% silt/clay in 1979 similar to 1.84-2.17 phi with 0.06-0.09% silt/clay in 1974-1975. Greater variety of species and similar to higher densities in Nov 1979 compared to Nov 1974; similar to greater variety of species and lower densities in May 1980 compared to May 1975. *Impact: No obvious long term effect.* Borrow Site – see borrow site part of table	Culter and Mahadevan 1982

Table B.3. (Continued)

Project (Locations, Year)	Volume (cy) and Sediment Character	Survey Period and Methods	Results (Listed Separately for Intertidal, Subtidal, and Borrow Sites, as Appropriate)	Reference
Berm Construction - Bulldozing				
Bogue Banks, North Carolina (Shore protection berm constructed by bulldozing sediment from low intertidal to back beach – no more than 30 cm depth removed) Apr 1993		Jul-Aug 1993 2 months After Project bulldozed and control sites (Cores, 1 and 3 mm sieve – examined *Donax, Emerita*, examined) (transects for ghost crab, *Ocypode*, burrows	No significant difference in abundance of large *Emerita* across tides. Small *Emerita* 35% fewer on low tide and 55% fewer on high tide at bulldozed sites compared to controls. Significantly more *Donax* at bulldozed sites. Significantly fewer ghost crab burrows i upper zone of beach, not lower zone at bulldozed sites. No apparent difference in beach slope, grain size, or wave and tide energy at bulldozed and control sites except in upper zone where sediments were coarser and shellier and did not hold hand excavations well. *Impact: Species specific ranging from no (Donax) to little (Emerita) impact to shallow burrowers, impact to deep burrower (Ocypode) in upper beach related to sediment change.*	Petersen et al. 2000
Beach and Nearshore Placement				
Perdido Key, Florida two phases Nov - Sep 1989-1990 and Nov-Sep 1990-1991 Nourishment (material dredged from Pensacola Pass ship channel) and pumped to beach and nearshore at approximately 22 ft (6.7 m) depth	5.36 million cy to beach, 3.9 million cy to subtidal Source materials - Good match of grain size but higher silt clay content Native 0.2--0.4 mm with 94% sands and < 6% shell hash	1989-1992 three years Before and after Project (Cores, 1 mm sieve)	<u>Intertidal</u> Insignificant species richness and abundance differences among transects across three post project autumn surveys. *Impact: Recovery substantial within 1 year* <u>Subtidal</u> Shift in community structure at inshore sites indirectly affected by silt/clay loading after beach placement. *Impact: Incomplete recovery within 2 years* At subtidal fill site, some recovery, but not complete 1 year after nourishment. *Impact: Incomplete after 1 year* Authors suggest possibly planktonic-benthic decoupling due to turbidity during construction.	Rakocinski et al. 1996, 2001

Table B.3. (Continued)

Project (Locations, Year)	Volume (cy) and Sediment Character	Survey Period and Methods	Results (Listed Separately for Intertidal, Subtidal, and Borrow Sites, as Appropriate)	Reference
Nearshore Placement				
Ventura Harbor Maintenance Dredging Project, California (Harbor dredging and nearshore placement (-40 ft) offshore McGrath State Beach (1992)		January 1992 (prior to project), April 1992 (after project) Two stations inside and two outside receiver site, diver cores, 0.5 mm sieve Two stations outside and one station in receiver site, trawls	<u>Subtidal</u> One receiver site showed a 30% reduction in number of taxa and 52% reduction in abundance immediately after discharge. The other receiver site and control sites showed an increase in number of taxa and abundance, presumably due to spring recruitment. Trawl caught invertebrates showed greater difference among control sites between survey periods than did the receiver site. *Impact: Localized to not obvious*	Chambers 1992
North Sea, Netherlands Sand extraction at depths of ≥ 66 ft (20 m) Shoreface nourishment	Sandy	General summary from three projects – 1 borrow site and 2 nourishment sites	<u>Subtidal</u> Recovery characterized by initial increase in opportunistic polychaetes with decrease in opportunists after 8 months. Abundance recovered in 2 years, biomass and number of species recovered in 2-4 years. *Impact: No long term negative effect.* <u>Borrow Site</u> Population structure (species composition and age structure) recovered in 4 years. *Impact: No long term negative effects*	Dalfsen and Essink 2001

Table B.3. (Continued)

Project (Locations, Year)	Volume (cy) and Sediment Character	Survey Period and Methods	Results (Listed Separately for Intertidal, Subtidal, and Borrow Sites, as Appropriate)	Reference
Borrow Site Dredging				
Long Beach Harbor, California Channel deepening borrow area for landfill construction, completed 1991, but additional dredging delayed biological study	Fine sediments Borrow Site: 92.8% fines, 7% sand, median grain size 9.17μm Reference: 89% fines, 10.6% sand, median grain size 12μm	Aug 1994; Feb, Jul 1995; Jan 1996 2 years, quarterly samples; 3 to 4 years after project 5 borrow site stations, 1 reference station box core, 1 mm sieve (infauna) otter trawl (macroinvertebrates)	No significant difference in sediment grain size characteristics and total organic carbon between borrow site and reference area, although median grain size was slightly, but significantly larger. No significant difference in mean water clarity (Secchi disc), transmissivity, pH, dissolved oxygen, salinity, and temperature between borrow site and reference area. Significantly higher mean number of species and diversity, similar abundance and biomass, and similar number of species among taxonomic groups at borrow site compared to reference site. Significantly higher abundance, but similar biomass and number of species of trawl-caught macroinvertebrates at borrow site compared to reference area. *Impact: No obvious long term negative effect.*	SAIC and MEC 1996
Kure Beach, North Carolina Aug 1997-Jan 1998		Jun 1995-May 1997 (before), Feb 1998-Oct 1999 (after) 5 stations, 3 transects each Borrow and reference sties Grab samples, ROV of hard bottom	3 hurricanes occurred 1996, 1998, 1998; significant differences in benthic communities related to dates. Little change in sediment grain size. No significant differences between borrow site and control for density, diversity, or species richness. Dominance by opportunistic species borrow and reference sites. Little net change in hardbottom habitat. *Impact: Not obvious against natural variability.*	Posey and Alphin 2001

Table B.3. (Continued)

Project (Locations, Year)	Volume (cy) and Sediment Character	Survey Period and Methods	Results (Listed Separately for Intertidal, Subtidal, and Borrow Sites, as Appropriate)	Reference
Asbury Park to Manasquan, New Jersey Borrow areas were bathymetric peaks rather than depressions	8,083,440	Biannually (Spring and Fall) beginning in May 1995 and ending in May 2000 – before and after mining. 3 borrow sites 10 stations per site Smith McIntyre grab (6.35, 3.35, 2.0, 1.0, and 0.5 mm sieves) Water quality data including temperature, salinity (ppt), dissolved oxygen (mg/l)	Abundance, biomass, and taxa richness recovered after the first dredging operation with no detectable difference between dredged and undisturbed areas by the following spring. Abundance recovered quickly after the 1999 dredging, but biomass and taxa richness still reduced in May 2000. Changes in biomass took 1.5 to 2.5 years to recover (sand dollars, major contributor to biomass, took 2.5 years to recover population structure). Silts and clays increased ~ 20%, but appeared to be a wide-scale, periodic phenomenon. No significant change in water depth; water quality displayed similar highs and lows before and after dredging. *Impact: Recovery within 2.5 years.*	Burlas et al. 2001
Myrtle Beach, South Carolina Phase 1 1996 Hopper dredge	2,600,000	Nov 1995-Feb 1998, quarterly, Feb 1999 Before and up to 30 months after dredging 10 stations in borrow area and in reference area Young grab, 0.5 mm sieve	Sand content exceeded 90 % throughout study. Mean grain size ranged between 2-2.1 phi (medium sand) before and after dredging, but coarsened (< 1.9 phi) between the winter of 1998 and winter 1999. Sediment grain size more variable at reference area (2.2-2.4 phi). No significant difference in species number or abundance, except last survey higher at borrow site. Diversity similar between area before and 6 months after dredging. Cluster analysis showed dissimilarity between fall-winter (1995-1996) and remaining surveys at reference site. Borrow and reference site assemblages more similar fall-winter 1995-1996 than remaining surveys (including both before and after). *Impact: No obvious long term negative effect.*	Jutte et al. 2002

Table B.3. (Continued)

Project (Locations, Year)	Volume (cy) and Sediment Character	Survey Period and Methods	Results (Listed Separately for Intertidal, Subtidal, and Borrow Sites, as Appropriate)	Reference
Fort Pierce, Florida Borrow site at 23 ft (7 m), dredged to depth of 11.5 ft (3.5 m) 1980	372,780 (285,000 cm)	Aug 1980-Aug 1981, quarterly Before disturbance (Aug 1980), After (Nov 1980, Feb, May, Aug 1981) 1 year 2 transects perpendicular to borrow area (each with 5 stations – 3 inside and 2 outside trench), and 1-2 control transects Smith-McIntyre grab, 600 micro sieve	Grain size changed from medium to very fine sand; 1 year after dredging mean grain size back to medium sand. Transects across borrow areas with similar number of taxa in trench as non trench and control areas 9 months. Abundance lower in trench than non trench and 1 control, and similar to other control after 1 year. Species composition in trench areas became more dominated by polychaetes and did not return to pre-disturbance conditions after 1 year. *Impact: Recovery not complete after 1 year.*	Johnson and Nelson 1985
Hillsboro Beach, Florida Aug to Sep 1972 Borrow site dredging between inshore and offshore reefs and beach fill (see under beach placement)	342,000 Sandy	Jun-1977 – 1978 1 year, quarterly samples PVC cores at 3 stations within borrow site and at 3 stations away, 24 samples/station, 1 mm sieve, grain size	Grain size medium sand all stations, but coarser fractions at borrow site. No significant difference in TOC, which was low (1.1-1.6%) at all stations. No reduction in number of species, Shannon-Wiener diversity index, or abundance among stations. Change in species composition. *Impact: Recovery led to changed community after 6 years, but no long-term indication of adverse effect.*	Turbeville and Marsh and 1982

Table B.3. (Continued)

Project (Locations, Year)	Volume (cy) and Sediment Character	Survey Period and Methods	Results (Listed Separately for Intertidal, Subtidal, and Borrow Sites, as Appropriate)	Reference
Panama City, Florida Borrow site dredging and pumped to shore 6 borrow sites dredged to depths of 5 m or less 1976	306,000 from several borrow areas at 6-9 m depth,	Apr 1976-Nov 1977 6 stations (40 reps/station) inside and outside borrow sites surveyed 1 year after dredging. Station 1 inside and outside borrow site (16-36 reps) sampled prior to dredging (Apr, Jun, Jul 1976), 2 days after dredging (Aug 1976), and weekly to monthly for 16 months after dredging (Aug 1976-Nov 1977) 20 months diver core, 0.7 mm sieve	Sediment similar 1 year after dredging inside (98.6 to 99.86% sand) and outside (99.52-99.88% sand) borrow sites. Mean grain size was coarser at one borrow site (1.75 phi), but otherwise similar inside (2.01-2.50 phi) and outside (2.11-2.45 phi) borrow sites. Station 1 borrow site initially filled with dark, silty material, but at end of study (16 months later) had filled to within 1 meter of surrounding bottom with grain size similar to conditions outside borrow pit. After 1 year, several community structure measures similar inside and outside the borrow sites: i.e., average number of species 86 inside and 92 outside, average Shannon-Weaver diversity 3.2 inside and 3.1 outside, and Pielou's equitability 0.7-0.8 inside and 0.7 outside. Similar range of abundance inside (2,422 to 4,037) and outside (1,408 to 4,326) borrow sites. Faunal similarity (Morisita's Index) inside and outside borrow sites 86 to 96 at four borrow site areas, and 38 and 63 percent at two borrow site areas. Cluster analysis showed similar results as Morisita's Index. No biomass reported. The authors considered recovery generally complete, or nearly so, within 1 year of dredging. This interpretation is not fully supported by results; particularly at 3 of the 6 borrow site areas. Consistently fewer species each survey and a greater variability in number of species over time at borrow site. In addition, no information was collected to assess recovery of biomass. *Impact: Substantial recovery after 1 year, but not complete, insufficient information on full recovery.*	Saloman et al. 1982

Table B.3. (Continued)

Project (Locations, Year)	Volume (cy) and Sediment Character	Survey Period and Methods	Results (Listed Separately for Intertidal, Subtidal, and Borrow Sites, as Appropriate)	Reference
Panama City, Florida Offshore borrow sites hydraulically dredged and sands placed on beach in 1976 (Saloman et al. 1982)		Nov-Dec 1979, May1980 Three years after project 2 stations inside 20 ft (6.1 m) and 2 stations outside borrow sites 29 to 33 ft (9-10 m) Cores, 0.7 mm sieve	2.29 phi with 0.02% silt/clay inside borrow sites similar to 2.26 phi with 0.22% silt/clay outside borrow sites in 1979. Number of species and densities in borrow site 20 ft (6.1 m depth) lower than deeper stations 29 to 33 ft (9-10 m) outside, but more similar to those at shallower 10 to 13 ft (3-4 m) depths. *Impact: Sampling design lacked direct comparison of similar depth, more similar species number with shallow than deeper depths suggests recovery nearly complete after 3 years.*	Culter and Mahadevan 1982
North Norfolk, United Kingdom 500 x 270 m area experimentally dredged with suction-trailer dredge, and recovery examined 1992	52,000 tons	Experiment and reference site Pre-dredge Jan, Mar 1992; post-dredge May 1992, May 1993, May 1994 2 years Hamon grab, diver observations.	After dredging, sea bed lowered by 1 to 6.5 ft (0.3 to 2 m) in dredge areas; tracks weathered/eroded and were only just visible with side scan sonar 2 years later. Grain size more variable and somewhat coarser after dredging due to exposure of gravel layer. Within 1 year, 67% of taxa recolonized, and number and type of species not significantly different from reference 1 year after dredging. However, abundance and biomass significantly lower than reference 1 and 2 years after dredging. Authors suggested bottom may have been more susceptible to tide and wave action disturbance after dredging. *Impact: Incomplete recovery within 2 years of dredging.*	Kenny and Rees 1996

APPENDIX B.4

Representative Reports of Impacts to Fish from Sediment Management Activities

Table B.4. Reported responses of fish to beach nourishment.

Project	Volume (cy) and Sediment Character	Survey Period	Intertidal	Subtidal	Reference
Beach Placement					
Imperial Beach Mar-Jun 1976 (Material dredged from San Diego Bay and pumped to beach)	1,000,620	15 months	Grunion - Spawned 1 month after nourishment. *Impact: No apparent influence*		Parr et al. 1978
San Diego Regional Beach Sand Project 2001 Borrow site sands and pumped to beach	2,100,000	During construction	Grunion impacts avoided and/or minimized by pre-construction surveys and monitoring during construction *Impact: Avoided or minimized*		AMEC 2002
Santa Barbara Harbor Maintenance Dredging with Single-point surf-zone Disposal 1993-1997	26,000 cy per year	March-April 1993-1997	Statistical analysis indicated Mach-April discharge did not significantly affect grunion egg pod diameter, or depth in sand. However, discharge occurred early in season when grunion spawning densities were low. *Impact – No apparent impact.*		USACE 1998a
Santa Barbara Harbor Maintenance dredging and beach discharge 2001	Unknown	April 25-26, 2001	Some grunion spawned in the vicinity of the discharge *Impact - No apparent impact*		Chambers Group 2001
Oceanside Sand Bypass, California 1989-1991	Unknown	1986 - 1992		Fish community characteristics did not differ near the discharge point compared to controls away from the influence of the discharge. *Impact - No apparent impact*	Chambers Group 1994

Table B.4. (Continued)

Project	Volume (cy) and Sediment Character	Survey Period	Intertidal	Subtidal	Reference
Lincoln Park Beach, Seattle, Washington 1988	18,000 Gravel and sand	After construction		Overall density of important salmonid prey was similar to a control beach *Impact - no apparent impact*	USACE, 2002b
Carlin Park, Southeast Florida March and April 1995	457,800 Beach compatible	1994-1996		About 12 to 14 acres of nearshore hard bottom were buried. After one year the number of individual fishes was reduced by 30 times and the number of species by 10 times. *Impact – Significant.*	Lindeman and Snyder 1999
Bald Head Island, Caswell Beach, Oak Island, Holden Beach, North Carolina March 2001- May 2002 March 2001-Mayr 2002	5,600,000	Before nourishment to Winter 2003	<u>Surfzone</u> No significant decrease in fish abundance and diversity during and up to 8 weeks after, and one year after sand placement. Enhancement and/or inconsistent seasonal differences observed at nourished beach compared to reference beach. Data suggested fishes may move in and out of beaches impacted by replenishment operations. *Impact - No apparent impact*		Versar 2004

Table B.4. (Continued)

Project	Volume (cy) and Sediment Character	Survey Period	Intertidal	Subtidal	Reference
South Boca Raton, Florida 2002	342,000	2004		An artificial reef was constructed to compensate for burial of low-relief habitat. A greater number of fish species were detected on higher relief (2-3 ft) artificial than reefs (1 ft relief).	Coastal Planning & Engineering 2004 a
Asbury Park to Manasquan Section Beach Erosion Control Project, New Jersey 1997- 1999 (Phase 1 1997 completed Oct (Phase 2 1999-2000 completed mid-Dec) (Dredged from offshore borrow areas, pumped to beach)	8,083,440 Sand	1994-2000	<u>Surfzone</u> A bottom feeding fish species, northern kingfish, apparently attracted to beach nourishment areas. However, kingfish did not exhibit dietary changes. Visually-feeding bluefish appeared to avoid beach nourishment area perhaps in response to the turbidity. Rough and Atlantic silversides, water column species, with greater prey biomass in stomachs than reference areas perhaps due to prey being more rapidly resuspended. No change observed in diet 2 years later. *Impact - short-term beneficial and adverse impacts*		Burlas et al. 2001

Table B.4. (Continued)

Project	Volume (cy) and Sediment Character	Survey Period	Inter-tidal	Subtidal	Reference
Borrow Sites					
Pompano Beach and Lauderdale-by-the-Sea, Florida 1970 Borrow site dredging between inshore and offshore reefs and beach fill	Volume not specified Sandy	Aug 1970 to Jul 1972 (11 months) Post project Visual and Collections		Densities appeared to be the same between area in vicinity of project and unaffected sites, including species of limited mobility such as blennies, gobies, and cardinalfishes. *Impact: No long term effect*	Courtenay et al. 1972
Hallandale, Florida Jul-Sep 1971 Borrow site between inshore and offshore reefs and beach fill	Not specified (268,000 cited in Marsh et al. 1981) Sandy	Aug 1971 to Aug 1972 During and after project Qualitative observations		Movement of fishes from the area during and after dredging, return to area reported (note: time frame not specified). *Impact: Short term displacement*	Courtenay et al. 1972
Embayment Dredging					
Long Beach Harbor, California Channel deepening borrow area for landfill construction, completed 1991, but additional dredging delayed biological study	Fine sediments Borrow Site: 92.8% fines, 7% sand, median grain size 9.17μm Reference: 89% fines, 10.6% sand, median grain size 12μm	Aug 1994; Feb, Jul 1995; Jan 1996 2 years, quarterly samples 3 borrow site stations, 1 reference station Lampara net (pelagic fish), otter trawl (demersal fish)		<u>Borrow Site</u> Significant seasonal and day/night differences in pelagic fish population similar at borrow site and reference area. Sometimes significantly higher number of species, abundance, and biomass at borrow site compared to reference area. Number of species, abundance, and biomass of demersal fish not significantly different among borrow site and reference area. Size structure of dominant fish (queenfish, white croaker, California tonguefish) similar to reference area. *Impact: No apparent impact.*	SAIC and MEC 1996

APPENDIX B.5

Representative Reports of Impacts to Birds from Sediment Management Activities

Table B.5. Reported responses of birds to sediment management activities.

Project	Volume (cy) and Sediment Character	Mean or Median Grain Size	% Fines	Survey Period	Shorebirds	Terns and Pelicans	Gulls	Reference
Beach Nourishment								
San Diego Regional Beach Project, CA Encinitas Beaches Jun & Aug 2001 (sand from offshore borrow sites pumped to beach)	455,000	0.12-0.87 (source materials)	0.05-9.7	2003-2004 3-4 years after project	Generally, abundance and number of species of shorebirds higher across tide condition at receiver than non receiver sites. Foraging shorebirds observed during post project surveys at sites that changed from cobble (without fauna) to sandy beach (with fauna) as result of nourishment. *Impact - Benefit*	Pre-project data collected outside tern nesting season prevented pre- and post project comparisons of beach use. Tern use of beaches during post project appeared to relate to proximity to nesting sites at lagoons rather than to sites that did or did not receive sand. *Impact- No apparent Influence*	Generally, gull abundance appeared to be related to human use and creek discharges. Gulls observed foraging and loafing at site that changed from cobble to sand after nourishment. *Impact- Benefit to no apparent Influence*	SAIC 2006
Bald Head Island, Caswell Beach, Oak Island, Holden Beach, North Carolina	5 million Over distance of 14 miles			2001-2002	Shorebird abundance and species richness greater during high tide at inlet transects, no difference at beach and cape sites. No significant difference in abundance or species richness. Increased resting behavior. *Impact – Benefit, but foraging efficiency not evaluated*	<u>Terns and Gulls</u> Variable abundance and species richness with no consistent pattern with respect to nourishment sites. No relationship between abundance and tide level. Increased resting behavior. *Impact – Benefit*		CZR 2003

Table B.5. (Continued).

Project	Volume (cy) and Sediment Character	Mean or Median Grain Size	% Fines	Survey Period	Bird	Reference
Surfside-Sunset Beach, CA 1997 Hydraulic pumping of sand	Material slurry pumped into 2,000 ft x50 ft swale to reduce turbidity			May-Jul	<u>Least Tern Behavior</u> Greater number of diving and foraging behaviors observed off beach nourishment location than at entrance of Anaheim Bay and monitoring locations 500 to 1.5 mi downcurrent. Difference ranged from 1.8 to 9 times higher. During non-dredge period (July) when fewer terns were present , foraging behavior also higher at site where nourishment occurred – 3 to 24 times higher. *Impact: No obvious adverse effect on foraging behavior.*	MEC 1997a
Oceanside Harbor Dredging					<u>Least Tern Behavior</u> Greater foraging observed offshore, with varying levels in harbor and nearby estuary. Reduced foraging observed in harbor during red tide. Low foraging behavior observed at proposed discharge site at entrance of San Luis Rey River. About 10% of foraging dives observed in Harbor, suggesting harbor maintenance activities would have minor effect on overall foraging activity. Restriction of dredging prior to April 15 would avoid any impacts.	KBC and Aspen 2002
Morro Bay Sand Spit, CA Surf zone discharge				May-Aug	<u>Snowy Plovers</u> No evidence of birds moving from area of pipeline to breed. No evidence that discharge or pipeline removal decreased breeding success or damaged any eggs. *Impact: No obvious impact; however, monitoring and mitigation measures important to result.*	Hutchinson et al. 1987

APPENDIX C

WATER QUALITY TECHNICAL SUPPORT INFORMATION

C.1 Representative Water Quality Monitoring Requirements for California Sediment Management Projects

C.2 Water Quality Monitoring Data for Representative California Sediment Management Projects

C.3 Literature Data on Effects of Suspended Sediment on Invertebrates and Fish

APPENDIX C.1

Representative Water Quality Monitoring Requirements for California Sediment Management Projects

Table C.1. Representative water quality monitoring requirements associated with beach nourishment and/or sand placement projects in California.

Example Projects	Permit and/or Document	Visual Observations	Dredge and/or Nearshore Discharge Monitoring	Beach Monitoring
Northern California				
Crescent City Maintenance Dredging (80% sand) 1998	RWQCB WDR 92-103	Receiving water limitations – See Beach Monitoring	Monitoring in Harbor – Weekly measurement of suspended solids (mg/L), settleable solids (mg/L), and turbidity (NTU). *Criteria: turbidity no more than 20% above background.* 1. Effluent Limitations – discharge of wastewater from settling pond shall not exceed 30 mg/L (30 day average) or 60 mg/L (maximum) of suspended solids, and 0.1 mg/L (30 day average), 1.0 mg/L maximum) for settleable solids. 2. Receiving Water Limitations – See Beach Monitoring.	Monitoring offshore Beach Disposal – Daily sample (a) within plume and (b) in waters unaffected by discharge. Turbidity (NTU). *Criteria: turbidity no more than 20% above background;* (2. Receiving Water Limitations – (1) ph no more than 0.2 units of background; (2) no nuisance levels of floatables, liquids, foams, and scum; (3) no taste or odor producing substances that cause nuisance or adversely affect beneficial uses; (4) no undesirable discoloration; (5) no bottom deposits that cause nuisance or adversely affect beneficial uses; (6) no biostimulatiion which promote objectionable aquatic growths; (7) no toxic substance release that produce detrimental physiological response in human, plant, animal, or aquatic life; (8) no measurable temperature change in receiving waters; (9) no bioaccumulation of toxic substances in bottom sediments or aquatic life which are harmful to humans; (10) no oils, greases, waxes or other materials that result in visible film or coating on water or objects that cause nuisance or adversely affect beneficial uses; (11) no violation of applicable water quality standards adopted by Regional or State Boards; (12) discharge must not cause concentrations of toxic pollutants in water column, sediment, or biota that adversely affect beneficial uses; (13) discharge must not cause acute or chronic toxicity of discharge waters.

Table C.1. (Continued).

Example Projects	Permit and/or Document	Visual Observations	Dredge and/or Nearshore Discharge Monitoring	Beach Monitoring
Central California				
Moss Landing Harbor Dredging (80% sand) 2002	RWQCB WDR 01-007	1. Discoloration, 2. odors, 3. debris/solids	1. Pre-discharge bulk sediment analysis, solid phase bioassay, suspended particulate phase bioassay. 2. Pre-discharge Decant Water Discharge. *Criteria: Turbidity instantaneous maximum 225 NTU, 30-day average 75 NTU, daily average 100 NTU. Analyte concentrations specified for metals, pesticides, PAHs, tributyltin.* 3. Pre-discharge and weekly during project, turbidity (NTU). Sampling Locations: A. mouth of federal channel, B. Elkhorn Slough, C. Elkhorn Slough 1 mile upstream of B, D. within Moss Landing Harbor. *Criteria*: None specified.	NA
Southern California				
Goleta Beach BEACON Demonstration Project 2003	RWQCB 401 Water Quality certification Jun 18, 2003	Weather, turbidity plume, Color photographs	NA	1. Daily visual turbidity to confirm enhanced turbidity not being caused by project through construction, and records of maximum extent of plume, apparent cause of plume, plume duration, and likely biological significance. *Criteria*: None specified.
South Central Coast Enhancement Program	RWQCB 401 Water Quality certification Jun 28, 2005	Weather, waves, wind, turbidity plume Color photographs	NA	Compliance with Implementation Guidelines and Compliance Protocol (IGCP) document (Moffatt & Nichol 2005a) prepared for project, including turbidity plume mapping from vantage point. *Criteria*: None specified.

NA = not applicable

Table C.1. (Continued).

Example Projects	Permit and/or Document	Visual Observations	Dredge and/or Nearshore Discharge Monitoring	Beach Monitoring
USACE RGP 67 200401896-KW (2006) (For Los Angeles, Orange, San Diego, Ventura, Santa Barbara, and San Luis Obispo counties).	Water Quality Certification for USACE 200401896 KW	Turbidity plume, weather, surf conditions, public recreation use pattern, and turbidity level.	NA	Daily monitoring of the turbidity plume (map of maximum plume, digital photographs), weather (temperature, wind speed, cloud cover, rain), surf conditions (wave height, swell), recreational beach use (number of people, distribution), and turbidity level (murky, slightly murky, average, clear). *Criteria:* If turbidity is significant, discharge activities will be modified or suspended. If turbidity is greater than ambient one-half mile from the discharge site (offshore or downcoast) on two consecutive days, the RWQCB, Corps, CDFG, CSMW, and NOAA will be notified. If excessive turbidity persists on the third day, daily water clarity testing (using transmissometer) will be conducted at mid-depth at a minimum of four locations (close to discharge site, and one-half mile upcoast, downcoast, and offshore). If turbidity one-half mile away (offshore or downcoast) is greater than ambient for five consecutive days, the discharge will be halted or modified to reduce turbidity.
Santa Barbara Harbor Maintenance Dredging	2004-2005 Monitoring data sheets by Aquatic Bioassay & Consulting	Daily: 1. current speed/direction 2. tidal stage, 3. debris, solids 4. discoloration, 5. odors, 6. weather	1. Daily turbidity (NTU), dissolved oxygen, pH at Stations: A. 100 ft (30 m), B. 200 ft (60 m), C. 500 ft (150 m) downdrift, E. 500 ft (150 m) outside and south of harbor.	1. Daily turbidity (NTU), dissolved oxygen, pH at Station: 200 ft (60 m) downdrift. 2. Weekly bacteria 100 ft (30 m) from discharge.

NA = not applicable

Table C.1. (Continued).

Example Projects	Permit and/or Document	Visual Observations	Dredge and/or Nearshore Discharge Monitoring	Beach Monitoring
Santa Barbara Harbor Maintenance Dredging	1998-1999 Monitoring data sheets by Aquatic Bioassay & Consulting	Weekly: 1. current speed/direction 2. tidal stage, 3. debris, solids 4. discoloration, 5. odors, 6. oil/petroleum materials	1. Weekly water transparency (Secchi disk), dissolved oxygen, pH.	1. Weekly water transparency (Secchi disk), dissolved oxygen, pH. 2. Weekly bacteria 100 ft (30 m) from discharge.
Ventura Harbor Maintenance Dredging	2004 Monitoring data sheets by Applied Environmental Technologies according to RWQCB WDR 76-59	Weekly: 1. current speed/direction 2. wind,weather 3. tidal stage, 4. debris, solids 5. odors, 6. oil/petroleum materials, 7. discoloration	1. Weekly total suspended solids (mg/L), light transmittance (%), dissolved oxygen, pH, temperature at 2-m intervals throughout water column, except for suspended solids at mid depth. Stations: A. 100 ft (30 m) updrift, B. 100 ft (30 m) downdrift, C. 300 ft (100 m) downdrift, D. outside affected area.	NA
Marina Del Rey Maintenance Dredging	1998 Monitoring Data by MEC Analytical Systems	Daily: 1. current direction, 2. tidal stage, 3. debris, solids, 4. oil/petroleum materials, 5. color	Daily: Water clarity (Secchi disk), turbidity (NTU), TSS (mg/L), dissolved oxygen (mg/L), pH. Stations: 100 ft (30 m) updrift, 100 ft (30 m) downdrift, 300 ft (100 m) downdrift, control 1 - 650-800 ft (200-250 m) away, control 2 - 1000-1300 ft (300-400 m) away, 100 ft (30 m) opposite Ballona Lagoon Tide Gate during flood tide.	NA

NA = not applicable

Table C.1. (Continued).

Example Projects	Permit and/or Document	Visual Observations	Dredge and/or Nearshore Discharge Monitoring	Beach Monitoring
Marina Del Rey Maintenance Dredging and Nearshore Discharge off Redondo Beach	WDR, as amended Nov. 1998 1999-2000 Monitoring Data Sheets by Hart Crowser	Daily for 7 days, then twice weekly 1. current speed/direction 2. tidal stage, 3. trash, foatables, 4. oil/petroleum materials, 5. odors, 6. weather, wind velocity 7. discoloration, 8. odors Color photographs	Dredge Site: Daily for 7 days, then twice weekly: Water clarity (Secchi disk) and turbidity (NTU) Stations: a. 100 ft (30 m) updrift, b.100 ft (30 m) downdrift, c. 300 ft (100 m) downdrift at 3 locations, d. control 1 - 650-800 ft (200-250 m) away, e. control 2 - 1000-1300 ft (300-400 m) away, f. control 3 - 1000-1300 ft (300-400 m) away and 50 m from control 2, g. 100 ft (30 m) from Ballona Lagoon tide gate. *Criteria:* If turbidity exceeds 20% of baseline readings, operations modified to reduce turbidity to ambient levels Nearshore Disposal Site: Daily for 7 days, then twice weekly: Secchi disk, turbidity (NTU), dissolved oxygen, pH. Stations: a. 100 ft (30 m) updrift; b. 100 ft (30 m) and c. 300 ft (100 m) downdrift; d. 650-800 ft (200-250 m) away, e. 1000-1300 ft (300-400 m) away. *Criteria:* Same as above. Dredge and discharge site, same stations as above, mid-depth: Daily for 7 days, then weekly: dissolved oxygen, pH, suspended solids (mg/L). *Criteria:* If dissolved oxygen < 5.0 mg/L, operations modified to restore to ambient.	NA

NA = not applicable

Table C.1. (Continued).

Example Projects	Permit and/or Document	Visual Observations	Dredge and/or Nearshore Discharge Monitoring	Beach Monitoring
Marina Del Rey Emergency Dredging and Discharge at Dockweiler Beach	1996 Monitoring data sheets by Ogden	Daily: 1. current speed/direction 2. wind speed, direction, 3. tidal stage, 4. debris, solids 5. odors, 6. weather, 7. discoloration	Weekly dissolved oxygen, pH, light transmittance (FTU), suspended solids (mg/L). Statons: A. 100 ft (30.5 m) updrift, B. 100 ft (30 m) downdrift, C. 300 ft (100 m) downdrift, D. 100 ft (30 m) opposite Ballona Lagoon Tide Gate during flood tide. .	NA
Los Angeles Harbor Maintenance Dredging	1998 Monitoring data sheets by MEC Analytical Systems	Daily: 1. current speed/direction 2. tidal stage, 3. debris, solids 4. odors, 5. water color, 6. oil or petroleum	1. Daily turbidity (NTU), water transparency (Secchi disk), dissolved oxygen, pH. Stations: 100 ft (30 m) updrift, 100 ft (30 m) downdrift, 300 ft (100 m) downdrift, 1,000 ft (300 m) away from dredge, 1300 ft (400 m) away from dredge.	NA
Los Angeles River Estuary Maintenance Dredging	1999 Monitoring data sheets by Aquatic Bioassay & Consulting	Daily: 1. current speed/direction 2. wind speed, direction, 3. tidal stage, 4. debris, solids 5. odors, 6. weather	1. Daily total suspended solids (mg/L), turbidity (NTU), dissolved oxygen, pH, water transparency (Secchi disk). Stations: A. 100 ft (30 m) downdrift, B. 100 ft (30 m) updrift, C. 300 ft (100 m) updrift, D. 1,000 ft (300 m) updrift, E. 1300 ft (400 m) updrift.	1. Daily total suspended solids (mg/L), turbidity (NTU), dissolved oxygen, pH, water transparency (Secchi disk). Stations: A1.100 ft (30 m) downdrift, B1. 100 ft (30 m) updrift, C1. 300 ft (100 m) downdrift, D1. 1,000 ft (300 m) away, E1.1300 ft (400 m) away.

NA = not applicable

Table C.1. (Continued).

Example Projects	Permit and/or Document	Visual Observations	Dredge and/or Nearshore Discharge Monitoring	Beach Monitoring
Los Angeles River Estuary Emergency Dredging	1995 Monitoring data sheets by Converse Consultants	Weekly: 1. current speed/direction 2. wind speed, direction, 3. tidal stage, 4. debris, solids 5. discoloration, plume, 6. odors, 7. oil or petroleum, 8. weather	1. Weekly total suspended solids (mg/L), turbidity (NTU), dissolved oxygen, pH, water transparency (Secchi disk). Stations: a. 98 ft (30 m) downdrift, b. 98 ft (30 m) updrift, c. 328 ft (100 m) updrift; d. 984 ft (300 m) updrift, e. 1,312 ft (400 m) updrift. *Criteria:* Water clarity within 20% of average ambient.	1. Weekly total suspended solids (mg/L), turbidity (NTU), dissolved oxygen, pH, water transparency (Secchi disk). Stations: a. 98 ft (30 m) downdrift, b. 98 ft (30 m) updrift, c. 328 ft (100 m) downdrift; d. 984 ft (300 m) from disposal site, e. 1,312 ft (400 m) from disposal site. *Criteria:* Water clarity within 20% of average ambient.
Bolsa Chica Lowlands Restoration Project	RWQCB 401 Water Quality Certification Apr 23, 2002		NA	Routine monitoring and reporting plan to be developed and implemented during construction of ocean inlet to ensure bacteria levels do not exceed pre-project findings.
Dana Point Harbor Maintenance Dredging May 2000	RWQCB WDR 96-32, with conditions specified in Aug 25, 1997 letter (File No. P 260 996 986), CDP 5-97-232.	Daily: 1. current speed/direction 2. tidal stage, 3. trash, debris, 4. oil or other petroleum materials, 5. discoloration, 6. extent of plume, 7. odors	1. Daily turbidity (NTU). Stations: A. 500 ft (150 m) updrift, B. inside plume, C within 250 ft (75 m) downdrift. *Criteria:* Turbidity at Station C no more than 20% over Turbidity at Station A. 2. Chemical – Monthly Lab analysis. Same sampling locations as turbidity. Analyzed for: TSS (mg/L), hydrogen sulfide (mg/L), polar & non polar oil & grease. *Criteria: none specified.* 3. Barge supernatant - Sample collected from loaded barge 3 times/week. Analyzed for polar & non polar oil & grease. *Criteria: none specified.*	1. Daily turbidity (NTU). Stations: D 3,000 ft (914 m) updrift & 500 ft (150 m) offshore, E. 1500 ft (450 m) downdrift & 500 ft (150 m) offshore, F. disposal site & 500 ft (150 m) offshore. *Criteria:* Turbidity at Station E no more than 20% over Turbidity at Station D. 2. Bacteria – Weekly. Sampling Location: 100 ft (30 m) downdrift. Analyzed for total and fecal coliform bacteria. *Criteria:* If any sample exceeds water contact standards, notify and additional daily sampling at 100, 200, 500, 1000 ft (30, 60, 150, 300 m) downdrift until standards met for 3 consecutive days.

NA = not applicable

Table C.1. (Continued).

Example Projects	Permit and/or Document	Visual Observations	Dredge and/or Nearshore Discharge Monitoring	Beach Monitoring
City of San Clemente Opportunistic Sand Program	RWQCB 401 Water Quality Certification File No. 02C-059 June 2004	Turbidity plume	NA	Turbidity plume - Three days prior, during, and following sand placement -
Oceanside Harbor Dredging 1999	Monitoring data report by Ogden Environmental	NA	1. Daily Secchi disk for first week of operations. Stations:75 m (250 ft) up and downdrift, 150 m (500 ft) up and downdrift, control 1 at basin, control 2 at mouth. 2. Water samples per dredge cycle, turbidity (NTU), pH, temperature, dissolved oxygen.	Water samples per dredge cycle, turbidity (NTU, Secchi disk), pH, temperature, dissolved oxygen, bacteria. Stations: 75 m (250 ft) up and downdrift, 150 m (500 ft) up and downdrift, control 1 downcoast, control 2 downcoast and within plume, control 3 pier.
Oceanside Harbor Dredging 1998	RWQCB WDR W98B0016 (Jan 1998 Modification)	Daily for: 1. current speed, direction 2. tidal stage, 3. trash, debris, 4. oil/petroleum materials, 5. discoloration/ extent of plume, 6. odors	1. Daily Turbidity - Secchi disk or turbidity meter. Stations at dredge and nearshore disposal site: a. 30 m (100 ft) downdrift, b. 75 m (250 ft) downdrift, c. 150 m (500 ft) updrift, d. control 300-450 m (1000-1500 ft) updrift, e. control 300-450 m (1000-1500 ft) updrift and at least 150 m (500 ft) from first control. *Criteria: none specified.* 2. Water Samples each dredge cycle. Sampling locations a-c, f-h. Analyzed for TSS, hydrogen sulfide, polar & non polar oil & grease. *Criteria: none specified.*	1. Daily Turbidity - Secchi disk or turbidity meter. Stations: k. 3,000 ft (914 m) updrift & 500 ft (150 m), l. 1500 ft (450 m) downdrift & 500 ft (150 m) offshore, m. directly offshore in plume. *Criteria: none specified.* 2. Bacteria weekly. Three replicate samples. Sampling location: 100 ft (30 m) downdrift. Total and fecal coliform. *Criteria*: If any sample exceeds water contact standards, notify and additional daily sampling at 30, 60, 150, 300 m (100, 200, 500, 1000 ft) downdrift daily until no exceedance for 3 consecutive days.

NA = not applicable

Table C.1. (Continued).

Example Projects	Permit and/or Document	Visual Observations	Dredge and/or Nearshore Discharge Monitoring	Beach Monitoring
Oceanside Harbor Sand Bypass 1997	Construction Specifications	Daily first week. 1. current speed and direction, 2. tide stage, 3. debris/solids, 4. oil or petroleum, 5. odors, 6. discoloration	1. Turbidity, daily for first 7 days then weekly– Secchi disk. Stations:a. 250 ft updrift, b. 500 ft updrift, c. 250 ft downdrift, d. 500 ft downdrift, e. control at least 1000 ft distant and outside visible plume, f. control at least 1000 ft distant and outside visible plume. *Criteria: none specified.* 2. Weekly Water Samples Turbidity – NTU at stations a-d. *Criteria: none specified.*	NA
Oceanside Harbor Dredging 1994	WDR 94-124	Same as above	1. Turbidity - Daily for 7 days, then review with RWQCB to determine if monitoring can be reduced to weekly. Secchi disk. Stations: 250 and 500 ft updrift, every 100 ft downdrift until ambient reached. *Criteria:* Turbidity 250 ft from dredge perimeter no more than 20% over average ambient. 2. Grab sample every two weeks – Turbidity (NTU). Stations: 250 and 500 ft updrift, inside plume, and 250 and 500 ft downdrift. *Criteria:* Turbidity 250 ft from dredge perimeter no more than 20% over average ambient. 3. Barge supernatant - Weekly, total petroleum hydrocarbons. *Criteria:* none specified.	Bacteria - Beginning of each cycle. 3 replicate water samples analyzed for total and fecal coliform bacteria. . *Criteria:* If any sample exceeds 200/100 ml, notify and additional daily sampling at 300, 600, 1500, and 3000 ft downdrift until standards met for 3 consecutive days.

NA = not applicable

Table C.1. (Continued).

Example Projects	Permit and/or Document	Visual Observations	Dredge and/or Nearshore Discharge Monitoring	Beach Monitoring
Agua Hedionda lagoon Dredging 1995-1999 Oceanside Harbor Dredging 1995-1996 Maintenance dredge/fill projects with 80% sand	RWQCB General WDR 96-32, Maintenance Dredge/Fill Projects – San Diego Region	Daily: 1. current speed/direction 2. tidal stage, 3. trash, debris, 4. oil/petroleum materials, 5. discoloration/ extent of plume, 6. odors	1. Daily Turbidity - Secchi disk or turbidity meter. Stations: A. 500 ft updrift, B. Within plume, C. Within 250 ft downdrift. *Criteria:* Turbidity at Station C no more than 20% over Station A. 2. Chemical – Monthly Lab analysis. Two grab samples at mid-depth within visible plume at dredge site and at nearshore disposal site and one sample at same stations analyzed for turbidity. TSS (mg/L), hydrogen sulfide (mg/L), polar & non polar oil & grease. *Criteria*: none specified. 3. Barge supernatant – When dredged materials are deposited directly on beach. Sample collected from loaded barge 3 times/week. Analyzed for polar & non polar oil & grease. *Criteria:* none specified	1. Weekly Turbidity - Secchi disk or turbidity meter. Stations: D. 3,000 ft (914 m) updrift & 500 ft (150 m), E. 1500 ft (450 m) downdrift & 500 ft (150 m) offshore, F. Discharge site inside any visible plume, if possible. *Criteria:* Turbidity at Station E no more than 20% over Station D. 2. Bacteria – Weekly. Sampling Location: 100 ft (30 m) downdrift. Total and fecal coliform bacteria. *Criteria:* If any sample exceeds water contact standards, notify and additional daily sampling at 100, 200, 500, 1000 ft downdrift until standards met for 3 consecutive days.
Batiquitos Lagoon Restoration 1995-1996	WDR 93-50	NA	NA	Discharger shall not cause violations of the following water quality objectives: a) color, b) tastes and odors, c) floating material, d) suspended material, e) settleable solids, f) oil and grease, g) biostimulatory substances, h) sediment, i) turbidity, j) changes in normal pH shall not exceed 0.2 units.

NA = not applicable

Table C.1. (Continued).

Example Projects	Permit and/or Document	Visual Observations	Dredge and/or Nearshore Discharge Monitoring	Beach Monitoring
San Diego Regional Beach Sand Project 2001	RWQCB 401 Water Quality Certification File No. 00C-063, USACE 1999-15076-RLK, USFWS Biological Opinion FWS Log. No. 1-6-01-F-1046.	Visual observations during water quality monitoring: 1. current speed/direction 2. tidal stage, 3. trash, debris, 4. odors	1. Daily Water Quality for first week, followed by weekly. Stations: A. 250 ft (75 m) downdrift, B. 500 ft (150 m) downdrift, C. 250 ft (75 m) updrift, D. 500 ft (150 m) updrift, E. Control 1000-1500 ft (300-450 m) from dredge, F. 1000-1500 ft (300-450 m) from dredge and at least 500 ft (150 m) from first control. Analyzed for dissolved oxygen, turbidity (NTU) and Secchi disk, temperature, conductivity, pH. *Criteria:* turbidity not to exceed ambient by more than 20%. 2. Water clarity (Secchi disk *USFWS/USACE Criteria:* reduction in water clarity no more than 2.47 acres (1 hectare).	1. Daily nearshore water clarity (Secchi disk) immediately west of active wave break on beach. *USFWS/USACE Criteria:* reduction in water clarity no more than 2.47 acres (1 hectare). 2. Weekly Bacteria. Three replicate samples collected offshore discharge point. Analyzed for total and fecal coliform. *Criteria:* If any sample exceeds 200/100 ml, notify and additional sampling until standards met for 3 consecutive days.
San Diego Bay Channel Deepening 2004-2005	401 Water Quality Certification File No. 03C-139	Daily: 1. current speed/direction 2. tidal stage, 3. debris, solids, 4. oil/petroleum materials, 5. discoloration, 6. odors	1. Dredge site: Turbidity (turbidity meter or Secchi disk). Stations: A. 500 ft (150 m) upcurrent, B. within plume, C. 0 to 250 ft (75 m) downcurrent and outside plume. *Criteria:* If turbidity at Station C increases more than 20% over Station A, operations suspended, remedial measures implemented, and notification of RWQCB. 2. Monthly total suspended solids, hydrogen sulfide, polar and non polar oil and grease, mid-depth, two samples in plume at dredge and nearshore disposal sites, and one sample at same sites monitored for turbidity.	NA

NA = not applicable

Table C.1. (Continued).

Example Projects	Permit and/or Document	Visual Observations	Dredge and/or Nearshore Discharge Monitoring	Beach Monitoring
SCOUP	Moffatt & Nichol 2006a	Turbidity plume, weather and surf conditions.	NA	Daily monitoring of the turbidity plume (map of maximum plume, photographs) and environmental conditions (e.g., waves, wind, weather). *Criteria*: halt or modify operation if turbidity is excessive (greater than ambient beyond one-half mile offshore or downcoast of the placement site) for a prolonged period, assumed to be 5 days.

NA = not applicable

APPENDIX C.2

Water Quality Monitoring Data for Representative California Sediment Management Projects

Table C.2. Suspended sediment, turbidity, light transmittance, and/or water clarity values measured during representative sediment management projects in California.

Project	% Fines	Method	Surveys	Distance upcoast (u) or downcoast (d) from turbidity plume					
				0-100 ft (0-30 m)	100-300 ft (30-100 m)	500 ft -1000 (150 -300 m)	1000-2000 (300-450 m)	2000-3000 (450-900m)	>3000 (>1000 m)
Beach Placement									
Santa Barbara Harbor Maintenance, Discharge East Beach (Mar, Nov 2004, Mar 2005)		NTU	13		0.7-5.6 d Mean = 2				
(Nov 1998-Mar 1999, Nov 1999)		Secchi (feet)	8	1-5.6 mean = 4 18-45% reduction	1.6-14.7 u mean = 8		2.9-18 d mean = 9		
Dana Point Harbor Maintenance, Discharge Capistrano Beach (May 2000)	4	Secchi (feet)	2	3.5-4 mean = 4			3.3-3.5 d mean = 3	3.5-4.3 u mean = 4	
		TSS mg/L	1	24-66 mean = 45					
Dana Point Harbor Maintenance, Discharge to Baby Beach (2000)	4	Secchi (feet)	1	1.2 76% reduction			2	5	
		TSS mg/L	1	389-515 mean = 452					
Agua Hedionda Lagoon Maintenance, Discharge Carlsbad beaches (Mar 1999)	2.5	NTU	2	30-31 mean = 30			7-8 d mean = 7	8 u mean = 8	
(Oct-Dec 1998)	10.5	NTU	13	21-225 mean = 78			3-89 d mean = 20	3-80 u mean = 16	
(Sep-Dec 1997)	2.6-9.1	NTU	10	1-15 mean = 7			2-5 d, mean = 3	2-10 u mean = 4	

Table C.2. (Continued)

Project	% Fines	Method	Surveys	Distance upcoast (u) or downcoast (d) from turbidity plume					
				0-100 ft (0-30 m)	100-300 ft (30-100 m)	500 ft -1000 (150 -300 m)	1000-2000 (300-450 m)	2000-3000 (450-900m)	>3000 (>1000 m)
Agua Hedionda Lagoon Maintenance (1996)		NTU	8	6-115 mean = 36			7-187 d mean = 39	23-110 u mean = 60	
Oceanside Harbor Maintenance, Discharge Oceanside Beach (Mar 1999)		NTU	1		2 u surface 2.2 mid 5.1 bottom, 2.2 d surface 2.6 mid 3.9 bottom	2 u surface 2.3 mid 8 bottom, 2 d surface 2 mid 4 bottom	1.9 d surface 1.8 mid 50.2 bottom	1.4 d surface 2.5 mid 5.2 bottom	
		Secchi (feet)	1		8.2 u 7.2 d	7.5 u 8.2 d	9.2 d	9.2 d	11-18% reduction *
Batiquitos Lagoon Restoration, Discharge Batiquitos Beach (1994)	5-10	NTU	2	2.1-39.5 mean = 21			7.5 u	10.7 u 0.5 d	
Opportunistic Sand Placement, Ponto Beach (Apr 1997)	18	TSS mg/L	2	590-1,606 mean = 1,045			414-1,500 mean = 957	201-561 mean = 381	93-295 mean = 138
Nearshore Placement									
Marina Del Rey Maintenance, Discharge Redondo Beach (Feb 2000)	2	NTU	6		2.7-4.3 u mean = 3 2.6-4.5 d mean = 3	2.6-4.3 d mean = 3	2.6-4.3 d mean = 3	2.9-4.3 d mean = 3	
		Secchi (feet)	6		3.9-19.2 u mean = 8, 3.5-19.3 d mean = 8	4.1-19.2 d mean = 8	3.5-19.4 d mean = 8	3.5-19.5 d mean = 8	

*Note: The percent reduction ranges when reported in the last column are based comparison of each sampling distance to the one farthest away

Table C.2. (Continued)

Project	% Fines	Method	Surveys	Distance upcoast (u) or downcoast (d) from turbidity plume					
				0-100 ft (0-30 m)	100-300 ft (30-100 m)	300-500 ft (100-150 m)	500-1000 (150-300 m)	1000-2000 (300-450m)	>2000 (>450 m)
Marina Del Rey Maintenance , Nearshore Discharge (off Dockweiler Beach) (Mar 1998)	2-10%	TSS mg/L	8		1.3-30.2 u mean = 7.2 0.7-38 d mean = 8.8	0.8-31.9 d mean = 8.5			
		NTU	21		0.7-7 u mean = 3 1.4-8 d mean = 3	1.4-7.1 d mean = 3.3			
		Secchi (feet)	21		3-21.3 u mean = 9.5 3-19.7 d mean = 9.2	1.5-16.4 d mean = 8.2			No control
Los Angeles River Estuary Maintenance, Discharge in borrow site off Long Beach (Feb-Mar 1995)	29-81	TSS mg/L	3		79-94 u mean = 87 68-98 d mean = 83	83-88 u mean = 86 71-110 d mean = 97	55-93 d mean = 80		
Oceanside Harbor Maintenance (Jan-Feb 1998)		TSS mg/L	1	43 mid depth	< 20 d	61 u (10-12 ft waves)			
		Secchi (feet)	18	2-4 d mean = 2.9	2-4 d mean = 3	2-4 u mean = 3		1. 2.5-4 u mean = 2.9 2. 2.5-4 u mean = 3.1	

Table C.2. (Continued)

Project	% Fines	Method	Surveys	Distance upcoast (u) or downcoast (d) from turbidity plume					
				0-100 ft (0-30 m)	100-300 ft (30-100 m)	300-500 ft (100-150 m)	500-1000 (150-300 m)	1000-2000 (300-450m)	>2000 (>450 m)
Oceanside Harbor Maintenance (Nov-Dec 1997)		NTU	1		2.2 u 2.7 d	3.2 u 2.3 d			
		Secchi (feet)	7		8.8-16.4 u mean = 11.5 8.5-16.1 d mean = 10.8	9.5-16.7 u mean = 11.8 9.2-14.7 d mean = 10.8		10.5-17.4 u mean = 12.1 10.5-16.4 d mean = 12.1	5-11% reduction *
(Dec 1995-Jan 1996)		NTU	3		1.2-2.2u mean = 1.6 1-1.8 d mean = 1.4	1.1-2.4 u mean = 1.7 0.9-2 d mean = 1.6			
		Secchi (feet)	9		4.5-10.1 u mean = 6.1 2.6-9.8 d mean = 5.6	4-10.2 u mean = 6.3 4.4-10.7 d mean = 5.8		5.8-6 mean = 5.9	No reduction
(Dec 1994)		Secchi (feet)	7		12’2”-15’1” u mean = 13’5” 10’1”-15’3” d mean = 13’7”	11’9”-15’1” u mean = 13’8” 10’7”-15’ d mean = 13’7”		1. 11’7”-16’7” u mean = 13’7” 2. 11’9”-17’1” u mean = 15’2”	No reduction
San Diego Channel Deepening, Discharge off Imperial Beach (2004-2005)		TSS mg/L	4					2.4-53 d mean = 20.2	6.2-155 u mean = 47.6
		Light transmittance (%)	56					7-93 d mean = 60	28-95 u mean = 73

*Note: The percent reduction ranges when reported in the last column are based comparison of each sampling distance to the one farthest away

Table C.2. (Continued)

Project	% Fines	Method	Surveys	Distance upcoast (u) or downcoast (d) from turbidity plume					
				0-100 ft (0-30 m)	100-300 ft (30-100 m)	300-500 ft (100-150 m)	500-1000 (150-300 m)	1000-2000 (300-450m)	>2000 (>450 m)
Harbor Dredging									
San Francisco Bay		TSS mg/L	?	approx. 75 near surface, 50 mid , 280 bottom	approx. 40 near surface, 52 mid, 100 bottom			approx. 30 near surface, 20 mid, 45 bottom	
Santa Cruz Harbor Maintenance (Mar 2001)	20.2	NTU	1	1.3-11 mean = 4.6				1.7 d	
Santa Barbara Harbor Maintenance (Nov 2004, Mar 2005)		NTU	13	0.8-3.7 d mean = 2	0.9-5.2 d mean = 2	1.1-3.4 d mean = 2			
(Nov 1998, Nov 1999)		Secchi (feet)	8	3.9-10.1 mean = 7	4.9-9.8 d mean = 8	7.2-11.1 d mean = 9			22% reduction *, but No control
Ventura Harbor Maintenance (Feb 2004)	< 20%	TSS mg/L	5	29-31 (before) 38-46 (after)	39-58 u mean = 52 45-65d mean = 55	42-60 d (300 ft) mean = 49		41-129 u mean = 64	28-41 reduction *
		% light transmittance	6	83-88 (before) 82-90 (after)	18-77 u surface mean = 45, 22-66 u bottom mean = 49; 37-65 d surface mean = 51 17-65 d bottom mean = 39	30-65 u surface mean = 47, 27-95 u bottom mean = 54		7-83 d surface mean = 43, 10-83 d bottom mean = 41	

*Note: The percent reduction ranges when reported in the last column are based comparison of each sampling distance to the one farthest away

Table C.2. (Continued)

Project	% Fines	Method	Surveys	Distance upcoast (u) or downcoast (d) from turbidity plume					
				0-100 ft (0-30 m)	100-300 ft (30-100 m)	300-500 ft (100-150 m)	500-1000 (150-300 m)	1000-2000 (300-450m)	>2000 (>450 m)
Marina Del Rey Harbor Maintenance (Oct 1999-Mar 2000)	2-16%	TSS mg/L	21		2-135 u mean = 17 1-93 d mean = 12	1-230 d mean = 22	1-348 mean = 25	1-217 mean = 17.5	
		NTU	35		3.6-10 u mean = 5 3.1-13.9 d mean = 7	3.5-13.1 d mean = 6	3.3-14.2 mean = 6	3.2-16.6 mean = 6	
		Secchi (feet)	40		2.5-14.3 u mean = 6 2.3-11.3 d mean = 5	2.9-17.4 d mean = 6	2.9-14.9 mean = 6.7	2.9-11.6 mean = 7	14-29% reduction *
(Mar-Apr 1998)		TSS mg/L	9		4.2-37.9 u mean = 13.5 1.1-24.8 d mean = 12.6	2.9-41.1 d mean = 13.5			
		NTU	24		2.9-12.3 u mean = 4.9 2-13.7 d mean = 4.6	2.2-16.3 d mean = 7.1			
		Secchi (feet)	24		3-6.5 u mean = 6.2 3-8.2 d mean = 5.2	3-9.8 d mean = 4.9			No control
(Mar-Apr 1996)		TSS mg/L	3		10-11 surface mean = 10 d 10-38 bottom mean = 24 d	8-14 surface mean = 11 d 11-27 bottom mean = 19 d			

*Note: The percent reduction ranges when reported in the last column are based comparison of each sampling distance to the one farthest away

Table C.2. (Continued)

Project	% Fines	Method	Surveys	Distance upcoast (u) or downcoast (d) from turbidity plume					
				0-100 ft (0-30 m)	100-300 ft (30-100 m)	300-500 ft (100-150 m)	500-1000 (150-300 m)	1000-2000 (300-450m)	>2000 (>450 m)
Los Angeles Harbor Maintenance (Mar 1998)		NTU	7		1.3-4 u mean = 3 5.5-98.4 d mean = 37	6.5-48.1 d mean = 19	1.3-4.1 u mean = 3	1.3-3.6 u mean = 3	
		Secchi (feet)	7		4.9-13.1 u mean = 7 0.8-5.2 d mean = 4	0.8-5.2 d mean = 3	6.5-11.5 u mean = 6	6.5-11.5 u mean = 9	22-56% reduction *
Los Angeles River Estuary Maintenance (Feb-Mar 1999)		TSS mg/L	10		11-25 u mean = 18 8-85 d Mean = 21	10-160 u mean = 34		10-32 mean = 15	
		NTU	10		2.9-9.8 d mean = 5 2.7-7.1 u mean = 5	2.8-8 u mean = 5		2.9-8.1 u mean = 4	
(Feb-Mar 1995)		TSS mg/L	3		28-110 u mean = 74 39-95 d mean = 67	58-97 u mean = 79 80-85 d mean = 83		46-130 u mean = 89	
		NTU	3		5-24 u mean = 12 3.8-25 d mean = 12	6.6-15 u mean = 11 2.8-25 d mean = 11		8.2-25 u mean = 19	
		Secchi (feet)	3		0.3-2.3 u mean = 2 0.3-3.3 d mean = 2	0.6-2.6 u mean = 2 1-3.6 d mean = 3		0.6-3.9 u mean = 2	No reduction *

*Note: The percent reduction ranges when reported in the last column are based comparison of each sampling distance to the one farthest away

Table C.2. (Continued)

Project	% Fines	Method	Surveys	Distance upcoast (u) or downcoast (d) from turbidity plume					
				0-100 ft (0-30 m)	100-300 ft (30-100 m)	300-500 ft (100-150 m)	500-1000 (150-300 m)	1000-2000 (300-450m)	>2000 (>450 m)
Dana Point Harbor Maintenance (May 2000)	4	TSS mg/L	2	26-66 mean = 47	18-162 d mean = 90	22-59 u mean = 41			
		Secchi (feet)	6	1.2-3.5 mean = 2	2.5-5.5 d mean = 4	3-7.5 u mean = 5			No control, 60% reduction *
Oceanside Harbor Maintenance (Mar 1999)		NTU	1		4.8 u surface 6.9 u mid 8.3 u bottom, 5.4 d surface 7.8 d mid 7.1 d bottom	2.4 u surface 3.2 u mid 7.9 u bottom, 4.6 d surface 5.7 d mid 11.3 d bottom		1. 2.4 surface 2.6 mid 6.7 bottom, 2. 1.7 surface 1.8 mid 2.0 bottom	
		Secchi (feet)	6		4.9-7.5 u mean = 6.7 3.3-7.5 d mean = 6	5.2-7.5 u mean = 6.9 4.9-7 d mean = 6.4		1. 5.2-8 mean = 7.3 2. 6-10 mean = 8.4	8-28% reduction *
(Jan 1998)	< 10	TSS mg/L	1	118 mid depth	< 20 d	26 u			
		Secchi (feet)	19		2-3.5 d mean = 3	2.5-3.5 u mean = 3		1. 2.5-4 u mean = 3 2. 2.5-3.5 u mean = 3	No reduction

*Note: The percent reduction ranges when reported in the last column are based comparison of each sampling distance to the one farthest away

Table C.2. (Continued)

Project	% Fines	Method	Surveys	Distance upcoast (u) or downcoast (d) from turbidity plume					
				0-100 ft (0-30 m)	100-300 ft (30-100 m)	300-500 ft (100-150 m)	500-1000 (150-300 m)	1000-2000 (300-450m)	>2000 (>450 m)
Oceanside Harbor Maintenance (Nov 1997)		NTU	4		1.7-6.6 u mean = 4.2, 1.8-3.1 d mean = 2.5	2-4.9 u mean = 3.6, 1.8-3.3 d mean = 2.7			
		Secchi (feet)	8		7.5-9.8 u mean = 9.2 3.9-10.5 d mean = 6.9	6.6-10.5 u mean = 9.2 6.6-12.1 d mean = 8.5		7.8-11.5 u mean = 9.8 7.2-11.2 d mean = 9.5	6% reduction *
Oceanside Harbor Maintenance (Dec 1995-Jan 1996)		NTU	3		1.9-2.6 u mean = 2.3 1-44.9 d mean = 16.1	1.2-3.9 u mean = 2.2 0.8-5.5 mean = 2.8			
		Secchi (feet)	9		1.5-3.8 u mean = 2.2 0.6-3.7 d mean = 2.2	1.7-5.7 u mean = 3 1.9-4.5 d mean = 2.9		1. 2.1-8.1 u mean = 5.2 1. 2.6-7.8 u mean = 5.5	58-60% reduction *
(Dec 1994)		Secchi (feet)	7		5’8”-11’ u mean = 8’2” 6’1”-11’3” d mean = 8’7”	5’8”-11’6” u mean = 8’3” 5’7”-10’5” d mean = 8’7”		1. 10’5”-16’7”u mean = 14’2” 2. 11’1”-16’5” u mean = 13’9”	37-42 5% reduction *

*Note: The percent reduction ranges when reported in the last column are based comparison of each sampling distance to the one farthest away

Table C.2. (Continued)

Project	% Fines	Method	Surveys	Distance upcoast (u) or downcoast (d) from turbidity plume					
				0-100 ft (0-30 m)	100-300 ft (30-100 m)	300-500 ft (100-150 m)	500-1000 (150-300 m)	1000-2000 (300-450m)	>2000 (>450 m)
San Diego Bay Channel Deepening (2004-2005)		TSS mg/L	4	4.1-48 mean = 18		5-12 u mean = 7.6			
		light transmittance (%)	73	26-91 surface mean = 70, 22-94 bottom mean = 71	66-93 u surface mean = 82, 35-94 u bottom mean = 81; 64-92 d surface mean = 78, 27-95 d bottom mean = 75	67-93 u surface mean = 82, 36-97 u bottom mean = 81; 3-92 d surface mean = 79 26-95 d bottom mean = 76			
Offshore Borrow Site Dredging									
San Diego Regional Beach Sand Project (2001) S0-9 Borrow Site	1-51	NTU	4		1.1-3.6 u surface mean = 1.8, 2.7-5.8 u bottom mean = 3.6; 1.4-10.4 d surface mean = 7.4, 12.8-28.1 d bottom mean = 19.5	1.2-1.5 u surface mean = 1.3, 2.6-5.5 u bottom mean = 3.8; 1.3-10.3 d surface mean = 6.9, 1.9-23 d bottom mean = 14.4		1.2-2 surface mean = 1.6, 3-4.5 bottom mean = 3.8	1.3-2.3 surface mean = 1.6,, 3.2-4.5 bottom mean = 3.8
		Secchi (feet)	4		8.8->32 u mean = 21.6, 3.6-22.9 d mean = 8.9	8.8->32 u mean = 17.7, 3.6-28.5 d mean = 10.1		7.5->32 mean = 17.3	6.5-> 32 mean = 15.1 0-49% reduction*

*Note: The percent reduction ranges when reported in the last column are based comparison of each sampling distance to the one farthest away

Table C.2. (Continued)

Project	% Fines	Method	Surveys	Distance upcoast (u) or downcoast (d) from turbidity plume					
				0-100 ft (0-30 m)	100-300 ft (30-100 m)	300-500 ft (100-150 m)	500-1000 (150-300 m)	1000-1500 (300-450m)	1500-2000 (450-600 m
S0-7 Borrow Site	0.05-9.7	NTU	15		0.7-2.3 u surface mean = 1.1, 1.6-18.7 u bottom mean = 4.7; 1.4-29.2 d surface mean = 6.8, 1.2-120.3 d bottom mean = 18.1	0.7-1.5 u surface mean = 1.1, 1.3-10.2 u bottom mean = 4.6; 1.4-16.1 d surface mean = 6.1, 1.5-95.3 d bottom mean = 18.6		0.8-1.0 surface mean = 1.2, 1.2-11.9 bottom mean = 4.3	0.7-2.2 surface mean = 1.2, 1.1-68.5 bottom mean = 8
		Secchi (feet)	15		15->32 u mean = 26.5, 1.6-16.4 d mean = 5.9	8.5->32 u mean = 26.5, 2.6-11.4 d mean = 5.2		9.2->32 mean = 26.9	11.8->32 surface = 27.2 0-81% reduction*
S0-6 Borrow Site	1-3	NTU	4		1.1-5.2 u surface mean = 2.6, 1.4-12.7 u bottom mean = 4.6; 4.4-15.3 d surface mean = 8.8, 4.4-12.2 d bottom mean = 8.7	1.2-2.6 u surface mean = 1.6, 1.4-3.7 u bottom mean = 1.9; 1.6-19.5 d surface mean = 7.6, 1.8-12.5 d bottom mean = 9.2		1.2-2.6 surface mean = 1.6, 1.7-6.4 bottom mean = 3.7	1.2-2.4 surface mean = 1.8, 1.5-8.4 bottom mean = 4.3-
		Secchi (feet)	4		6.2-20.6 u mean = 13.1, 1.6-9.5 d mean = 4.6	7.9-23.6 u mean = 15.1, 2.6-5.6 d mean = 3.9		7.5-21.4 mean = 14.1	7.5-14.1 mean = 11.1 0-59% reduction*

*Note: The percent reduction ranges when reported in the last column are based comparison of each sampling distance to the one farthest away

Table C.2. (Continued)

Project	% Fines	Method	Surveys	Distance upcoast (u) or downcoast (d) from turbidity plume					
				0-100 ft (0-30 m)	100-300 ft (30-100 m)	300-500 ft (100-150 m)	500-1000 (150-300 m)	1000-1500 (300-450m)	1500-2000 (450-600 m)
S0-5 Borrow Site	1.3-13.8	NTU	13		0.9-5.8 u surface mean = 2.1, 1.6-20.3 u bottom mean = 4.6; 1.4-10.8 d surface mean = 3.8, 2.1-43.1 d bottom mean = 14.4	0.9-3.7 u surface mean = 1.6, 1.1-10.1 u bottom mean = 4.4; 1.1-6.2 d surface mean = 3.3, 1.8-18.8 d bottom mean = 9.4		0.8-2.4 surface mean = 1.5, 0.9-12.7 bottom mean = 3.3	0.9-4.6 surface mean = 1.7, 0.9-6.8 bottom mean = 1.8
		Secchi (feet)	13		2.3-32 u mean = 17.7, 2.9-21.3 d mean = 9.8	4.3-32 u mean = 19, 4.6-20 d mean = 8.8		4.3-32 mean = 18	2.9-23.9 mean = 16.7 0-47% reduction*
MB-1 Borrow Site	<1	NTU	5		0.7-0.9 u surface mean = 0.8, 0.8-1.2 u bottom mean = 0.9; 0.8-2.9 d surface mean = 1.4, 1.0-3.6 d bottom mean = 2.8	0.7-1.0 u surface mean = 0.9, 0.9-2.1 d bottom mean = 1.2; 0.9-3.3 d surface mean = 1.6, 0.6-10.2 bottom mean = 4.7		0.6-0.9 surface mean = 0.8, 0.8-1.3 bottom mean = 1	0.6-0.9 surface mean = 0.8, 0.9-1 bottom mean = 0.9
		Secchi (feet)	6		24.9-32 u mean = 31.4, 3.6-32 d mean = 18.4	23.9-32 u mean = 31.4, 5.6-32 d mean = 16.7		26.9-32 mean = 31.8	29.2-32 mean = 32 0-48% reduction*

*Note: The percent reduction ranges when reported in the last column are based comparison of each sampling distance to the one farthest away

Table C.2. (Continued)

Project	% Fines	Method	Surveys	Distance upcoast (u) or downcoast (d) from turbidity plume					
				0-100 ft (0-30 m)	100-300 ft (30-100 m)	300-500 ft (100-150 m)	500-1000 (150-300 m)	1000-1500 (300-450m)	1500-2000 (450-600 m
SS-1 Borrow Site	>0.5	NTU	1		0.9 u surface, 1.4 u bottom; 3.6 d surface, 27.9 d bottom	0.9 u surface, 1.1 u bottom; 6.9 d surface, 23.7 bottom		1.1 surface, 1.0 bottom	1.5 surface, 0.9 bottom
		Secchi (feet)	1		23.6 u, 5.2 d	21.6 u, 3.2 d		18.4	16.1 0-80.2% reduction*

Sources: ABC 1999a, 1999b, 2004; AET 2004; AMEC 2002 (San Diego Regional Beach Sand Project); Agua Hedionda Lagoon dredging water quality monitoring reports; CCIE 1995; County of Orange 2000, Hart Crowser 2000; Kinnetic Laboratories 2003; MEC Analytical Systems, Inc. 1998; Merkel & Associates 2005; O'Connor 1991; Ogden Environmental 1998, 1999; Sherman et al. 1998.

*Note: The percent reduction ranges when reported in the last column are based comparison of each sampling distance to the one farthest away

APPENDIX C.3

Literature Data on Effects of Suspended Sediment on Invertebrates and Fish

Table C.3.1. Reported responses of invertebrates to suspended sediments.

Species	Life Stage	Concen-tration (mg/L)	Exposure Duration	Type of Sediment	Response	Reference
Crustaceans						
Amphipod *Anisogammarus confervicolus*	Adult	35,000	200 hrs (8 days)	Kaolin clay	LC_{50}	Peddicord et al. 1975*
American lobster *Homarus*	Juvenile	20,000	25 days	Natural (contaminated)	No mortality	Peddicord and McFarland 1978*
American lobster	Adult	50,000	Not stated	Artificial	No mortality	Saila et al. 1968*
Rock lobster *Jasus edwardsii*	Adult	360	Several days	Natural	Survived	Perry 1999
Dungeness crab *Cancer magister*	Juvenile	2,000-20,000	25 days	Natural	38% mortality at 9,200 mg/L, Abnormalities 1,800-4,300 mg/L, No mortality <4,300 mg/L	Peddicord and McFarland 1978*
Dungeness crab	Adult	3,500	21 days	Natural (contaminated)	LC_{10}	Peddicord and McFarland 1978*
Dungeness crab	Adult	35,000	200 hrs (8 days)	Kaolin clay	LC_{50}	Peddicord et al. 1975*
Black tailed sand shrimp *Crangon nigricauda*	Subadult	21,500	21	Natural (contaminated)	20% mortality	Peddicord and McFarland 1978*
Black-tailed sand shrimp	Adult	50,000	200 hrs (8 days)	Kaolin clay	LC_{50}	Peddicord et al. 1975*
Spot-tailed shrimp *Palaemon macrodactylus*	Adult	50,000	200 hrs (8 days)	Kaolin clay	LC_{50}	Peddicord et al. 1975*
Mysid shrimp *Mysidopsis bahia*	Adult	45, 230, 1,000	28 days	Not available	75 percent mortality at high dose, No effects over 4 days	Nimmo et al. 1982*

Table C.3.1 (Continued).

Species	Life Stage	Concen-tration (mg/L)	Exposure Duration	Type of Sediment	Response	Reference
Mollusks						
Crassostrea virginica (American Oyster)	Egg	188-375	Not stated	Natural silt, Artificial	22-34% Reduced normal egg developme nt	Davis and Hidu 1969 *
American Oyster	Egg	1,000 to 2,000	Not stated	Fuller's earth, Kaolin clay	Developed normally	Davis and Hidu 1969 *
American Oyster	Larvae	750-2,000	12 days	Natural silt, Artificial	20-31% mortality	Davis and Hidu 1969*
American Oyster	Adult	100-4,000	Not stated	Mud, silt	Reduced pumping, No effect	Loosanoff and Tommers 1948*, Mackin 1961*
American Oyster	Adult	4,000-32,000	Extended	Not stated	Detrimental	Wilson 1950*,
Mercenaria mercenaria (Quahog)	Egg	125-4,000	Not stated	Clay, chalk, Fuller's earth, natural silt	8-35% Reduced normal egg developme nt	Davis 1960*
Quahog	Larvae	500-1,000	Not stated to 12 days	Natural silt Artificial	No effect (1,000 silt)	Davis 1960*
Quahog	Juvenile	25	Not stated	Not stated	Reduced growth	Bricelj et al. 1984*
Mya arenaria (Soft-shelled clam)	Adult	100-200	30 days	Not stated	7 days - partial siphon retraction, 30 days – prolonged siphon protrusion	Grant and Thorpe 1991***
Mytills californianus (California Mussel)	Adult	96,000	200 hrs (8 days)	Kaolin clay	50% mortality	Peddicord et al. 1975**
Mytilus edulis (Blue Mussel)	Subadult	100,000	5 days	Kaolin clay	10% mortality	Peddicord et al. 1975*
Mytilus edulis (Blue Mussel)	Adult	96,000-100,000	8-11 days	Kaolin clay	10% -50% mortality	Peddicord et al. 1975**
Tapes japonica (Clam)	Adult	100,000	10 days	Kaolin clay	No mortality	Peddicord et al. 1975**
Worms						
Phragmatopoma lapidosa (reef building worm)	Adult	2,000, 4,000, 6,000	1 to 4 days	Fuller's earth	No apparent effect	Main and Nelson1988

Cited in: *LaSalle et al. 1991 (modified from Priest 1981), ** O'Connor 1991, *** Clarke and Wilber 2002

Table C.3-2. Reported responses of estuarine and marine fish to suspended sediments.

Species	Life Stage	Concen-tration (mg/L)	Exposure Duration	Type of Sediment	Effect	Reference
Atlantic silverside	Adult	58	24 hours	Fuller's earth	10% mortality	Sherk et al. 1975**
Atlantic silverside	Adult	250	24 hours	Fuller's earth	50% mortality	Sherk et al. 1975**
Atlantic silverside	Adult	1,000	24 hours	Fuller's earth	90% mortality	Sherk et al. 1975**
Bay anchovy	adult	2,300	24 hr	Artificial	10% mortality	Sherk et al. 1975*
Blueback herring	egg	50-5,000	Not stated	Natural	Hatching success	Auld and Schubel 1978*
Bluefish	Juvenile	800	24 hours		100% mortality	Sherk et al. 1974[2]
Pacific Herring West Coast	Larvae	500-8,000	24 hours (2 hr pulses)	Estuarine	Epidermal damage ≥4,000	Boehlert 1984
	Larvae Feeding	a)500 to 8,000	2 hours static/15 min stir	Estuarine, Volcanic	Enhanced at 500, Reduced 1,000-8,000	Boehlert and Morgan 1985[1]
		b)500 to 8,000	2 hours	Estuarine, Volcanic	Enhanced at 500, Reduced 1,000-8,000	
	Egg Hatching, Larvae Survival	500-10,000	to 96 hours post-hatch	Contam-inated sediment	Reduced survival at 500, hatching at 10,000,	Morgan and Levings 1989[1]
		500-8,000	9 days static/72 hr renewal	Estuarine, Volcanic Ash	Reduced hatching ≥ 1,000	Boehlert 1984[1]
			8-9 days		None	
Atlantic herring East Coast	Larvae Feeding	4-20 Estuarine	3 hours		Reduced at 20	Johnston and Wildish 1982
		0-80 JTU		Diatom-aceous earth	Enhanced to 35 JTU, Reduced at 80 JTU	Utne-Palm 2004[1]
	Egg Hatching	Egg layers on slides			100% lower eggs	Messieh et al. 1981[1]
		Slides with sediment			Reduced	Messieh et al. 1981[1]
	Egg Hatching, Larvae Survival	5-300	11 days	Estuarine	None	Kiorboe et al. 1981[1]
		500	11 days	Estuarine	None	Kiorboe et al. 1981[1]
		10-7,300	15 days	Fine grained	Reduced fish length at 7,300	Messieh et al. 1981[1]
		700-19,000	14 days, 48 hr renewals	Fine grained	Reduced at 6,000, 100% at 19,000	Messieh et al. 1981[1]
	Egg Hatching	1 cm burial			100%	Messieh et al. 1981[1]

Table C.3-2. (Continued)

Species	Life Stage	Concen-tration (mg/L)	Exposure Duration	Type of Sediment	Effect	Reference
Chinook salmon	Adult	650	7 days		No damage to olfactory epithelium	Brannon et al. 1981**
	Adult	39,000 to	1 to 24 hours		No mortality	Newcomb and Jensen 1996**
	Adult	82,400	6		60% mortality	Newcomb and Jensen 1996
	Adult	207,000	1		100% mortality	Newcomb and Jensen 1996
	Juvenile	6	60 days		Growth reduced	MacKinley et al. 1987**
	Juvenile	1,400	36 hours		50% mortality	Newcomb and Jensen 1996
	Juvenile	9400	36 hours		50% mortality	Newcomb and Jensen 1996
	Juvenile	39,400	36 hours		90% mortality	Newcomb and Jensen 1996
	Smolt	488	96 hours		50% mortality	Strober et al. 1981**
	Smolt	11,000, 19,364	96 hours		50% mortality	Strober et al. 1981**
Chum salmon	Juvenile	28,000	96 hours		50% mortality	Smith 1940**
Coho salmon	Juvenile	25	1 hour		Feed rate decrease	Nogle 1978**
	Juvenile	88	Minutes		Alarm, avoidance	Bisson and Bilby 1982**
	Juvenile	100	1 hour		Feeding 55% of maximum	Nogle 1978**
	Juvenile	102	14 days		Reduced growth	Sigler et al. 1984**
	Juvenile	250	1 hour		Feeding 10% of maximum	Nogle 1978**
	Juvenile	300	1 hour		No feeding	Nogle 1978**
	Juvenile	1,200	96 hours		Mortality 1%	Servizi and Martens 1992**
	Juvenile	1,547	96 hours		Gill damage	Noggle 1978**
	Juvenile	6,000	1 hour		Avoidance	Noggle 1978**
	Juvenile	27,700	96 hours		50% mortality	Servizi and Martens 1991**
	Juvenile	35,000	96 hours		50% mortality	Noggle 1978**
	Smolt	509	96 hours		50% mortality	Strober et al. 1981**
	Smolt	1,217	96 hours		50% mortality	Strober et al. 1981**
	Smolt	28,184, 29,580	96 hours		50% mortality	Strober et al. 1981**
	juvenile	25 NTU			Reduced growth	Sigler et al. 1984**

Table C.3-2. (Continued).

Species	Life Stage	Concen-tration (mg/L)	Exposure Duration	Type of Sediment	Effect	Reference
Steelhead	Adult	500	3 hours		Sublethal stress	Redding and Schreck 1982**
	Juvenile	102	14 days		Reduced growth	Sigler et al. 1984**
	juvenile	25 NTU			Reduced growth	Sigler et al. 1984**
Striped bass	egg	500	Not stated	Natural	Delay in time to hatching at 100 mg/L	Schubel and Wang 1973*
		20-2,300	Not stated	Natural (fine)	Delay in development at ≥ 1,300 mg/L	Morgan et al. 1983*
		50-5,000	Not stated	Natural (fine)	Hatching success	Auld and Schubel 1978*
	larvae	1,557-5,210	24-48 hrs		Significant effect on hatching success at 1,000 mg/L	Auld and Schubel 1978*
	subadult	4,000	21 days	Natural	10% mortality	Peddicord and McFarland 1978*
Striped killifish	adult	23,770	24 hr	Artificial	10% mortality	Sherk et al. 1975*
White perch	egg	500	Not stated	Natural	Delay in time to hatching at 100 mg/L	Schubel and Wang 1973*
		50-5,250	Not stated	Natural	Delay in development at ≥ 1,500 mg/L	Morgan et al. 1983*
		50-5,000	Not stated	Natural (fine)	Significant effect on hatching success at 1,000 mg/L	Auld and Schubel 1978*
	larvae	1,626-5,380	24-48 hr		15-49% mortality	Morgan et al. 1983*
	adult	9,970	24 hrs	Natural	10% mortality	Sherk et al. 1975*
Yellow perch	egg	500	Not stated	Natural	Delay in time to hatching at 100 mg/L	Schubel and Wang 1973*
	egg	50-5,000	Not stated	Natural (fine)	Hatching success	Auld and Schubel 1978*
	larvae	50-1,000	4 days	Natural	Survival reduced at ≥ 500 mg/L	Auld and Schubel 1978*

Cited in: *LaSalle et al. 1991, **Berry et al. 2003, [1]Pacific EcoRisk 2005, [2] Wilber and Clarke 2001

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APPENDIX D

REPRESENTATIVE SIGNIFICANCE CRITERIA AND MITIGATION MEASURES APPLIED TO CALIFORNIA SEDIMENT MANAGEMENT PROJECTS

D.1 Representative Biological Impact Significance Criteria

D.2 Representative Mitigation Measures, Environmental Commitments, and/or Other Protective Measures

APPENDIX D.1

Representative Biological Impact Significance Criteria

Table D.1. Significance criteria that have been used for evaluating potential impacts to biological resources associated with representative California sediment management projects.

Type of Criteria					
Federal and/or State Listed Sensitive Species	**Essential Fish Habitat**	**Native Species and/or Other Sensitive Resources**	**Wildlife Movement**	**Commercial Fishing**	**Environmental Policies**
Northern California					
USACE 1998c, Crescent City Harbor O&M Dredging, Del Norte County California, EA and FONSI					
Forceful effect causing change in existing conditions.		Forceful effect causing change in existing conditions.	Forceful effect causing change in existing conditions.		
USACE 2002c, Operations & Maintenance Dredging of the Moss Landing Harbor Federal Channels, Monterey County, California, EA and FONSI					
If it is expected to affect the population status of a State or Federally listed, proposed, or candidate species or is expected to affect the breeding or foraging habitat of such a species so as to result in increased mortality or reduced reproductive success.		Causes the loss or long-term degradation of any environmentally sensitive habitat. Causes a measurable change in species composition or abundance of a sensitive community or causes a substantial change to marine habitat within the harbor or bay for a period of five years or longer. An impact is a forceful effect causing a change in conditions.	Interferes substantially with the movement of any resident or migratory fish or wildlife species.		
Central California					
USACE 2001, Morro Bay Harbor Six-Year Maintenance Dredging Program, Final EA					
Not specified, but potential to impact threatened and endangered species assessed.	Not specified, but potential impacts to grunion and essential fish habitat assessed.	Not specified, but potential impacts to plankton, invertebrates assessed		Not specified, but potential for impacts to commercial oyster bed assessed.	

Table D.1. (Continued)

Type of Criteria					
Federal and/or State Listed Sensitive Species	**Essential Fish Habitat**	**Native Species and/or Other Sensitive Resources**	**Wildlife Movement**	**Commercial Fishing**	**Environmental Policies**
USACE 1999a, Morro Bay Harbor Three-Year Maintenance Dredging Program, EA					
Not specified, but potential to impact threatened and endangered species assessed.		Not specified, but potential impacts to plankton, invertebrates, fish, eelgrass, marine mammals assessed		Not specified, but potential for impacts to commercial oyster bed assessed.	
Southern California					
Chambers Group, Inc. 1992, BEACON Beach Nourishment Demonstration Project, Final EIR/EA					
Directly affects the population or the breeding or foraging habitat of a State or Federally listed, proposed or candidate species.		(1) Causes the loss of any Environmentally Sensitive Habitat; (2) causes a measurable change in species composition or abundance of a community or if it causes more than a 10 percent loss of a natural habitat within the project area for a period of five years or longer.;	Interferes substantially with the movement of any resident or migratory fish or wildlife species.		
Chambers Group, Inc. 2001c, BEACON South Central Coast Beach Enhancement Program, Biological Resources Report					
Negative effects to individuals or the habitat of a listed species, a species that is a candidate for listing, or a species of concern.		(1) Substantial degradation of any significant biological habitat including kelp beds, rocky intertidal, high relief subtidal, marine grass beds, pinniped haul out areas, or tidal wetlands (substantial degradation implies that impacts would last for more than one year and would affect a significant portion of the habitat). (2) substantial loss in the population or habitat of any native fish, wildlife or plants.	Substantial impediment to the migration or movement of native fish or wildlife.		

Table D.1. (Continued)

Type of Criteria					
Federal and/or State Listed Sensitive Species	**Essential Fish Habitat**	**Native Species and/or Other Sensitive Resources**	**Wildlife Movement**	**Commercial Fishing**	**Environmental Policies**
Chambers Group, Inc. 2002. Goleta Beach Five-Year Winter Dike Project Construction, Maintenance, and Lowering, Analysis of Environmental Effects					
Effects Checklist questions: (1) A loss or disturbance to or a reduction in the numbers or restriction in the range of any unique, rare or threatened species of plant or plant community; (2) A reduction in the numbers, a restriction in the range, or an impact to the critical habitat of any unique, rare, threatened, or endangered species of animals.		Effects Checklist questions: (1) A reduction in the extent, diversity, or quality of native vegetation; (1) An impact on non-native vegetation whether naturalized or horticultural if of habitat value;(3) the loss of healthy native specimen trees; (4) introduction of herbicides, pesticides, animal life, human habitation, non-native plants, or other factors that would change or hamper the existing habitat; (4) A reduction in the diversity or numbers of animals onsite; (5) A deterioration of existing fish or wildlife habitat.	Effects Checklist question: (1) introduction of barriers to movement of any resident or migratory fish or wildlife species. (2) introduction of any factors (light, fencing, noise, human presence, and/or domestic animals) which could hinder the normal activities of wildlife.		
USACE 1998a, Santa Barbara Harbor Six-Year Maintenance Dredging Program, Final EA					
Not specified, but the potential for impacts to federal endangered and threatened species assessed.		Not specified, but the potential for impacts to vegetation, invertebrates, fish, birds, and marine mammals assessed.			

Table D.1. (Continued)

Type of Criteria					
Federal and/or State Listed Sensitive Species	**Essential Fish Habitat**	**Native Species and/or Other Sensitive Resources**	**Wildlife Movement**	**Commercial Fishing**	**Environmental Policies**
USACE 1993, Santa Barbara Harbor Maintenance Dredging (FY 94, 95, 96), Final EA					
Not specified, but the potential for impacts to federal endangered and threatened species assessed.		Not specified, but the potential for impacts to vegetation, invertebrates, fish, birds, and marine mammals assessed.			
USACE 1998b, Ventura Harbor Six-Year Maintenance Dredging Program, Final EA					
Not specified, but potential impacts to federal endangered and threatened species assessed.		Not specified, but potential impacts to invertebrates, fish, birds, and vegetation assessed.			
City of Buenaventura 2002, Surfer's Point Managed Shoreline Retreat, Draft EIR					
Cause a loss or disturbance or reduction in the numbers of, or a restriction in the range of, or any other impact to any unique, rare, threatened, or endangered species of animals or plants or their critical habitat.		(1) Cause a loss or disturbance or reduction in the numbers or diversity of or restriction in the range of any other species of animals or plants or their habitat; (2) cause a reduction in the extent, diversity or quality of native or non-native vegetation; (3) involve the use, production or disposal of materials which pose a hazard to animal or plant populations; (4) impact wetland or riparian habitat, particularly those under the jurisdiction of Section 404 of the Clean Water Act; (5) impact historically designated species (e.g., heritage trees) or locally designated natural communities; (6) cause the loss of other healthy specimen trees;	Cause the introduction of any factors that could hinder the normal activities of wildlife or cause a deterioration of their habitat.		Conflict with local or regional conservation plans or State goals.

Table D.1. (Continued)

Type of Criteria					
Federal and/or State Listed Sensitive Species	**Essential Fish Habitat**	**Native Species and/or Other Sensitive Resources**	**Wildlife Movement**	**Commercial Fishing**	**Environmental Policies**
USACE 1994a, Channel Islands/Port Hueneme Harbors Maintenance Dredging, Final EA					
The population of a threatened, endangered, or candidate species is directly affected or if its habitat is lost or disturbed.		(1) if there is a substantial loss in the population or habitat of any native fish, wildlife or vegetation (substantial loss defined as any change in a population which is detectible over natural variability for a period of 5 years or longer); (2) If there is a net loss in the habitat value of a sensitive biological habitat including marine mammal haul-out site or breeding area, seabird rookery, or Area of Special Biological Significance.	If the movement or migration of fish or wildlife is impeded.		
USACE 2000a, Channel Islands/Port Hueneme Harbors Maintenance Dredging Project EA					
The population of a threatened, endangered, or candidate species is directly affected or its habitat lost or disturbed.					
CRM 1997, Malibu Area Sediment Placement Sites Study, Marine Biological Resources Inventory and Environmental Assessment					
		(1) Burial of 10 percent or more of a shoreline or subtidal habitat and associated biological communities for a period greater in duration than one year and which are directly attributable to the sediment placement site program; (2) The loss of 10 percent or more of surfgrass habitat which does not recover over a period of one year following shoreline sediment placement activities.			

Table D.1. (Continued)

Type of Criteria					
Federal and/or State Listed Sensitive Species	**Essential Fish Habitat**	**Native Species and/or Other Sensitive Resources**	**Wildlife Movement**	**Commercial Fishing**	**Environmental Policies**
CRM 1997, Malibu Area Sediment Placement Sites Study, Marine Biological Resources Inventory and Environmental Assessment					
		(1) Burial of 10 percent or more of a shoreline or subtidal habitat and associated biological communities for a period greater in duration than one year and which are directly attributable to the sediment placement site program; (2) The loss of 10 percent or more of surfgrass habitat which does not recover over a period of one year following shoreline sediment placement activities.			
USACE 1999b, Marina Del Rey Harbor Maintenance Dredging, Final EA					
Not specified, but potential impacts to federal endangered and threatened species assessed.		Not specified, but potential impacts to plankton, invertebrates, fish, birds, and marine mammals assessed.			
Tekmarine, Inc. and Analytic Planning Service, Inc. 1990, Cabrillo Beach Nourishment Project, Negative Declaration and Initial Study					
Not specified, but potential impacts to endangered species assessed.		Not specified, but potential impacts to plants, invertebrates, fish, and birds assessed.			

Table D.1. (Continued)

Type of Criteria					
Federal and/or State Listed Sensitive Species	**Essential Fish Habitat**	**Native Species and/or Other Sensitive Resources**	**Wildlife Movement**	**Commercial Fishing**	**Environmental Policies**
Chambers Group 2000, Bolsa Chica Lowlands Restoration EIR/EIS					
(1) Substantially affect habitat of a rare, threatened, or endangered species or species of concern; (2) Substantially affect a critical yet limited resource used by state- or federal- listed sensitive species.		Substantially diminish the population or habitat for native fish, wildlife, or plants.	Substantially affect the movement of any resident or migratory fish or wildlife.		
USACE 1995a, Surfside-Sunset/West Newport Beach Nourishment Project, EA					
The population of a threatened, endangered, or candidate species is directly affected or its habitat lost or disturbed.					
CRM 2000, City of San Clemente Beach Replenishment Program, Marine Biological Impact Assessment Report					
Population of an endangered species, threatened species, or fully protected species was directly affected, its breeding impaired, or critical foraging or breeding habitat was lost or substantially affected.		(1) There was a substantial loss of a population or habitat where long-term loss (greater than one year was projected; (2) sensitive resources such as reefs, surfgrass beds, and kelp beds were affected for a period of time that would substantially reduce the ability of the resource to recover (surfgrass criteria of > 2/3 cover for > 6 months used to limit long-term damage).	The movement of any resident species of fish or wildlife was impeded.		

Table D.1. (Continued)

Type of Criteria					
Federal and/or State Listed Sensitive Species	**Essential Fish Habitat**	**Native Species and/or Other Sensitive Resources**	**Wildlife Movement**	**Commercial Fishing**	**Environmental Policies**
SANDAG and U.S. Navy 2000, San Diego Regional Beach Sand Project, Final EIR/EA					
Adversely affect an individual or population of a threatened or endangered species.	Adversely affect fisheries protected under Essential Fish Habitat designation.	Long-term adverse impacts from sediment transport that result in irreversible removal or disturbance or destruction of sensitive resources (i.e., high relief reefs and vegetated low relief reefs with feather boa kelp, giant kelp, surfgrass, large sea fans, and/or sea palms).		Note: criteria not explicitly defined, but impacts evaluated according to potential for area preclusion, adverse effects to nursery habitat, and gear loss/limit access.	
MEC Analytical Systems 2000a, San Diego Regional Beach Sand Project EIR/EA, Technical Appendix D					
(1) Sensitive species habitat was lost; (2) the population of a threatened, endangered, or fully protected species was directly affected, its breeding impaired, or its habitat substantially disturbed.		(1) Substantial loss in the population or habitat of any native fish, wildlife, or vegetation; (2) A high probability for dredged sands burying sensitive resources (i.e., low- and high-relief reefs containing mature perennial biota with the following indicator species: surfgrass, feather boa kelp, giant kelp, sea palm, and/or sea fans) for a period long enough to cause irreversible removal, disturbance, or destruction of sensitive resources (substantial burial for ≥ 1 year considered significant); (3) objectionable aquatic growths or development of nuisance species was enhanced.	The movement of any resident or migratory fish or wildlife species was impeded	(1) If the project reduced or precluded fishing activity by 10% or more during peak season; (2) if the project permanently excluded 10% or more of a local fishing area; (3) if any fish/shellfish population of commercial or recreational importance has the potential to be reduced by 10% or more in the local area (4) if the project resulted in increased losses or damage to traps and nets.	

Table D.1. (Continued)

Type of Criteria					
Federal and/or State Listed Sensitive Species	**Essential Fish Habitat**	**Native Species and/or Other Sensitive Resources**	**Wildlife Movement**	**Commercial Fishing**	**Environmental Policies**
U.S. Navy 1997a, Beach Replenishment at South Oceanside and Cardiff/Solana Beach, California, EA					
Not specified, but potential for direct impact to sensitive species assessed.		Not specified, but potential for permanent impacts resulting in the irreversible removal, disturbance, or destruction of the following indicator species: surfgrass, feather boa kelp, giant kelp, sea palm, and/or sea fans.			
U.S. Navy 1997b, Beach Replenishment at North Carlsbad, South Carlsbad, Encinitas, and Torrey Pines, EA					
Not specified, but potential for direct impact to sensitive species assessed.		Not specified, but potential for permanent impacts resulting in the irreversible removal, disturbance, or destruction of the following indicator species: surfgrass, feather boa kelp, giant kelp, sea palm, and/or sea fans			
USACE 2000b, Oceanside Harbor Maintenance Dredging, Final EA					
Degrade habitat for, or reduce, the population size of a federal listed species		(1) Degrade biologically important habitats and/or areas of high biological activity; (2) create a long-term (over 10 years) measurable change in species composition and/or abundance beyond that of normal variability; (3) create a long term (over 10 years) measurable change in ecological function within a localized area.		Create a measurable change in commercial fishing opportunities, such that: (a) ten percent or greater loss of, or preclusion from, current productive fishing grounds in the project area for more than 10 percent of the open or peak season, (b). ten percent or more of the fishermen regularly using fishing grounds in the project area are precluded from fishing for 10 percent or more of the open or peak season.	

Table D.1. (Continued)

Type of Criteria					
Federal and/or State Listed Sensitive Species	**Essential Fish Habitat**	**Native Species and/or Other Sensitive Resources**	**Wildlife Movement**	**Commercial Fishing**	**Environmental Policies**
USACE 1995b, Oceanside Harbor Experimental Bypass System, Final Supplemental EA					
Not specified, but potential to impact federal endangered and threatened species assessed.		Not specified, but potential to impact plankton, fish, invertebrates, and birds assessed.			
USACE 1994b, Oceanside Harbor Maintenance Dredging, Final EA					
Not specified, but the potential for impacts to federal endangered and threatened species assessed.		Not specified, but the potential for impacts to invertebrates, fish and birds assessed.			
USACE 2002d, Imperial Beach Shore Protection Project, Final EIS/EIR					
Substantial adverse effects would occur to individuals or the habitat of a rare, threatened, endangered species or other special status species.	Substantial adverse effects would occur to fish species or habitat listed in the Fishery Management Plans.	(1) Substantial adverse modification would occur to species diversity or ecosystem functions and values beyond the immediate vicinity of the study site; (2) substantial adverse effects would occur to a species, natural community, or habitat that is specifically recognized as biologically significant in local, State, or Federal policies, statutes, or regulations.	Substantial adverse effects would occur to the migration of fish and wildlife populations.		Substantial conflict would occur with local, State, or Federal policies designed to protect biological resources.

APPENDIX D.2

Representative Mitigation Measures, Environmental Commitments, and/or Other Protective Measures

Appendix D.2. Mitigation measures, environmental commitments, and/or other protective measures proposed to minimize adverse impacts to biological resources associated with representative California sediment management projects.

Document (Sand Volume cy)	Type of Protective Measure						
	Final Design	Discharge Location	Construction Method	Buffers	Schedule	Monitoring	Mitigation
USACE 1998c FONSI/EA (Crescent City) (82,000 cy)		65,000 Whaler Island, 17,000 upland			late Aug-late Sep to avoid Dungeness crab and spawning activities of rockfish in eelgrass beds		
USACE 2002c FONSI/EA (Moss Landing) (40,295 cy)		20,227 cy to South Sandspit, 20,068 cy to aquatic SF-12disposal site within MBNMS.		50 m from sea otters or pelicans	Oct –Nov 2002 WDR 01-007 allows Sep 1 to Jun 1 timeframe		
USACE 2001, Final EA (Morro Bay Harbor Dredging) (Up to 1,086,800 cy)		(1) All activities within boundaries of construction and staging areas, avoiding sensitive resource areas and commercial oyster beds. Surf zone discharge.	(1) If necessary construct berm 50 feet from center of creek to prevent its blockage. (2) Surf-zone disposal within 50-foot corridor and in unvegetated areas, when possible.		Mar 1 to Sep 15 (restricted to nearshore) to avoid conflicts with nesting season of snowy plover. Discharge beyond scheduled dates coordinated with wildlife agencies.	Bacteria during discharge.	

Table D.2 (Continued)

Document	Type of Protective Measure						
	Final Design	**Discharge Location**	**Construction Method**	**Buffers**	**Schedule**	**Monitoring**	**Mitigation**
USACE 2001, Final EA (Morro Bay Harbor Dredging) (Up to 1,086,800) (Continued)		Surf zone rather than upper beach disposal to avoid direct impacts to beach profile in nesting areas. Start discharge at north end and work south to allow more time between disposal and beginning of breeding season of plovers.	Use of aggregates (sand, gravel, asphalt, concrete) in association pipeline prohibited in eelgrass area. No use of helicopters to avoid possible impacts to peregrine falcons. No recreational use of all-terrain vehicles by contractor. Use of propellers in “no work” areas prohibited to avoid impacts to eelgrass.				
Moffatt & Nichol 2003	Conduct survey to finalize pipeline routes and barge mooring locations					(1) Grunion during construction, (2) kelp, eelgrass, surfgrass before and after project, (3) Goleta Slough inlet status, (4) turbidity plume.	If inlet closes, material will be removed.

Table D.2 (Continued)

Document	Type of Protective Measure						
	Final Design	**Discharge Location**	**Construction Method**	**Buffers**	**Schedule**	**Monitoring**	**Mitigation**
Chambers 1992, EIR/EA (BEACON Beach Nourishment Demonstration (125,000 to 250,000 cy) Chambers 2000, Addendum EIR/EA (BEACON Beach Nourishment Demonstration Project)	Measure 4 – Conduct pre-construction survey at Goleta Beach and develop placement plan to minimize impacts to sensitive habitats. Measure 6, 8 – Establish routes to avoid impacts to kelp canopy from dredge and support vessel traffic. Measure 25 – conduct pre-construction survey at Oxnard Shores area for Pismo clam beds and develop plan to avoid these areas		Measure 11 – Reduce risk of damage to sensitive biological habitats from catastrophic accident by implementing Measures 18, 19. Measure 18 – coordinate mariner notifications to reduce chance of vessel collision and spilled materials. Measure 19 – locate Santa Clara River borrow site to avoid oil and gas pipelines	Measure 7 – Pre-construction survey to establish kelp boundaries, confine dredging to greater than 1,000 ft from kelp bed. Measure 24 – establish transportation corridor between borrow and receiver sites to minimize potential for damage to fishing gear	Measure 9, 10 – Mar 15 to Sep 15 (restricted) to avoid grunion spawning and snowy plover impacts,	Measure 1, 3 - monitor Goleta Slough inlet	Measure 1, 3 - Remove material as necessary to keep Goleta Slough open, Measure 5 – Develop and implement kelp and eel grass restoration plan at Goleta Beach and monitor success

Table D.2 (Continued)

Document	Type of Protective Measure						
	Final Design	**Discharge Location**	**Construction Method**	**Buffers**	**Schedule**	**Monitoring**	**Mitigation**
Chambers 2001c, Biological Analysis (BEACON South Central Coast) (100,000-275,000 cy depending on site)		(1) Below mean high tide line if material finer grained than existing beach sand. (2) Berm if material is higher in fines content and turbidity needs to be more controlled.		(1) Receiver site located 1,000 feet south of Carpinteria reef to minimize potential impacts. (2) Construction of protective berms to buffer grunion eggs if spawning observed during construction.	Fall-winter schedule Mar 15 to Sep 15 (restricted) at sites in proximity to least tern and snowy plover nesting areas.	(1) Turbidity during construction, (2) post-construction monitoring of sensitive habitats (eelgrass, surfgrass, kelp beds, reefs), (3) grunion monitoring during construction as necessary, (4) inlet monitoring of creeks, slough, and rivers.	Bulldozer used to keep inlet open, if necessary.
USACE 1998a, EA (Santa Barbara Harbor Dredging) (350,000 up to 600,000 cy)		During Mar and Apr, disposal limited to fixed-point surf zone discharge within 500-ft swath zone of operation with no movement of vehicles or pipelines outside that zone to minimize impacts to grunion and snowy plover.			Sep 1 to Apr 30, during Mar and Apr discharge location restrictions and monitoring, no discharge between May 1 and Aug 31.	Weekly bacteria sampling during disposal; if disposal during Mar and Apr, grunion spawning and snowy plover monitoring and telephone coordination with resource agencies (CCC, CDFG, NMFS, USFWS) to report results of monitoring and determine disposal site.	

Table D.2 (Continued)

Document	Type of Protective Measure						
	Final Design	**Discharge Location**	**Construction Method**	**Buffers**	**Schedule**	**Monitoring**	**Mitigation**
USACE 1993, EA (Santa Barbara Harbor Dredging) (250,000 cy)		During Mar and Apr, single-point surf zone discharge with disposal confined to within 500 ft swath of operations with minimal positional changes of beach pipeline to minimize impacts to grunion and snowy plover.	No more than 250,000 cy discharged during Mar and Apr and no more than 600,000 cy annually.		Discharge in Mar and Apr requires monitoring and discharge restrictions, no discharge between Apr 30 and Sep 30.	if Mar and Apr disposal, coordinate with resource agencies to determine discharge site, monitor grunion spawning success, monitor snowy plovers, collect water quality data, and other abiotic factors) during monitoring.	
USACE 1998b, EA (Ventura Harbor Dredging) (500,000 to 1,000,000 cy)		Pipeline to avoid impacts to dune vegetation. No discharge at mouth of Santa Clara River so spawning and juvenile steelhead trout will not be affected. If operations extend beyond Mar. 15, diked beach or single-point surf zone discharge only at South Beach to limit affected area and minimize impacts.	Operators of dredge or other heavy equipment shall not harass any marine mammal, bird, or fish in the project area. No recreational use of all-terrain vehicles by the contractor. Stockpiling confined to authorized staging areas.	If operations extend beyond Mar. 15, fence one or more corridors between dunes and surf to protect plovers to be considered. Vehicular activity associated with pipeline maintenance near least tern nesting area shall be adjacent to the pipeline to minimize disturbance s.	Mar 15 to Sep 15 (restricted) to avoid conflicts with grunion spawning and nesting seasons of snowy plover and least terns. If operations extend beyond Mar 15, coordinate with wildlife agencies and implement Contingency Plan, if beyond Mar 31 initiate section 7 (ESA) consultations. Pipeline removed after nesting season.	(1) Port responsible for monitoring water quality during dredging in conformance with Waste Discharge Requirements of RWQCB, (2) monitor for plover nesting activity if operations extend beyond Mar 15, (3) monitor for least tern disturbance if operations extend beyond Apr 15.	

Table D.2 (Continued)

Document	Type of Protective Measure						
	Final Design	**Discharge Location**	**Construction Method**	**Buffers**	**Schedule**	**Monitoring**	**Mitigation**
City of Buenaventura 2002, Draft EIR (Surfer's Point) (11,000 cy sand, 54,000 tons of cobble)							
USACE 2000a, EA (Channel Islands/Port Hueneme Harbors Dredging) (2,000,000 cy Channel Islands, 300,000 Port Hueneme)		Beach disposal limited to diked, single-point discharge to minimize turbidity and grunion smothering.			Mar 15 to Sep 30 (restricted); in no event will disposal. extend beyond Mar 31	Water quality monitoring plan at dredge and disposal sites.	
USACE 1994a, EA (Channel Islands/Port Hueneme Harbors Dredging) (1,025,000 Channel Islands, 200,000 Port Hueneme)		If discharge beyond Mar 15, diked or single-point surf zone discharge.			Nov to Mar 15 to avoid impacts to snowy plover, least terns, and grunion. Discharge beyond Mar 15 coordinated with resource agencies and implement Contingency Plan protective measures.	If discharge beyond Mar 15, monitor snowy plover nesting activities and determine impacts. Night time grunion monitoring during CDFG predicted runs.	If necessary to place material below +3 feet MLLW, mitigation developed in coordination with resources agencies prior to activities, including surveys (transects at 5-foot widths) between +3 and -5 feet MLLW for Pismo clam, and collection and relocation of clams either up- or downcoast of activity.

Table D.2 (Continued)

Document	Type of Protective Measure						
	Final Design	**Discharge Location**	**Construction Method**	**Buffers**	**Schedule**	**Monitoring**	**Mitigation**
CRM 1997, Biological Analysis (Malibu Area Sediment Placement Sites Study) (100,000 cy at 4 sites (25,000 cy per site)							
USACE 1999b, EA (Marina Del Rey Harbor Dredging) (Up to 379,000)		(1) All dredging and disposal limited to boundaries specified in EA. (2) After Mar 15, surf-zone discharge within 500 ft wide fixed position; lateral movement only allowed when seaward extension of pipeline no longer feasible and discharge remains within 500 ft zone of operation.		35 m (120 ft) to be established between dredge and breakwater	(1) If beach disposal after Mar 15, zone of operation restricted within 500 ft area; (2) Operations to be complete prior to April 1 to avoid impacts to least terns.	(1) Turbidity at dredge and disposal site; (2) beach surveyed for snowy plovers prior to disposal, (3) pelican night roost at breakwater monitored and if roost abandonment occurs buffer zone to be increased by 15 m (50 ft) increments to maximum distance of 80 m (270 ft).	
Chambers 2000, EIR/EIS (Bolsa Chica Lowlands Restoration) (1,331,100 cy in ebb bar, 190,000 cy on beach)					Schedule project between August and March to avoid grunion spawning season.		

Table D.2 (Continued)

Document	Type of Protective Measure						
	Final Design	**Discharge Location**	**Construction Method**	**Buffers**	**Schedule**	**Monitoring**	**Mitigation**
Tekmarine, Inc. and Analytic Planning Service, Inc. 1990, Initial Study (Cabrillo Beach Nourishment) (300,000 cy)			Implement rapid completion of exterior boundary of nourishment area separated from remaining fill by dike so grunion have area for spawning without being disturbed by rest of nourishment, disruption will occur during approximately 1 month (equivalent to about 3 runs out of 10 to 12 that occur per year).	300-ft buffer zone between kelp bed and western end of project site. Project designed so sand in equilibrium profile will remain at least 100 feet away from nearest kelp boundary.	Schedule of late Aug or early Sep to Jan or Feb will avoid most of breeding season. (Note, project description specified operations commencing after April).	Plan contemplated to implement grunion watch program to sand placement procedures could be continuously upgraded to reduce impacts to very minimum.	
USACE 1995a, EA (Surfside-Sunset/West Newport Beach) (1,600,000 cy at Surfside-Sunset, 140,000 cy at Newport)		Beach material placed as slurry on upper portion of beach and allowed to slowly migrate seaward to minimize suffocation effects to Pismo clam.			Mar 30 to Sep 30 (restricted) to avoid impacts to least tern, snowy plover, brown pelican, and grunion; discharge beyond Mar requires coordination with resource agencies.		

Table D.2 (Continued)

Document	Type of Protective Measure						
	Final Design	**Discharge Location**	**Construction Method**	**Buffers**	**Schedule**	**Monitoring**	**Mitigation**
CRM 2000, Biological Analysis (City of San Clemente) (<125,000 cy per project, up to 400,000 cy at four sites)							
SANDAG and U.S. Navy 2000, EIR/EA (San Diego Regional Beach Sand Project) (2,000,000 cy total, 101,000 to 421,000 cy each at 13 receiver sites)	Surveys to finalize pipeline route, vessel routes, and anchorages.	Receiver sites located to avoid rocky intertidal and nearshore sensitive reef areas.	Training dikes to reduce turbidity.	350 to 500 feet between borrow dredge areas and nearest kelp bed and/or reef.	Spring-Summer 2001 (in accordance with conservation measures specified in Biological Opinion for least terns, snowy plovers, and brown pelican.	Grunion, turbidity, snowy plover nesting, and night lighting monitoring during construction, and pre- and post-construction monitoring of sensitive habitats.	Additional predator control at tern/plover nesting sites, Fund for increased dredge volume and/or inlet opening of coastal lagoons. Artificial reefs if necessary to compensate for habitat loss.
USACE 2002 EIS/EIR (Imperial Beach) (1,587,912 cy)						Regularly monitor off- and onshore activities to ensure impacts associated with turbidity minimized to extent feasible.	

Table D.2 (Continued)

Document	Type of Protective Measure						
	Final Design	**Discharge Location**	**Construction Method**	**Buffers**	**Schedule**	**Monitoring**	**Mitigation**
U.S. Navy 1997a, EA (Beach Replenishment at South Oceanside and Cardiff/Solana Beach) (1,100,173 cy)		Behind longitudinal dikes, where practical, to minimize turbidity.		If grunion spawning, diked buffer zone established (100 feet up and downcoast of spawning area, and 65 feet shoreward of highest high water mark at spawning area). Buffer zone to remain in place for minimum of 14 days (the period of time for eggs to hatch).		(1) Kelp beds surveyed at least 30 days prior to pumping operations, and mono buoy and sinker lines placed to minimize impacts to kelp bed areas. (2) Qualified biologist to monitor grunion spawning activities at discharge sites during CDFG predicted grunion runs, (3) Prepare and implement monitoring plan to verify significant impacts do not occur.	Mitigate any significant, long-term adverse impacts to sensitive resources at 1:1 ratio (like habitat or artificial reefs) with a total mitigation cost not exceeding $700,000.
U.S. Navy 1997b, EA (Beach Replenishment at North Carlsbad, South Carlsbad, Encinitas, and Torrey Pines) (2,850,000 cy)		Behind longitudinal dikes, where practical, to minimize turbidity.				Same as Above	Mitigate any significant, long-term adverse impacts to sensitive resources at 1:1 ratio (like habitat or artificial reefs) with a total mitigation cost not exceeding $1.1 million.

Table D.2 (Continued)

Document	Type of Protective Measure						
	Final Design	**Discharge Location**	**Construction Method**	**Buffer**	**Schedule**	**Monitoring**	**Mitigation**
USACE 2000b, EA (Oceanside Harbor Dredging) (130,800 to 300,000 cy)		Discharge of sand slurry on upper beach (0 to +4.9 m MLLW) or in nearshore just beyond surf zone; if discharge beyond Mar 15 then either diked beach or fixed point surf zone discharge.			Mar 15 to Sept 15 (restricted); if discharge beyond Mar 15, then agency coordination and other measures required.	Turbidity to ensure negligible impacts; If discharge beyond Mar 15, grunion and snowy plover monitoring. If future dredging required in zones containing eelgrass, Corps to perform eelgrass surveys, avoid and minimize impacts.	Perform mitigation per the Southern California Eelgrass Policy, if necessary.
USACE 1994b, EA (Oceanside Harbor Dredging) (200,000 to 400,000 cy)		Discharge beyond Mar 15 requires either diked disposal or single-point surf zone discharge to minimize impacts to snowy plover.			Mar 15 to Sept 15 (restricted) construction to avoid snowy plover impacts; discharge beyond Mar 15 requires Contingency plan with resource agency coordination, either diked disposal or single-point surf zone discharge, and monitoring for nests.	If discharge beyond Mar 15, monitor for snowy plover nests.	
EIR/EIS (Batiquitos Lagoon Restoration) (2,294,000 cy)							