REGIONAL SEDIMENT MANAGEMENT - OFFSHORE CANYON SAND CAPTURE

FINAL POSITION PAPER REPORT (100%)

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1.0 Introduction

The concept of "regional sediment management" (RSM) originated with the notion of coordinating dredging activities in the coastal zone for retaining sand in the littoral system in order to foster more balanced natural system processes and reduce project costs. The need for RSM is based on recognition of the regional implications of dredging and other activities in the littoral zone, as well as appreciation of sand as a resource.

Regional sediment management is being actively pursued throughout the State of California led by the U.S. Army Corps of Engineers (USACE) and the California Resources Agency via the California Coastal Sediment Management Workgroup (CSMW). Problematic sedimentation occurs at locations such as harbors requiring maintenance dredging, while erosion is ongoing at other areas exposing the coast to damage and necessitating beach nourishment. RSM has the potential to reduce adverse shoreline impacts and reduce dredging costs. The USACE works with other federal, state, and local agencies to better manage sediment and reduce efforts for both dredging and nourishment, and to better effect solutions to these respective problems. Part of this management involves researching and assessing approaches to solving previously unresolved problems, specifically sand losses into submarine canyons. Interest exists in identifying opportunities to capture and retain these sediments as one measure to manage this important resource.

1.1 Problem Statement

Sand captured in the steep, shallow heads of submarine canyons is lost forever. Rather than being returned to the littoral zone by natural processes, it is usually carried seaward through ever-deeper portions of those underwater valleys. Its final resting place can be thousands of feet below the sea surface. Shepard (1951) and Shepard and Dill (1964) were pioneers in the systematic study of this capture and downslope transport mechanism. The USACE and CSMW have identified the opportunity to manage this sediment resource for the public benefit. Explaining and developing opportunities to capture and retain these sediments as one measure to manage this important resource is needed.

1.2 Purpose of the Study

The purpose of this study is to provide a position paper, or white paper, as defined in the USACE scope of work, addressing the feasibility of capturing littoral sediments adjacent to offshore canyons for beneficial re-use along the California coast. Specifically, this paper assesses the potential of capturing sand before it is lost into submarine canyons, and provides several project concepts with cost estimates. The study area is the coast of California and the study is part of the overall *California Sediment Master Plan* (CSMW, 2006a).

This paper identifies canyons within the state where artificial measures to reduce or eliminate the canyon capture rate might prove cost-effective and environmentally benign, and offers suggestions about how that might be accomplished. The focus is on canyons that: (1) have an estimated present capture rate of at least 10,000 cubic yards of littoral sand per year (arbitrarily proposed as the threshold below which no discernible effect would occur to

the coast from sand being trapped by the canyon); (2) are located near one or more popular, high-use recreational beaches; and 3) is near a Beach Erosion Concern Area (BECA) as defined by the Draft California Beach Restoration Survey (CSMW, 2008) such that the captured sand could solve an existing erosion problem. The latter criteria are included since they indicate the captured sand has a high potential commodity value that may justify reducing or eliminating its loss in a submarine canyon.

1.3 Scope of Work

The services performed for this study are as follows:

A. Specify the problem statement;
B. Research and review relevant existing data;
C. Identify pertinent policy and regulatory issues;
D. Identify Regional Sediment Management (RSM) opportunities;
E. Provide two concept examples of sediment management; and
F. Prepare a position (white) paper summarizing the findings.

2.0 Review of Relevant Existing Data

Existing data for submarine canyons along the California coast consist of their locations, respective sand capture rates, and other pertinent descriptive information as presented below.

2.1 Submarine Canyons in California

The California Continental Shelf is notched by dozens of submarine canyons. Fifteen of these canyons extend close to or into the littoral zone to capture sand and are shown in Figure 1. Each canyon was initially considered as a candidate for a project, depending on how they met criteria presented in section 1.2 of this document.

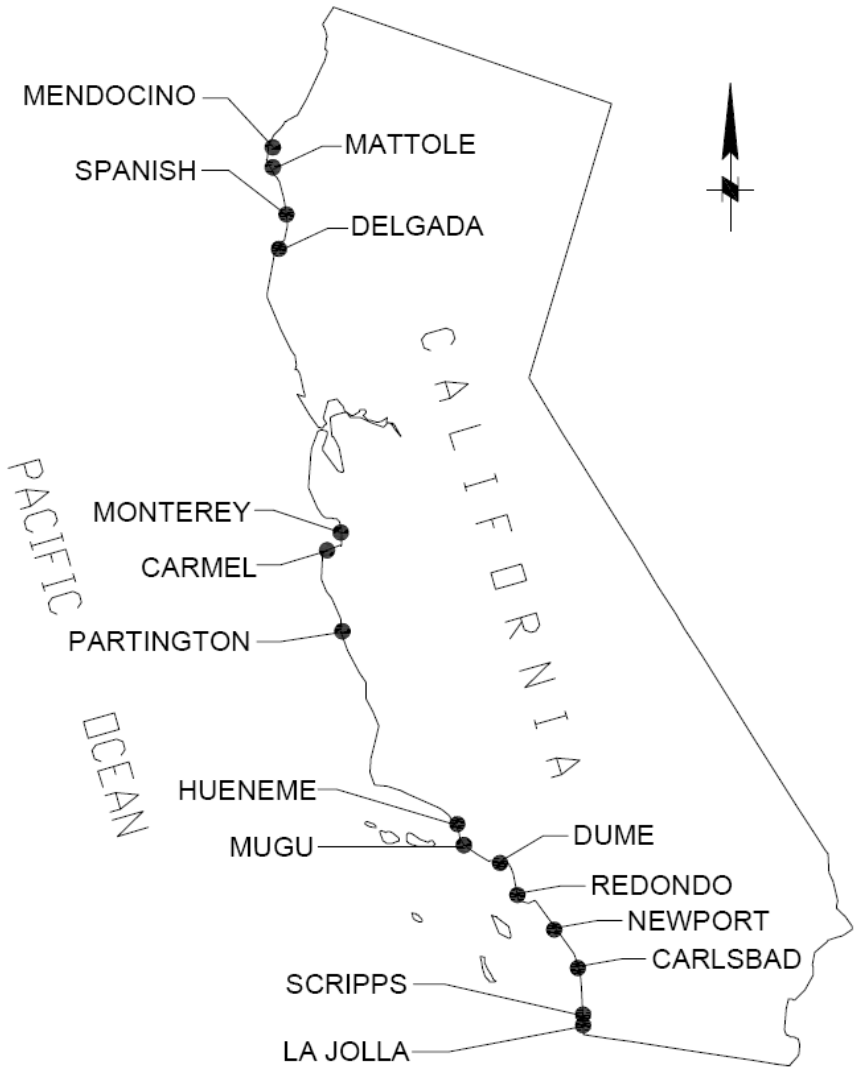

Figure 1 – Submarine Canyons in California

2.2 Recent Sand Capture Rates

Estimates of sand capture rates for those California submarine canyons that capture at least 10,000 cubic yards of sand per year (cyy) are shown in Table 1. These estimates are dependent upon the time interval of the hydrographic survey programs, in-canyon measurement projects, and/or sediment budget investigations that were used to establish the rates. Capture rates for other periods may differ from those shown in the table.

Submarine Canyon	*Location*	*Estimated Sand Capture Rate, cubic yards per year*	*Reference*
Monterey	Monterey County	Perhaps 750,000 Perhaps 410,000 Perhaps 40,000 (Uncertain of nearly 95%)	Patsch and Griggs (2007); Smith et al. (2005); Arnal et al. (1973)
Hueneme	Ventura County	Perhaps 50,000 and certainly <100,000 (1960-1995 average) (Uncertainty of 50%)	Moffatt & Nichol Engineers, or M&N, (1995)
Mugu	Ventura County	980,000 to 1,240,000 (1990-1995 average); 1,065,000 (Uncertainty of 20%)	Moffatt & Nichol (1995); Patsch & Griggs (2007)
Redondo	Los Angeles County	Approximately 160,000 (1953-1990 average) Approximately 80,000 (thousands of years average) (Uncertainty of approximately 50%)	Everts and Eldon (2003); Yerkes et al. (1967)
Scripps	San Diego County	29,000 (1984-1987 average) Approximately 200,000 (1950's average) (Uncertainty of approximately 50% to 75%)	Everts and Dill (1988); Chamberlain (1960)

Table 1 - Estimated Sand Capture Rates In Selected California Submarine Canyons

2.2.1 Southern California Canyons

Everts and Eldon (2005) summarize the capture rates for eight Southern California canyons (Figure 2) and the investigative efforts that went into providing them. Four of these Southern California canyons meet the selection criteria (Table 1); from north to south they are Hueneme, Mugu, Redondo, and Scripps Submarine Canyons.

Hueneme Canyon captures between 50,000 and 100,000 cyy of sand, and is not considered among the more significant sand trapping canyons in California. Historically the rate of sand capture was 50,000 cyy (M&N, 1995) and it increased with construction of the Naval harbor at Hueneme in 1938. The sand capture rate subsequently appears to

have been reduced toward the lower historic rate by implementation of a major federal project at Channel Islands Harbor, described in more detail in section 4.0 of this report.

Mugu Canyon captures the highest portion of longshore sediment transport in its vicinity than any other submarine canyon in California. Perhaps as much as 90% of the longshore transport at this location enters the canyon and is lost (Everts and Eldon, Personal Communication, 2006 and 2007). The longshore transport rate is approximately 1,065,000 cyy at this location (Patsch and Griggs, 2007).

Redondo Canyon captures approximately 160,000 cyy of sand, up from an historic average of 80,000 cyy. Everts and Eldon (2005) note the capture rate in Redondo Canyon has been greater in recent times. They determined that the increased capture is due to increased net longshore transport of sand resulting from huge beachfills placed on upcoast beaches in the last century. Based on the size of the sand deposit at the deep seaward fan of the canyon, Yerkes et al., (1967) suggest the present 160,000 cyy estimate is on the order of twice the very long-term rate.

Scripps Canyon traps approximately 29,000 cyy, down from an earlier estimation of 200,000 cyy. The 1984-87 Scripps Canyon sand capture rate (Everts and Dill, 1988) is based on an intensive set of weekly and monthly measurements in the canyon heads made by divers over that 3-year period. Chamberlain's (1960) larger estimate is based on lead line and sonic hydrographic surveys, mostly from the 1950's. Everts and Dill hypothesize that the difference in the two estimates is due to the large amount of kelp that was recorded in Chamberlain's hydrographic surveys as a seabed elevation rise, and on different net longshore sand transport rates (higher in the 1950's than the late 1980's). The amount of measured sand capture in Scripps Canyon in the 1980's is near the net longshore sand transport rate that was defined using directional wave data from near-coast gauges for that period (CDIP, 2007).

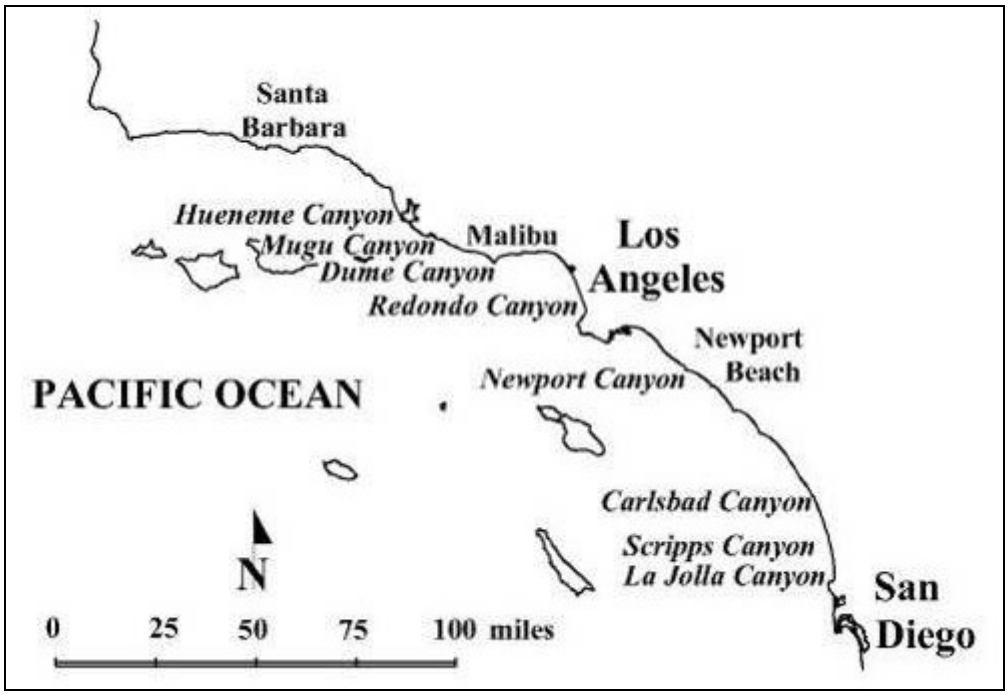

Figure 2 - Submarine Canyons in Southern California (Everts and Eldon, 2005)

2.2.2 The Central / Northern California Canyon

Monterey Submarine Canyon appears to be the only canyon in Northern/Central California that meets the capture rate, the recreational beach use, and BECA criteria of this investigation. Investigations of submarine canyons in the northern and central portions of the state have not been focused on sand capture rates to the same extent as they have in the south. Estimates of the amount of sand captured in Monterey Canyon range broadly.

Arnal et al. (1973) concluded that not more than 40,000 cyy of littoral sand is captured by Monterey Canyon. Their estimate is founded on diver observations and measurements of sand movement in the southernmost of the three tributary heads of the canyon at discrete times over a period of six years. Instead of sand transport in a net direction toward the canyon from beaches both north and south of it, as postulated by Patsch and Griggs (2007) and Smith et al. (2005), Arnal et al., hypothesized a longshore transport divergence on either side of the canyon with subsequent deposition offshore and away from the canyon heads. In summary they state, "*The noteworthy and surprising result of our work is in regard to the present role of Monterey Canyon…* and *…its lack of importance* <u>*today*</u> *… as an avenue for transport of nearshore sediment to deeper water."*

In great contrast to the Arnal (1973) estimate, Patsch and Griggs (2007) conclude Monterey Canyon is the sink for 750,000 cyy of sand. They hypothesize that sand reaches the canyon from beaches both north and south of the canyon head. Their work estimates that a part of the total capture rate is the net 265,000 cyy of sand that moves alongshore to the south at the south end of the Santa Cruz Littoral Cell. While not

explicitly stated, the difference between the total captured (750,000 cyy) and the contribution from the north (265,000 cyy) is implied to be material transported from the south at about 485,000 cyy. This value is based on a sediment budget interpretation that relies on their estimate of the annual sand discharge in the Salinas River, net changes in the volume of sand in the littoral zone between the river and the canyon, and the net longshore sand transport magnitude and direction in this reach.

Smith et al. (2005) present a sediment budget for the heads of Monterey Canyon that is a bit over half that of Patsch and Griggs (2007). They surmise the capture rate is about 410,000 cyy with 260,000 cyy entering from the north (based on an earlier Griggs estimate), 90,000 cyy from the harbor mouth at Moss Landing (Elkhorn Slough), and 65,000 cyy from the south. Patsch and Griggs did not consider Elkhorn Slough a source of littoral sand, but the amount they deduce moves into the canyon from the south is much greater than the Smith et al. estimate. Smith et al.'s estimate is from Dingler et al. (1985). Partially to test their total estimated capture rate, Smith et al. measured a six-month change in volume of the tributaries of the canyon at depth, the margins of the canyon, and the seaward end of its axis, and calculated a loss of about 420,000 cy (plus or minus 100,000 cy). They also measured a 340,000 cy accretion (plus or minus 90,000 cy) along the rim of the canyon in shallower water. The latter 6-month accretional deposition is not necessarily indicative of the longer term capture rate, but it does support the order of magnitude range they and Patsch and Griggs proposed over the Arnal et al. (1973) rate.

Monterey Submarine Canyon lies in the center of Monterey Bay. The indented shoreline planform suggests net sand transport will most likely be along the coast toward the canyon from both the north and south. This is what both Patsch and Griggs (2007) and Smith et al. (2005) suggest. If the net transport direction diverged in both directions from the canyon the coast in its lee would experience a negative sand budget. It would be highly recessional or the alongshore amounts that leave the area plus that lost in the canyon would have to be made up with discharge from Elkhorn Slough, an unlikely scenario. The scenario offered by Patsch and Griggs, and Smith et al., of sand transport convergence at the canyon is likely a more realistic scenario than sand transport divergence at the canyon. Paull et al. (2005) present canyon sediment data and sediment trapping rates that fall within the rates discussed herein. In summary, data indicate that the (large) range of sand trapping estimates in Monterey Canyon associated with Patsch and Griggs and Smith et al. of 400,000 to 700,000 cyy are appropriate for planning purposes.

There is also limited information on sediment transport directions south of the canyon. Thornton, et al. (2006) and Patsch and Griggs (2007) indicate that sand transport in Southern Monterey Bay is both north and south, depending on location and season. Net sediment transport is northward at locations north of the Salinas River mouth, and southward to the south of the river mouth (Davenport, Personal Communication, 2007). The river delta appears to be an influence on wave approach angle and consequent sediment transport direction. Thus, it is possible to have sand movement in both directions within this littoral cell, slightly complicating the sand trapping function of the canyon.

3.0 PROPERTIES OF SUBMARINE CANYONS

This section is a preamble to the canyon-by-canyon discussion of project opportunities in Section 4.0 of this document. Its purpose is to outline the elements of the canyon settings that may be important in an evaluation of the options to reduce or eliminate sand capture, to define available options, and to describe possible adverse impacts if the options are implemented.

3.1 Setting of Submarine Canyons

For the purposes of this evaluation, significant attributes of a canyon include: (1) location within the plan view of the littoral cell, and sand transport rates and gradients along the coast relative to canyon head locations; (2) relationships between the shallow head or heads of the canyon and the nearby shoreline; (3) morphology of the regions where sand is initially trapped; and (4) canyon rim resistance to erosion.

Sand transport to and into a canyon, and conversely, past a canyon, affects the width of beaches located downdrift (downcoast, or in the direction of net sand movement along the coast). The available sand supply controls the capture rate. Canyons located at the downcoast and terminal end of a littoral cell capture the entire littoral drift (sand volume equal to the net longshore sand transport rate at that location). Some small rate of sand passage around the canyons must be maintained to preserve the width of any small beaches that exist downcoast or in the lee of such a canyon. Canyons that are located more toward the coastal center of their respective littoral cells may capture only a portion of the net littoral drift to not function as a complete sink and therefore a barrier to the littoral cell. The remainder of the sand passes landward of these canyons and must be retained in the littoral zone to nourish beaches further downcoast to maintain the function of the littoral cell.

All of the net littoral drift (longshore sand transport volume over time) at a canyon head could theoretically be artificially prevented from being permanently lost into the canyon without adversely affecting any beaches except possibly the one in the immediate lee of the canyon. While canyons capture sand from upcoast, their landward headcutting to reach a stable slope and profile is limited or restrained to an equilibrium condition. If sediment delivery from upcoast is prevented, the rate of landward canyon headcutting may be modified.

Canyons located off seaward protrusions in the shoreline tend to naturally capture much less of the net longshore sand transport volume than those that are adjacent to shoreline indentations (embayments). Sand more easily passes parallel to shore along a shoreline protrusion without being captured; capture is more likely along shoreline indents. This occurs because bathymetric contours are typically steeper and the littoral zone is correspondingly narrower around shoreline protrusions (e.g., Newport Point, Point Dume), and sand transport occurs closer to shore. In contrast, bathymetric contours are generally more gently sloping and the littoral zone is wider along shoreline embayments (e.g., Monterey Bay, Santa Monica Bay) and sand transport occurs farther from shore. All else

being equal, the capture rate is greater when the canyon head is close to shore than when it is distant from shore.

Some canyons have multiple, comparatively narrow, shallow-water heads or branches. If the ratio of the net to gross longshore sand transport rate (net transport rate/gross transport rate) is large, i.e., greater than perhaps 0.5 (meaning that sand movement is predominantly in one direction as it is in the canyons listed in Table 1, with the possible exception of Monterey Canyon), the upcoast head tends to capture more sand than the downcoast head. Similarly, in those canyons with a single comparatively wide canyon head, the amount of sand captured along the upcoast end tends to be higher than that captured in the downcoast portion.

Over time the rims of all canyons listed in Table 1 have migrated landward. Shorelines in the lee of these canyons have retreated as well. Differences in the rates of movement of the shorelines and canyon rims are responsible for the projecting or indented shorelines (Everts and Eldon, 2005). Major factors that dictate the rate at which the canyon rim erodes are: 1) the erosion resistance of the canyon rim to wave forces and sand abrasion; 2) the portion of time the rim is protected by a covering of captured sand; and 3) the effect of scour by rapid downslope sediment movement during episodic undersea canyon headscarp failures. A change in the sand cover can affect the canyon retreat rate. Any sand trapping project that removes the sand bound for a canyon before it reaches the rim would reduce the sand quantity accumulating along the rim over time, and therefore reduce the frequency of collapse of the rim and associated erosion of the canyon wall and head. This effect would likely slow the rate of canyon head retreat at that location and constitute another project benefit.

3.2 Benefits of Sediment Management at Submarine Canyons

The benefits of sediment management at submarine canyons consist of reduced losses of sand from the littoral zone and increased beneficial re-use of the sand at BECA's and other appropriate coastal habitat areas, in addition to the effect of reducing the rate of canyon headcutting and associated accelerated losses of littoral drift into the canyons. Benefits of reducing or eliminating sand capture in the five canyons will accrue by definition because sand is a valuable commodity and a natural resource. Benefits will differ greatly depending on the capture rate, how the "saved sand" is profitably used, and the costs of saving it, including the mitigation cost of dealing with adverse impacts. Since the cost to derive the benefit is potentially high, the true benefit can only be achieved when you consider the enhanced value of affected coastal environments and "value" in saving a natural resource.

Sand saved is sand gained. Benefits will be proportional to this amount and limited by the sand capture rate. This is one of the reasons only canyons with capture rates of 10,000 cyy or more are considered. Benefits of reducing or eliminating the loss of sand to submarine canyons fall into two categories. First and most obviously, the saved sand could be: (1) retained to widen the beach in the lee of the canyon; (2) passed around the canyon head to the downcoast beach, or "bypassed"; or (3) returned back to the upcoast beach or "backpassed." Bypassing and backpassing are used to widen and maintain nearby and distant beaches. Because there is a practical limit to the width of an enhanced beach adjacent to a canyon, bypassing and backpassing are the more likely scenarios.

In the second group of beneficial uses, the saved sand could be detained near the canyon and brokered with the proceeds used to offset the mining and selling operation, and to nourish other beaches within the littoral cell. Alternatively it could be used as a trade commodity to enhance or maintain artificially wide beaches at distant sites. In concert with the concept of "sand rights" the proceeds of this kind of enterprise, whatever they are, and the use of the sand should be applied to the littoral cell from which the canyon draws its sand.

3.3 Options for Sediment Management at Submarine Canyons

There are four general approaches to reduce or eliminate sand capture in a submarine canyon. An alternative option of permanently filling the nearshore head of a canyon to eliminate it as a trap is not considered because that is considered prohibitively expensive and impractical.

3.3.1 Project Option One – Trap Upcoast

In many instances the most realistic option will be to artificially trap littoral drift before it reaches a canyon. The location of the trap could be upcoast of the canyon or just inshore of it. A location just upcoast of the canyon head will usually be most efficient. Care should be taken to avoid creating a sand starvation zone between the trap and the coast in the lee of the canyon.

In places where the net to gross alongshore sand transport ratio is less than one, i.e., in all the locations identified in Table 1, the possibility exists that a reversal will carry sand from the downcoast beach into the canyon. If this situation were pervasive and could represent a large sediment loss, a structure to prevent upcoast transport into the canyon may be worth considering. An example is the Topaz Groin project at Redondo Beach in the South Bay region of Southern California.

This sand trapping option is the most feasible and is the one used as the basis for concept projects at suitable canyon sites identified in this study.

3.3.2 Project Option Two – Block the Rim

Another option is to artificially encourage and thereby increase the natural passage of the net longshore sand transport volume landward of the canyon head. Some sort of artificial barrier that functions like an underwater fence would be required to keep the alongshore-moving littoral sand from entering the canyon. The challenge would be to retain the longshore component of wave energy flux needed to move the sand in the structure's lee while at the same time the structure prevents the movement of sand over or through it, usually during a storm - not an inconsiderable conundrum and essentially technically infeasible. Due to these technical challenges, this sand trapping option is less feasible than option one, and is not considered further in this study.

3.3.3 Project Option Three – Dredge the Head

A third general option is to remove sand after it has been captured in a shallow canyon head. The procedure, either dredging with a floating plant or with a submerged pump system, will be repetitive and costly, but the canyon itself will serve as the sand trap.

Narrow scoop-shaped canyon heads best suit this option. Since they typically fill and flush in the winter during or after large storms, scheduling and accomplishing winter dredging could be uncertain. Such events are difficult to forecast.

The use of a floating plant would be hazardous in the open ocean during the winter. In addition to these impediments, removing captured sand from steep-rimed rocky canyon heads is likely to be difficult with a dredge because the deposits are thin and the headwall surfaces are irregular and often steep.

The alternative to dredging is a fixed or movable pump located in the canyon head. Jet pumps have been used to remove sand in harbors and to bypass sand at harbor entrances and this type of system might deserve consideration. It is noteworthy that these systems require on-going maintenance. Most of the maintenance requirements have been caused by marine organics, such as kelp, clogging the systems.

Due to these practical challenges, this sand trapping option is also less feasible than option one, and is therefore not considered further for a project in this study.

3.3.4 Project Option Four – Dredge the Downslope Deposit

The fourth option, which is presented to complete the range of choices, is economically and technically infeasible at the present. It involves the removal of littoral sand that has been flushed into permanent depositional sites, typically over a thousand feet deep. The advantage of targeting these deposits is that their volumes are huge. They accumulated over thousands of years of discharge through near-coast canyons and geologists have found many containing over a billion cubic yards of sand. Due to its infeasible status, this sand trapping option is not feasible and therefore not considered further for a project in this study.

3.4 Potential Adverse Impacts of a Project

An obvious potential adverse impact of any sediment management project at a submarine canyon would be the withdrawal of more sand than the canyon receives naturally. This situation would result in the sand trap capturing nearly all sand that moves behind (landward of) it, causing the canyon to headcut landward and erode the adjacent beach. If the captured sand is no longer available as a protective cover because it has been artificially trapped, and if the canyon rim is weak, the canyon head may advance at an accelerated rate in comparison to its “natural” rate. In contrast, canyon heads and walls experience scour due to abrasion by moving sand when the heads flush. Removing the scouring sand source might constitute a benefit.

Also, if sand trapped upcoast of a canyon were not bypassed to the downcoast beach at the existing sand delivery rate, the result would be a downcoast denial of sand. Where some portion of the net littoral drift now moves past a canyon, that rate must be maintained or downcoast beaches will suffer.

Other potential adverse impacts are those associated with the system(s) used to reduce or eliminate canyon sand capture, including the impacts of structures, bypassing plants, and

placement of sand on marine organisms. Swimmer, navigational safety, and aesthetic values are other impacts that must be considered.

4.0 EVALUATIONS OF SUBMARINE CANYONS AS POTENTIAL PROJECT SITES

Table 2 shows a list of the fifteen submarine canyons identified in this study, and five that meet the three criteria of: 1) trapping more than 10,000 cubic yards per year of sand; 2) existing in proximity to relatively high-use recreational beaches; and 3) able to supply sand to nearby BECAs. Four of the canyons that meet the criteria to be candidates for sand management are in Southern California and one is in Northern/Central California. Preliminary discussion of potential projects at each candidate canyon is also provided in this report section.

4.1 Monterey Submarine Canyon

4.1.1 Setting

Monterey Submarine Canyon is located in the indented center of Monterey Bay. It is the largest and deepest of all the submarine valleys along the California coast. By most accounts, it lies at the downcoast ends of two littoral cells. Figure 3 shows the location of the canyon, and Figure 4 shows a higher resolution image of the canyon head. One littoral cell lies to the north and the other to the south of the canyon, and sediment transport converges at the canyon. The Pajaro River discharges north of the canyon and the Salinas River discharges south of it. The canyon has three or four shallow water branches, depending on how they are defined. The northernmost one lies off the north jetty to the entrance to Moss Landing Harbor, the southerly one is adjacent to the Moss Landing Marine Laboratory, and the third lies near the south jetty to Moss Landing Harbor. The upper reaches of all the branches are within a few hundred feet of the shoreline. It is reasonable to assume the branch at the Moss Landing Harbor North Jetty captures most of the sand approaching from the north and the branches south of the Harbor entrance jetty capture most of the sand from the south. The canyon headwalls have not been observed for material characteristics. Shepard and Dill (1966) report rock was first encountered about 8 miles seaward from the head with only unconsolidated sediment in between.

A federal harbor exists at Moss Landing just south of the north branch. The harbor entrance is maintained with dredging by the USACE. A BECA, as identified by the State of California (CSMW, 2008) is located south of the canyon within the Southern Monterey Bay Littoral Cell. Also, the large (2,500-acre) federal Elkhorn Slough National Estuarine Research Reserve exists immediately adjacent to the canyon mouth and is undergoing erosion in critical areas of the preserve. Both of these sites need the sand that is presently lost into the canyon. The proximity of the BECA, the eroding Slough and the fact that the beaches in the vicinity of the Monterey Canyon are well utilized render this site as a probable candidate for a project.

4.1.2 Potential Benefits

Benefits will accrue proportional to the amount of sand that is backpassed or redistributed. Options include: (1) backpassing to the north, south, and redistributing

sand east from traps located on both the north and south sides of the canyon; (2) backpassing in only one coastal direction and/or redirecting it east into the Estuary from each of the two traps; or (3) backpassing or redistributing sand from only one trap (if the capture rate is only partially "saved"). In all cases, success will depend on where the backpassed or redistributed sand is placed.

Canyon	***Region***	***Characteristic***	***Project Candidate***
Mendocino	North Coast	Not near high-use beaches	No
Mattole	North Coast	Not near high-use beaches	No
Spanish	North Coast	Not near high-use beaches	No
Delgada	North Coast	Not near high-use beaches	No
Monterey	**Central Coast**	**Meets three criteria**	**Yes**
Carmel	Central Coast	Not near high-use beaches	No
Partington	Central Coast	Not near high-use beaches	No
Hueneme	**South Central Coast**	**Meets three criteria**	**Yes**
Mugu	**South Central Coast**	**Meets three criteria**	**Yes**
Dume	South Coast	Traps < 10,000 cy/yr	No
Redondo	**South Coast**	**Meets three criteria**	**Yes**
Newport	South Coast	Traps < 10,000 cy/yr	No
Carlsbad	San Diego Coast	Traps < 10,000 cy/yr	No
Scripps	**San Diego Coast**	**Meets three criteria**	**Yes**
La Jolla	San Diego Coast	Traps < 10,000 cy/yr	No

Table 2 – Candidate Submarine Canyons in California

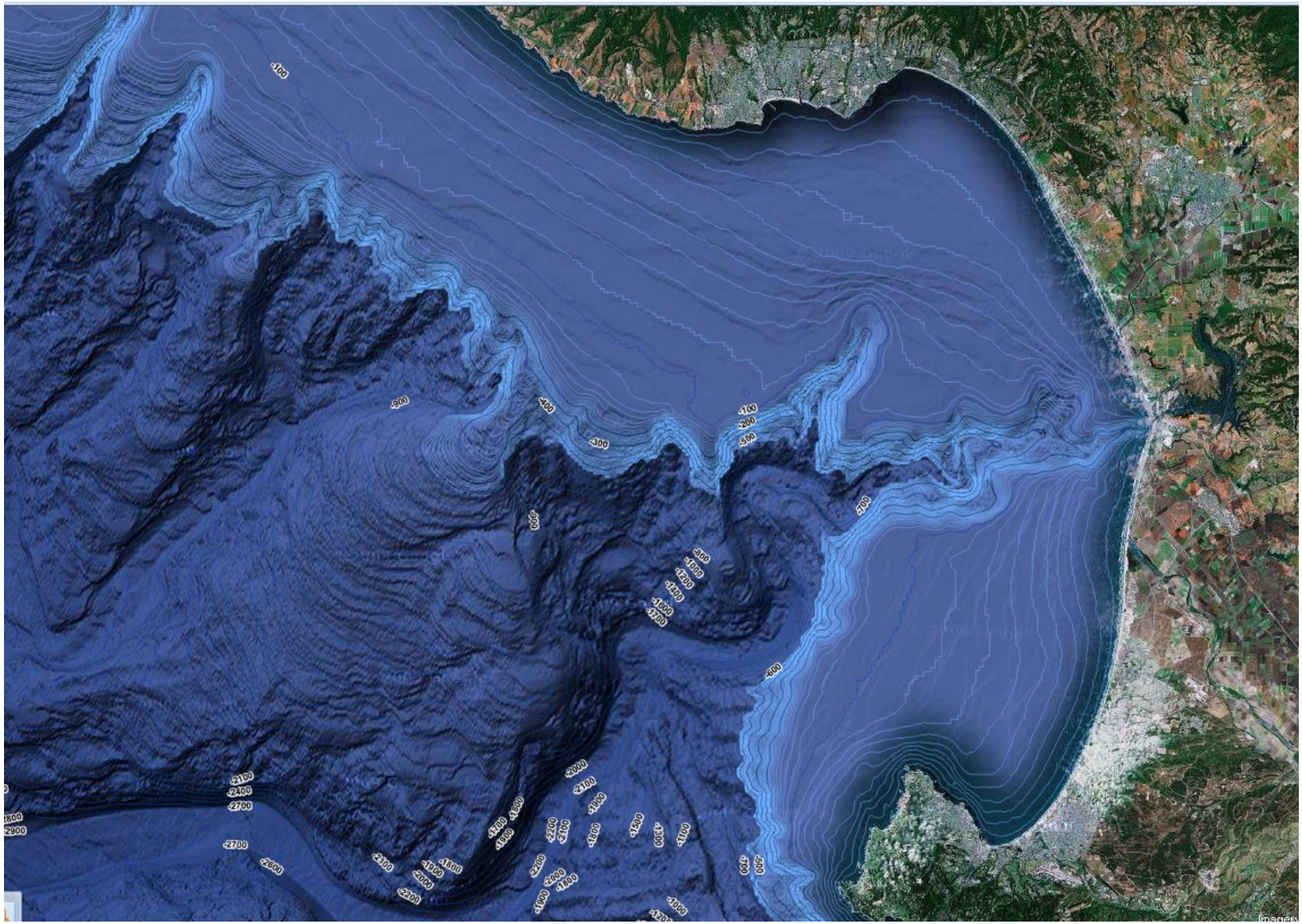

Figure 3 – Monterey Submarine Canyon
(Source: http://marinemap.org/marinemap/)

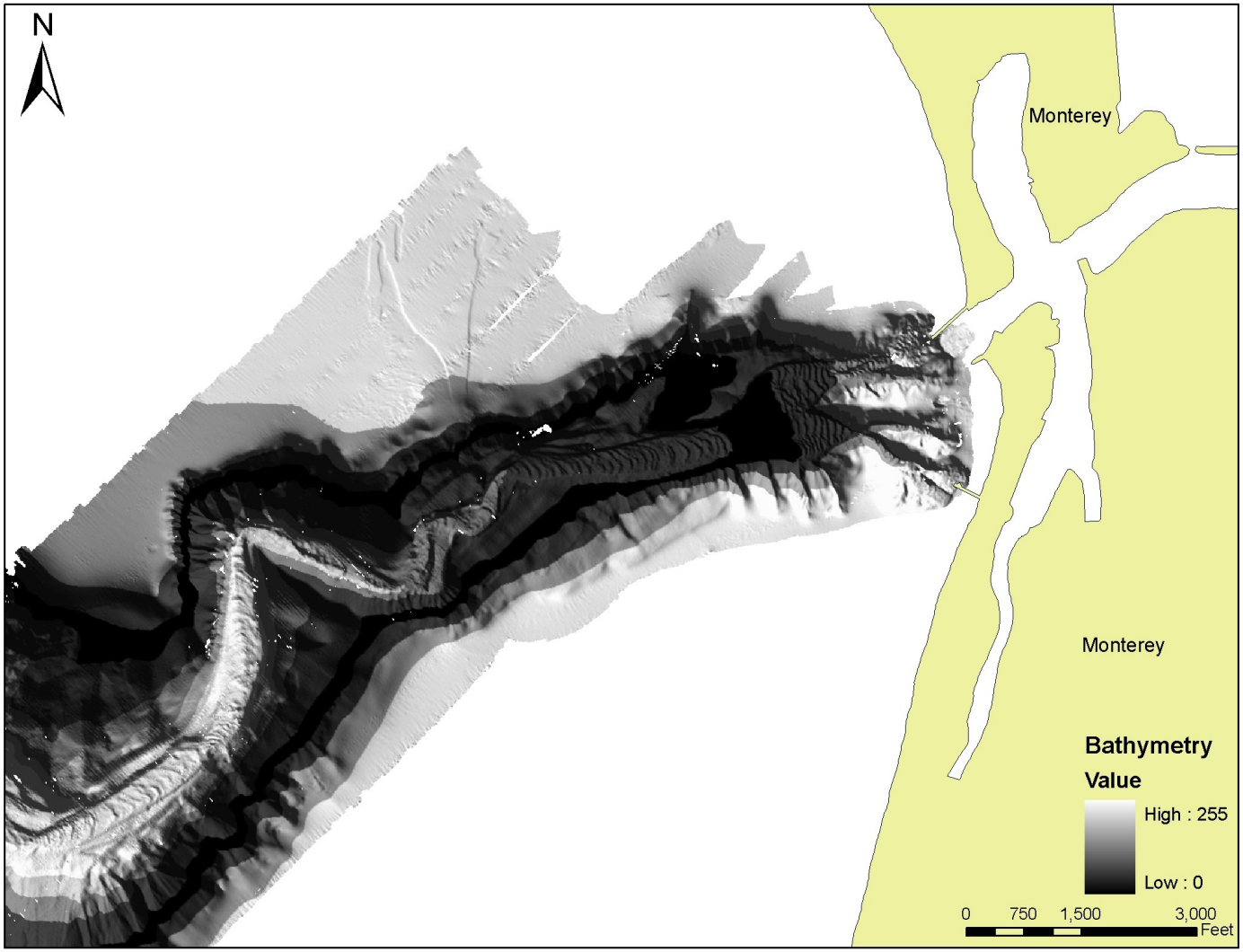

Figure 4 – Monterey Submarine Canyon Head
(Source: CA State University , Monterey Bay – Seafloor Mapping Lab, //seafloor.csumb.edu/SFMLwebDATA_mb.htm#CANYON)

4.1.3 Potential Sand Capture Scenarios

In order to save the entire capture volume, two traps would be required, one to the north of the north Moss Landing Harbor jetty and one just to the south of the Moss Landing Harbor south jetty. The north trap should be designed to catch an estimated 260,000 cyy of sand as downcoast impacts would not occur at this site (the canyon is at a point of convergence of sediment transport directions). The amount that must be caught in the south trap should be between an implied 490,000 cyy (Patsch and Griggs, 2007 estimate) and an estimated 65,000 cyy (Smith et al., 2005).

A trapping system proven effective from long-term observations is an offshore breakwater such as that now in place at Channel Islands Harbor in Oxnard. However, there are other trapping possibilities. The criteria of an effective trap are: (1) it immobilizes the entire or nearly the entire net littoral drift volume if located at the terminus of a littoral cell; (2) it retains the trapped sand in a small area amenable to artificial, but not natural, removal; (3) if a movable dredge is to be used, it creates a quiet region where a floating plant can operate in safety; (4) if a fixed plant is used it must immobilize sand within the range of the plant, an example being a groin with a dragline system fixed on the upcoast side; (5) if a mobile plant, such as a jet pump is to be used, the trap must hold the trapped sand within the range designated for that system or the pump(s) must be able to receive sand delivered naturally to the pump at a rate that proves economical.

A single trap would, of course, only be able to hold and backpass the net amount that reaches the canyon from the side of the trap location. The most effective side on which to provide a single trap will depend on whether the 490,000 cyy rate, the 65,000 cyy rate, or some other rate is the correct estimate for sand moving north to the canyon from the south. Another important consideration at this site is that an important surfing location exists a short distance north of the canyon so any project on the north side should not adversely affect that resource. The North Jetty to Moss Landing Harbor exists near the north side of the canyon that could serve as a platform for a jet pump system similar to that existing at the Nerang River in Australia (George Domurat, Personal Communication, March 7, 2007) and the experimental sand bypass system that existed at Oceanside, California in the early 1990's.

4.1.4 Possible Adverse Impacts

If indeed net transport converges in the lee of the canyon, then there are no beaches downcoast of the canyon in either direction. Therefore, preventing sand trapping of any amount captured would have no impact on beaches in either the littoral cell to the north or the south. However, constructing a structural sand trap north of the canyon could potentially cause a significant adverse impact to surfing just north of the North Jetty by blocking waves and modifying bathymetry. This option should not be pursued at Monterey Canyon. Any new or modified structures north of the Canyon should be placed outside or away from the surfing area.

4.2 Hueneme Submarine Canyon

4.2.1 Setting

Hueneme Canyon is located toward the downcoast area of a sand-rich littoral cell. Two large rivers, the Ventura River and the Santa Clara River episodically discharge huge quantities of sand upcoast of it. Under natural conditions, even though the distance from the shoreline to the single, and comparatively narrow, canyon head was only a few hundred feet, over 900,000 cyy of sand (M&N, 1995) passed along the shoreline protrusion in its lee. According to Herron and Harris (1966), Hueneme Beach, located just downcoast of the canyon as shown in Figure 5, was "extremely stable." In 1938 jetties were constructed to protect the entrance to Port Hueneme and all of the sand that was previously supplied to Hueneme Beach was lost into the canyon. A new scoop-shaped tributary formed just north of the north jetty as the conduit for this material. By 1948, the shoreline at Hueneme Beach had retreated over 600 feet and the erosion problem had progressed almost 10 miles downcoast. The problem has been mitigated by the federal Hueneme Canyon project with the artificial bypassing every two years of about 2.4 million cubic yards (mcy) of sand from behind a high, offshore breakwater on the upcoast side of the entrance to Channel Islands Harbor by the USACE. Some of this material is pumped to Silver Strand Beach, but most is discharged on Hueneme Beach, which is slowly accreting.

A second aspect of the Hueneme Canyon project is a small spur constructed approximately normal to the north Port Hueneme jetty as shown in Figure 6. Its objective was to reduce the movement of sand into the canyon from Silver Strand Beach, which is now dynamically stabilized with about 200,000 cyy of bypassed material from Channel Islands Harbor dredging. This amount is about what was captured under natural conditions. The balance of sand dredged from Channel Islands Harbor is bypassed farther downcoast to Hueneme Beach.

Hueneme Canyon is incised into the seaward edge of the Oxnard Plain, a subsiding series of alluvium interbedded with sandy beach and clayey lagoonal deposits (Crowell, 1952). The head is usually buried, and the rim is likely to be only moderately resistant to wave-caused scour, especially when accompanied by moving sand.

4.2.2 Potential Benefits

With the sand trapped near the canyon, it would have to be backpassed upcoast to near the south jetty at Channel Islands Harbor to ensure the effective maintenance of all of Silver Strand beach. If this system were implemented, the quantity of sand now bypassed from the Harbor to Silver Strand Beach could instead be completely bypassed to Hueneme Beach. The increase in sand delivery to Hueneme Beach under this scenario would be comparatively low compared to the existing bypassing rate from the Hueneme Canyon Project and would not constitute much of a benefit. It might be possible to bypass the sand even further to the east of Point Mugu toward the BECA's in the Santa Monica Littoral Cell, or alternatively to backpass the sand upcoast to Ventura toward four BECA's, but those options would involve a rather long transit and added costs.

4.2.3 Potential Sand Capture Scenario

The offshore breakwater at Channel Islands Harbor is a successful prototype of a trap. A similar offshore breakwater could be constructed just upcoast of Hueneme Canyon for the purpose of backpassing to maintain Silver Strand Beach. An extension of the small spur constructed approximately normal to the north Port Hueneme jetty (Figure 6) might also be used to create a quiet water zone from which to backpass.

4.2.4 Possible Adverse Impacts

Adverse impacts on beaches due to sand capture are slight. Surfing should not be impacted as no surf sites would be modified by this concept. A sensitive biological area exists at Hueneme Beach where a designated Critical Habitat Area exists for Snowy Plovers and Least Tern. Also, an Area of Special Biological Significance (ASBS) exists downcoast of the project site in the vicinity of Malibu where rocky reef habitat exists. Any effects of the project on sensitive biology would have to be mitigated as part of the project.

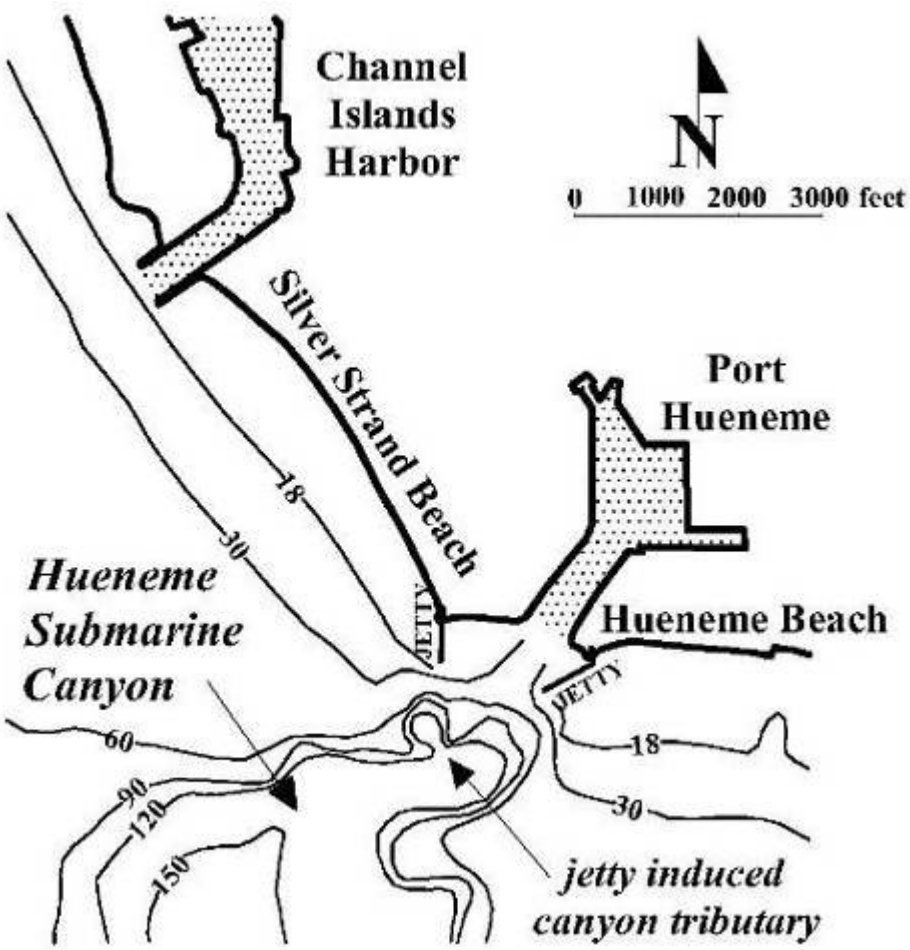

Figure 5 - Hueneme Submarine Canyon (from Everts and Eldon, 2005)

Figure 6 - Channel Islands Harbor Offshore Breakwater (Background) And Spur On The North Port Hueneme Jetty In The Foreground (From Everts and Eldon, 2003)

4.3 Mugu Submarine Canyon

4.3.1 Setting

Mugu Canyon is at the downcoast end of, and terminates, the Santa Barbara Littoral Cell and is located just downcoast of Hueneme Beach and Hueneme Submarine Canyon. It has a broad headwall broken in its alongshore middle by a projecting arm (see M&N, 1995 for details). Figure 7 shows the general canyon location within the box on the Figure, and Figure 8 shows the bathymetry of its head. The north embayment captures most of the sand being transported downcoast and bypassed around the Channel Islands and Port Hueneme Harbors. The headwall is about 4,000-feet long (parallel to the coast), nearly 150 feet high from toe to rim, steep (at an angle of 3:1, horizontal to vertical in dimension), and usually buried based on observations by researchers (Everts and Eldon, 2005). Qualitative observations show that once sand passes over its mostly covered rim it moves downslope in a thin veneer (Everts and Eldon, 2005). The gradient is at or just exceeds the underwater slope representing the angle of sand repose for the gradation of existing sediments at the site. The canyon rim substrate is very weak. It is composed of sedimentary material (siltstone) that is easily eroded by the oscillatory flow of passing waves (M&N, 1995).

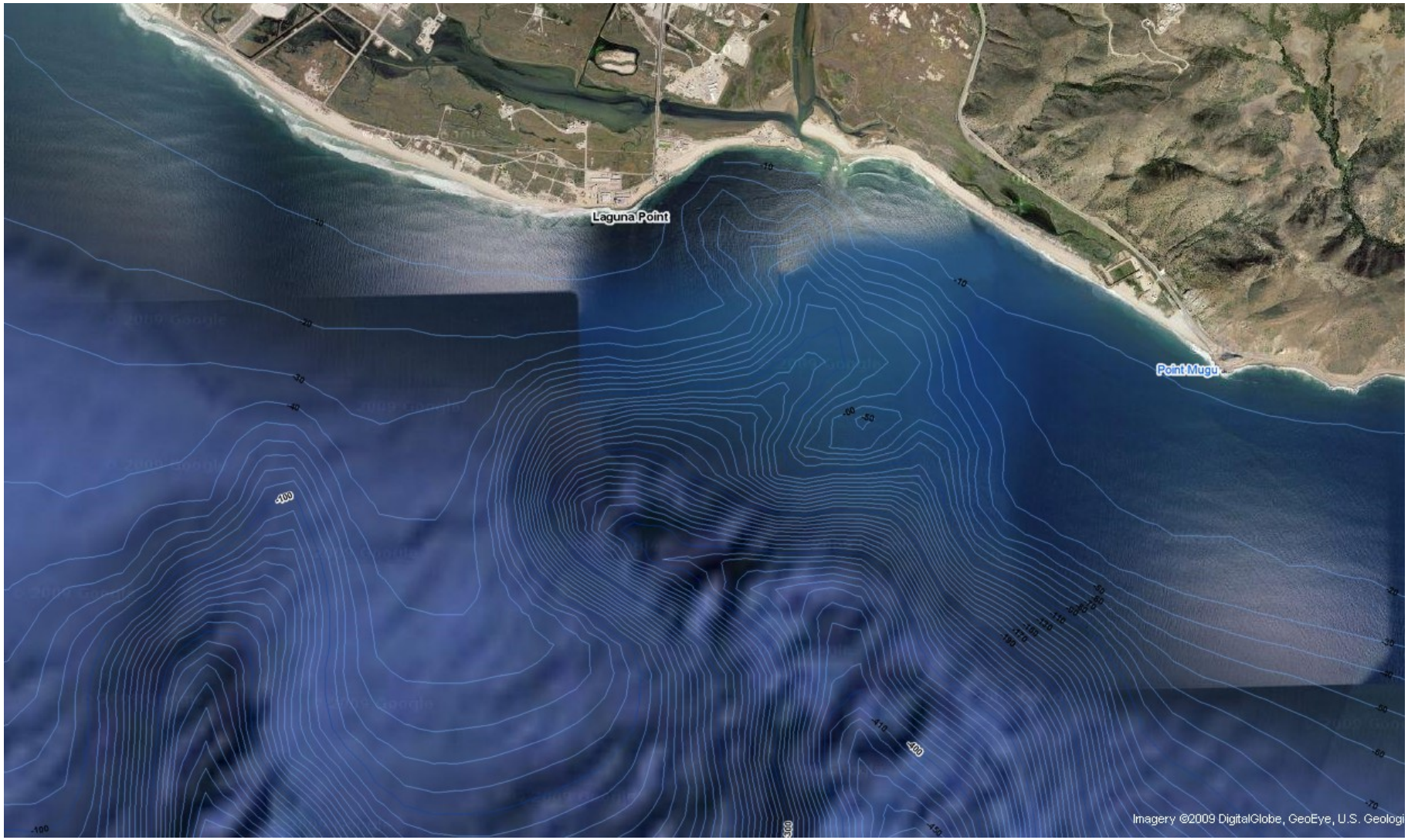

Figure 7 – Location of Mugu Submarine Canyon

(Source: http://marinemap.org/marinemap/)

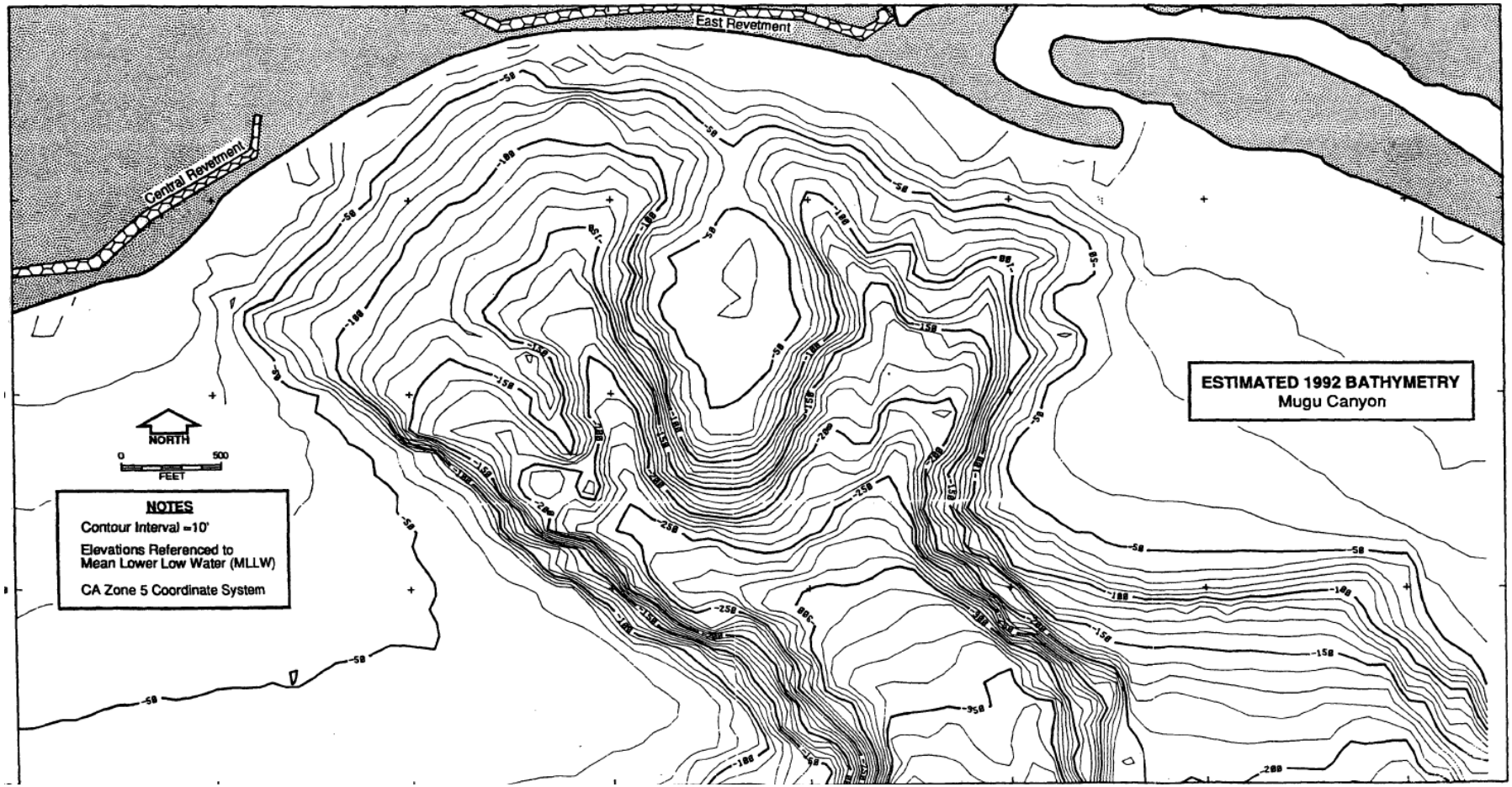

Figure 8 – Bathymetry of the Mugu Canyon Head

Between 1938 and 1995 the portion of the net longshore sand transport rate of 1,065,000 cyy that was captured in Mugu Canyon progressively increased from 0.88 to 1.0 as determined by measurements of the position of the canyon head relative to the shoreline in the canyon lee (M&N, 1995). In the 1960's a seawall was constructed at the back of the adjacent beach shown as the east revetment in Figure 8. In response to a retreating shoreline, the rim of the canyon intercepted the structure and progressively more of the net transport rate was captured. The result was a measurable level of shore retreat up to 15 miles downcoast. During a storm in 1995, the seawall was undermined and failed. Subsequently a large portion of what remained of the structure and many of the buildings behind it were removed. Afterward the beach reestablished its equilibrium width providing for the recovery of some of the alongshore transport that previously passed the canyon.

4.3.2 Potential Benefits

Mugu Canyon is a likely candidate for a project due to its relatively large capture rate (Table 1). If all of the captured sand were artificially placed and retained in the littoral zone (by also bypassing Dume Canyon) it could add, on a yearly basis, about 15 acres of new recreational and protective beach to the coast as far to the east as Marina del Rey, a distance of about 35 miles. There is disagreement among certain experts about the portion of littoral drift that passes Dume Canyon and is transported downcoast. As reported in Patsch and Griggs (2007), Inman (1986) estimates that 90% of longshore transport bypasses the canyon, while Orme (1991) estimates that only 10% of longshore transport bypasses the canyon, and Knur and Kim (1999) estimated that 30% of longshore transport bypasses the canyon. Everts and Eldon (2005, and Personal Communication 2007) estimated that sand capture at Dume Canyon was nominal and that sediment bypassing is greater than Inman's estimate of 90%. Four BECA'S exist downcoast of Point Mugu and upcoast of Point Dume, with eight more located throughout Santa Monica Bay. Sand bypassing around Mugu Canyon could potentially benefit all of these sites.

4.3.3 Potential Sand Capture Scenario

Artificial entrapment upcoast of the canyon with bypassing to a downcoast beach would seem a realistic option, especially since there is a successful precedent at Hueneme Canyon. This option is the project most likely to intercept and subsequently bypass sand that otherwise would enter the canyon. Due to technical and practical infeasibility discussed previously in this report, the other options to block sand loss to canyons are not considered.

4.3.4 Possible Adverse Impacts

Adverse impacts of any project must always be considered and that is especially true for this canyon. A project that removes the sand cover over its rim would possibly prove highly detrimental to a valuable coastal wetland. Because the headwall is composed of horizontal layers of fine to very fine sand and silt with weak bonds between grains it is highly susceptible to scour by the oscillatory action of waves alone. Moffatt & Nichol (1995) with assistance from Craig Everts notes the headwall retreat rate is function of: (1) the wave and current energy expended in producing scour-causing shear stresses; (2) the

resistance of the headwall to those factors; and (3) the extent of the headwall surface that is exposed at any given time. They estimate its recent retreat rate at about 1.7 feet/year when it was covered with a layer of littoral sand over 95 percent of the rim. Artificially preventing sand from entering the canyon thereby uncovering its headwall would do away with that protection. With the headwall exposed to wave forces most of the time M&N and Everts concluded it would withdraw toward land at 10-15 feet/year with 100% of the substrate exposed.

The headwall is very near a narrow sandy barrier spit that protects Mugu Lagoon, one of the few coastal wetlands remaining in southern California. An almost 10-fold increase in its retreat rate described above would soon put that valuable environment at risk. This is the only canyon that is characterized by a sensitive habitat immediately adjacent to the beach located in the canyon lee. The remaining canyons discussed herein are adjacent to either harbor entrances or upland areas.

The solution to this likely adverse impact involves a number of questions. First, what is the relationship between the sand cover over the rim and the amount of sand that is captured? It might be that by artificially trapping less than the amount that is presently captured in the canyon, but still a substantial and beneficial amount, that a small reduction in sand cover over the headwall would translate to an acceptable adverse effect on the headwall retreat rate. Second, what could be done to increase the resistance of the headwall to wave-caused scour? Would it be feasible or even possible to place a protective cover over the estimated 1 to 2 million square feet of headwall to halt its retreat? Or third, might it be somehow possible to inject the headwall with a "hardener" that would accomplish the same objective? Measures to attenuate wave action on the headwall are unlikely to be successful since it is unlikely the canyon substrate would support much in the way of a structure.

4.4 Redondo Submarine Canyon

4.4.1 Setting

Redondo Submarine Canyon is located near the downcoast end of the Santa Monica Littoral Cell. The shoreline in its lee is slightly indented as shown in Figure 9. Crowell (1952) indicates the upper part of the headwall is composed of recent dune sand and "coastal" deposits. This apparently weak material is likely to be relatively easily eroded if exposed.

Before the north breakwater at King Harbor was constructed in 1938, the canyon captured nearly all of the net longshore sand transport at the south end of its littoral cell, as it does today. However, not all of it was captured immediately as a small amount passed along the indented shoreline landward of its headwall and nourished what is now the two-mile long beach at Redondo Beach State Park (RBSP). An unknown portion later reversed direction, moving upcoast and into the canyon. The quantity that remained was enough to maintain a stable shoreline between the canyon and Palos Verdes Peninsula. After the breakwater was constructed the entire net longshore transport volume was captured immediately upon reaching the canyon. Over the subsequent period of about twenty

years sediment starvation caused the RBSP shoreline to retreat to the base of a seacliff behind the beach. In 1960, one of the most successful beach enhancement projects in California alleviated the problem. The U.S. Army Corps of Engineers added beachfill from an offshore source and installed a terminal groin. The sandfill widened the eroded beach, and the groin constructed at Topaz Street prevented most if not all of it from moving north into the canyon. Wave divergence due to refraction over the underwater valley appears to be an important factor inhibiting alongshore-transported sand from moving past that groin. This is a case where a sediment-blocking structure eliminated the effect of alongshore transport reversals that had carried sand into a canyon. At least through 1990, the beach at RBSP remained near its original artificial width (Everts and Eldon, 2003).

In its natural state Redondo Canyon accepted sand from the littoral zone along most of its broad rim. Now it appears that a new and more constricted conduit is the main path for sand entering the canyon and moving downslope (Figure 9). The upper part of this scoop-shaped reentrant lies in a water depth of less than 30 to 50 feet. It is located less than 200 feet from the south end of the outer leg of the breakwater and it appears similar to the one that was created off the north jetty at Hueneme Canyon (Figure 5). Patsch and Griggs (2007) indicate that this canyon traps only a limited quantity of sand due to the success of sand retention upcoast, but they do not provide an estimate.

4.4.2 Potential Benefits

In contrast to Patsch and Griggs (2007), Everts and Eldon (2005) indicate that Redondo Canyon is a case where the net longshore sand transport rate seems to have increased in recent years. They state that this makes it a more desirable candidate for some sort of interdiction (Everts and Eldon, 2005). Based on a sediment budget analysis using Coastal Frontiers (1992) survey data, Everts Coastal (2003) speculated the capture rate might have doubled or even tripled between 1938 and 1990. They hypothesize that massive beachfills that widened the upcoast beaches are responsible for the increase in the net longshore sand transport volume reaching the canyon.

4.4.3 Potential Sand Capture Scenario

This option calls for backpassing most of the net longshore sand transport volume to upcoast beaches (or for making some other valuable use of the sand). An amount equal to the amount lost, if any, on the downcoast beach must be bypassed. This amount was nil at least through 1990 (Everts and Eldon, 2005), but should a loss occur in the future a plan should be in place to address it.

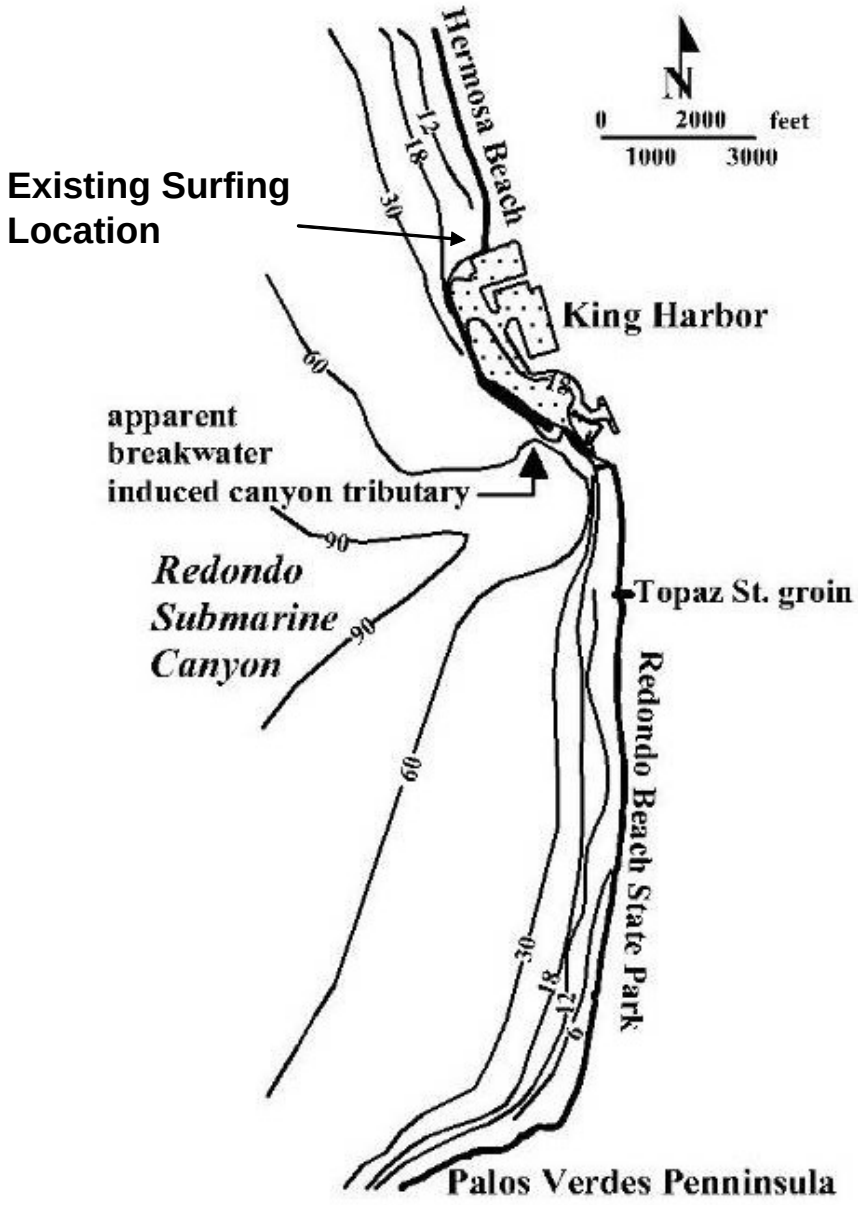

Figure 9 - Redondo Submarine Canyon (from Everts and Eldon, 2005)

4.4.4 Possible Adverse Impacts

Sand capture in a submarine canyon located near the end of its littoral cell has no obvious adverse impact on a downcoast beach as long as the amount needed is artificially provided. The goal would be to maintain the RBSP beach at its mean width during a period of rising sea level and to make up for any sand lost to the canyon around the Topaz Street groin. An additional need may be to maintain the sandy shore between the groin and the harbor, a distance of about 3,000 feet. The canyon's presence is not a negative

factor in the health of any upcoast beach. Any upcoast sand trap could significantly affect surfing at the high-quality South Bay surf spot at Redondo Breakwater and therefore be controversial.

4.5 Scripps Submarine Canyon

4.5.1 Setting

Like Redondo Canyon, Scripps Canyon is located near the end of its littoral cell with a relatively short, but highly prized beach downcoast of it. The shoreline in its lee is indented. Scripps Canyon has at least six branches as shown in Figure 10. Their headwalls are scoop-shaped and just a few hundred feet wide or less. The walls are resistant to erosion and in many places vertical or even overhanging. Because of their mild slopes (less than the 33-36 degrees angle of sand repose) the floors are buried most of the time. Exposure is normally of short duration just after the infill deposit has been evacuated. The capture rate is highest in the Sumner Branch, the most upcoast of the branches located close enough to shore to capture sand. Even though South Branch is about the same distance from shore and immediately downcoast, Sumner Branch captures about 10 times as much littoral sand. Indeed, Sumner Branch captures over 90 percent of all the littoral sand that is lost in Scripps Canyon (Everts and Dill, 1988).

4.5.2 Potential Benefits

La Jolla Shores is the downcoast beach and is now in near dynamic equilibrium. At present only about 3 to 5 percent of the littoral drift reaches the beach after passing landward of Scripps Canyon. Some sand is retained in the littoral system and the rest of the littoral drift is lost in La Jolla Canyon (Everts and Eldon, 2003). If all of the sand that reaches Scripps Canyon from the north were allowed to pass to La Jolla Shores, that beach would no doubt be wider. The extent of its expansion is not easy to forecast without a detailed analysis. In any event, almost all of the sand that bypasses the canyon would later be lost in La Jolla Canyon.

Most of the sand that is “saved” would probably best be utilized by backpassing it to beaches up to 10 miles to the north toward the locations of BECA’s at Carlsbad, Encinitas and Solana Beach. The benefit would be proportional to the distance it is backpassed. This is because as sand moves downcoast the benefits are proportional to the length of the coast it transits before it requires backpassing. But the cost of backpassing would also be relative to that distance, regardless of the backpassing technology. It might be best to backpass to the next upcoast erosion hotspot which would be Solana Beach according to CSMW (2008). In addition, the visible benefits in a wider beach will probably be lost in a relatively short distance. A study of the fate of bypassed sand at Oceanside Harbor found that positive effects were no longer noticeable south of Buena Vista Lagoon. South Oceanside Beach would serve as a possible feeder to North County San Diego BECA’s, although it may be located prohibitively far away to make such an operation economically-justifiable.

4.5.3 Potential Sand Capture Scenario

A trap, such as the offshore breakwater at Channel Islands Harbor, accompanied by the bypassing of a small amount to La Jolla Shores and the backpassing of a larger amount to an upcoast erosion hotspot (or especially popular beach that is too narrow for the recreational need), is probably the most feasible project. The bypassing system could be a floating plant – dredge – or some sort of fixed or mobile land device like the jet pump that was used in the past at Rudee Inlet, Virginia. The goal would be to remove from the salient in the lee of the breakwater the net longshore sand transport volume on a systematic basis. The length, height, and distance from shore of the breakwater will be dictated by the size of the salient and the bypass/backpass frequency.

4.5.4 Possible Adverse Impacts

Scripps Submarine Canyon is located off Blacks Beach and the Torrey Pines Beach. Its resistant and usually exposed rock walls are marine habitat, unlike the usually buried headwalls of the other canyons. Any in-canyon option would have to consider this situation. Also, any upcoast trap could significantly affect surfing at the world-class surf spot known as Blacks Beach and therefore be highly controversial.

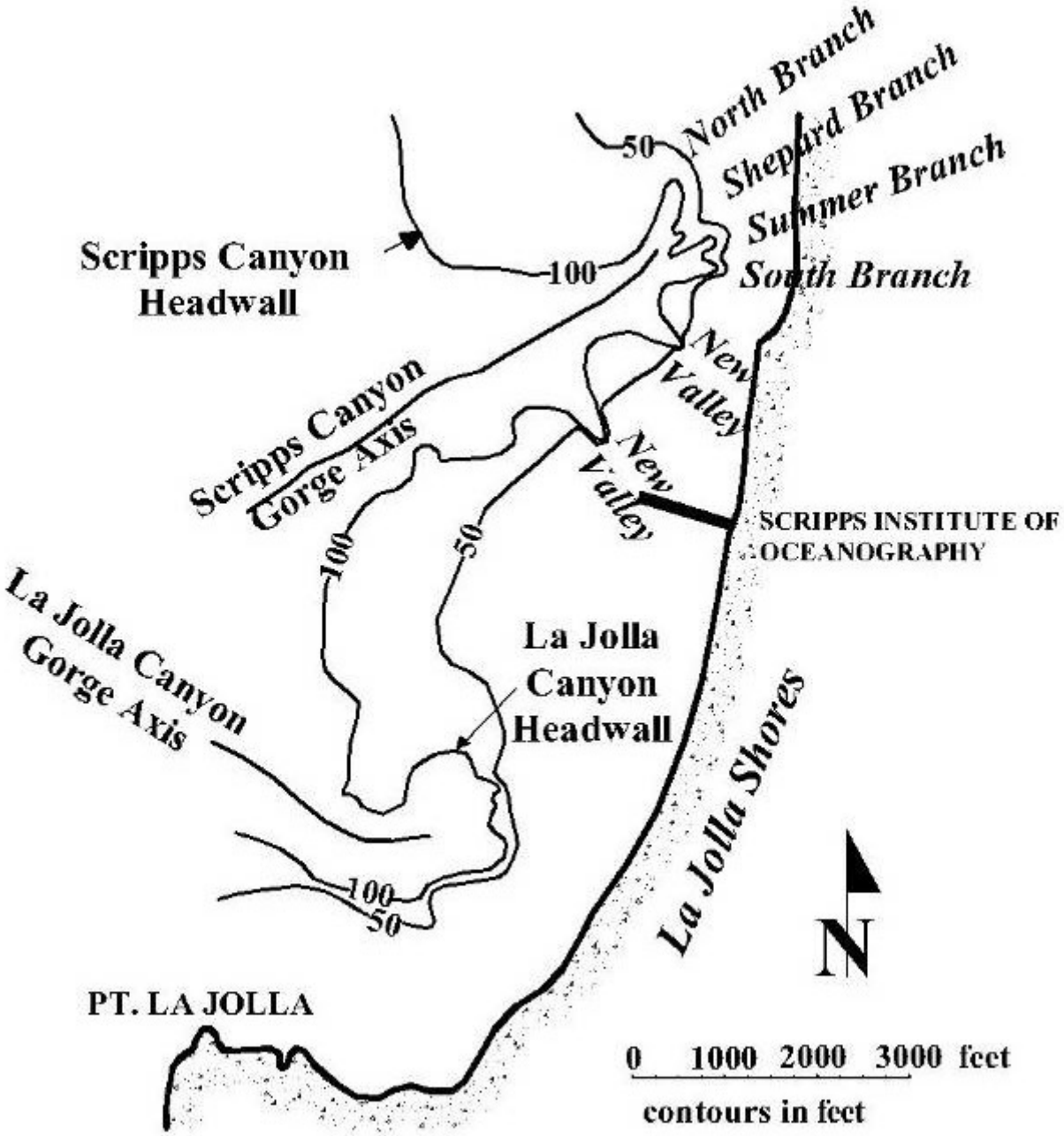

Figure 10 - Scripps Submarine Canyon (from Everts and Eldon, 2005)

5.0 EVALUATION CRITERIA

This report focuses on five near-coast submarine canyons in California. Each captures more than 10,000 cubic yards of littoral sand per year, is located near one or more prime urban or suburban beaches, and can supply sand to a BECA in the vicinity. Each of those beaches would benefit by artificial widening if the captured sand were bypassed or backpassed and placed upon them, thus potentially addressing or eliminating certain BECA's.

Table 3 lists potential canyons and an evaluation of benefits, feasibility, and adverse impacts. The offshore breakwater at Channel Islands Harbor in Ventura County serves as a model for feasibility assessment of trapping sand within a structural shelter. A variation on the upcoast trap concept is installation of a jet pump system on a structural platform (e.g., a pier), similar to the prototype at Nerang River in Australia and the experimental sand bypass system at Oceanside, that allows sand to be intercepted on its journey downcoast toward the canyon and pumped to a target receiver site. Adverse impacts, not including environmental and aesthetic ones, include beach erosion, especially on downdrift beaches that result from a project, increased retreat of the canyon headwall toward the coast, endangering critical habitats, and impacts to surfing from a structure.

Table 3 is a subjective summary, from low to high, of the evaluation items provided in the previous section. A low rating in the benefits column is a judgment that little benefit would be realized. On the other hand, a high rating in the benefits column is a judgment that the project would likely produce a very substantial benefit. Conversely, a high rating in the impacts column indicates significant adverse impacts very well might occur and mitigation is very likely to add to the complexity and cost of the solution. The averages at the bottom are offered for comparison purposes. The benefit average, for instance, provides a means to compare the potential benefits of saving the sand in a specific canyon with the potential benefit averaged for all five canyons.

Submarine Canyon	***Potential Benefits***	***Upcoast Trap Feasibility***	***Possible Adverse Impacts***
Monterey	High	High	Low
Hueneme	Low	Medium	Low
Mugu	High	High	High
Redondo	Medium	Medium	Low
Scripps	Medium	Medium	Medium
Average	Medium-High	Medium	Medium-Low

Table 3 – First-Order Summary Of Benefits, Feasibility And Adverse Impacts

While quite a bit is known about submarine canyon capture processes and rates in Southern California, the capture rate in Monterey Canyon, especially that reaching it from the south, is less clearly known. Estimates are based on sediment budget analyses that rely on river discharge estimates. While a multi-year in-canyon measurement program has occurred in Southern California canyons (Everts, 1988, with M&N in 1995, and 2005), such a program has not yet been undertaken in any of the three Monterey Canyon branches to our knowledge. That should occur before a project to capture sand at that location is undertaken. Environmental issues that would surely arise with any of these options have similarly not been covered. However, the potential benefits of a project at the canyon by solving the problems at the nearby BECA and Elkhorn Slough outweigh uncertainties. A project at Monterey Canyon is considered justifiable at this stage, however regulatory constraints exist that may pose serious issues to any project at this site.

Redondo Canyon initially appeared promising as well, but the feasibility of removing sand from the canyon head is relatively poor compared to other sites. Mugu Canyon presents an opportunity that is technically most feasible with the most significant benefits. Although potentially significant impacts could also occur, proper design and construction would likely offset them.

The list of canyons was further evaluated to identify which ones make most sense for potential projects considering benefits and costs, and Mugu Canyon and Monterey Canyon both appear very promising. As shown in Table 4, after discussions with USACE staff, Mugu Canyon and Monterey Canyons are chosen as project sites due to the overwhelming benefits from projects at those locations compared to other canyons. A project at Mugu Canyon also presents the greatest potential for adverse effects and therefore needs to be very carefully considered.

Canyon	***Considerations***	***Recommended for Concept***
Monterey	**Capture rate defined from the north, and it benefits both a local BECA and federal Elkhorn Slough Reserve**	**Yes**
Hueneme	Lower capture rate, lower benefit to cost ratio, possible impacts to surfing	No
Mugu	**Highest capture rate, benefits longest downcoast reach with high-use beaches and BECAs, high benefit to cost ratio**	**Yes**
Redondo	Moderate capture rate, benefits high-use beaches, moderate benefit to cost ratio	No
Scripps	Lowest capture rate, lower benefit to cost ratio; possible adverse impacts to surfing	No

Table 4 – Submarine Canyons Recommended for a Concept Project

6.0 CONCEPT PROJECTS

Concept projects at Mugu and Monterey Canyons are presented herein. Benefits of a project in Scripps, Hueneme, and Redondo Canyons are likely to be less than the benefits derived from projects in Mugu and Monterey Canyons.

6.1 Selected Canyons

The justification for the selection of Mugu and Monterey Canyons for project sites follows.

6.1.1 Mugu Submarine Canyon

Mugu Canyon is an obvious candidate because it has by far the largest capture rate of any of the California canyons and the beach downcoast is narrow for 30 miles (including potentially all of Malibu if sand bypasses Dume Canyon). This option is conceived based on assuming that the loss of sediment into Dume Canyon is less than 10,000 cyy (Everts and Eldon, 2005). After beaches in that long reach have equilibrated at a greater mean width with an enhanced longshore sand transport volume, the increased littoral transport would affect the beaches at Santa Monica and Venice, and finally the north side of the entrance to Marina del Rey. From there the added material could be bypassed to maintain the coast south of the marina all the way to King Harbor. Almost all of the beaches in Los Angeles County would then be positively affected. These beaches serve many millions of people. The benefits would be tremendous, especially now that river discharge is not providing as much sand as it did in the past, sea level is rising at an ever increasing rate, and opportunistic sand that was previously a major nourishment source is no longer such a large factor in the sand budget. A project at Mugu Canyon would assist and benefit the federal project at Channel Islands Harbor by retaining sand that was initially bypassed within the littoral system for a longer period of time.

The downside to such a project at the Mugu Canyon site is the expected increase in the retreat rate of the weak and easily eroded canyon headwall and its effect on the Mugu Lagoon wetlands. If the headwall retreated at 15 feet/year, as M&N (1995) with Everts suggests is a possibility if its sand cover is completely lost, in a century well over half of that valuable resource would be destroyed. This would be an unacceptable loss. To retain anywhere near the current estimated 1.7-feet/year headwall retreat rate the solution to this problem might be to bypass only a portion of the amount that is now being captured and allow the remainder to enter the canyon and provide a covering for the headwall. The bypass to capture ratio versus the headwall retreat rate is subject to additional analysis that is presently beyond the scope of this study.

6.1.2 Monterey Canyon

Multiple benefits would occur from a project at Monterey Canyon. The littoral cell south of the canyon is a BECA with sand mining still occurring just above the mean high tide line. Also, extensive tourism and coastal-dependent uses exist within the south end of the cell. Finally, the federal Elkhorn Slough National Estuarine Research Reserve adjacent to the canyon head experiences extensive headcutting and erosion that can only be solved on

a large scale, such as nourishing areas of the Slough with coastal sediment. Such a concept would provide massive environmental benefits with few discernible adverse impacts. The only potential impacts could be turbidity increases over small scales and direct burial of the active beach area during sediment placement. Research opportunities and funding from a project would also be extensive due to the site's proximity to the Moss Landing Marine Laboratories.

The most significant existing constraint to a project along the Southern Monterey Bay Littoral Cell is that it is located within and subject to regulations of the Monterey Bay National Marine Santuary. Sanctuary regulations presently limit discharges of dredged material to ocean disposal sites presently approved by the USEPA and USACE (U.S. Code of Federal Regulations, 1993). Permits can be secured from the Sanctuary Superintendent for new activities that do not adversely affect the Sanctuary. It is assumed for purposes of planning that a permit would eventually be able to be secured to move beach sand from one portion of the coastline to the other within the Sanctuary. This assumption may prove to be false at some point if the Sanctuary Superintendent does not issue a permit. The URL that describes regulations and permits for the Sanctuary is: http://montereybay.nos.noaa.gov/resourcepro/regulations.html.

6.2 Concept Projects

6.2.1 Mugu Submarine Canyon

Mugu Canyon lends itself to a project that captures sand prior to its loss into the canyon. Two concepts are presented here for consideration. Concepts consist of:

1. Creating a sand trap behind a breakwater that is hydraulically dredged; and
2. Hopper dredging a nearshore area and maintaining it as a perpetual shoaling basin.

The rate of sand bypassing should be below the threshold that could cause a depletion or reduction of the protective sand cover at the canyon rim. This rate is tentatively estimated to be a modest portion (20%) of the net longshore sediment transport rate of approximately 1,065,000 cubic yards per year (Patsch and Griggs, 2007), or a bypassing rate of 200,000 cubic yards per year.

Bypassing 20% of the net longshore transport rate at this location may impact the protective cover over the Mugu Canyon rim. Follow-up studies, measurements, and observations should occur to confirm or verify that impacts are not occurring and the retreat rate of the canyon head remains about 1.5 feet per year. Other options are not practicable concepts for this site.

Trap Upcoast With A Breakwater

A trap in the lee of an offshore breakwater along the design lines of the prototype at Channel Islands Harbor is an option for Mugu Canyon. Figure 11 shows an existing sand trap behind a breakwater in Oxnard that serves as a prototype for a concept at Mugu Canyon. The trap structure at Mugu would best be located just upcoast of the western

Figure 11 – Upcoast Sand Trap At Channel Islands Harbor as a Model for Mugu Submarine Canyon

landward portion of the canyon. Figure 12 shows the bypass concept for Mugu. The dredge plant could be a hydraulic cutterhead suction dredge pumping a slurry downcoast of Point Mugu. The dredge discharge line could either be a submerged line in the ocean or a stationary line placed on the beach across the lagoon mouth. One booster pump would be needed to pump the material from the sand trap to the downcoast discharge point. Bypassing would ideally be divided between two points, including a small discharge just downcoast of the east landward part of the canyon to feed the local beach near the lagoon mouth, and a major feeder point east of Point Mugu and downcoast of Mugu Rock to feed a large reach of Los Angeles County. This would maintain the beach between the canyon and the point. If only a portion of the net volume reaching Mugu Canyon from the west is trapped and bypassed, bypassing directly east of Point Mugu would be suitable since sand will likely move landward of the canyon to nourish that reach anyway. Thus the larger remainder of the bypass volume would be discharged east of Point Mugu to begin its journey toward Marina del Rey. Infrastructure from this type of project would be very difficult to remove if it were determined that the project caused adverse impacts to the site.

To mimic the Channel Islands Breakwater site, the breakwater at Mugu would have to be constructed 2,000 feet offshore and be approximately 2,000 feet long, with a crest elevation of +15 feet relative to mean lower low water (MLLW). The objective will be to trap only a modest portion of the net longshore transport rate and allow for a larger portion of the rate to pass the trap and reach the canyon head to maintain the protective sand cover over the rim. Figure 13 shows a typical cross-section of the breakwater for the sand trap. Further analysis needs to be performed to design the breakwater to fit the site conditions. Breakwater elevation and length could be modified as needed to optimize project effects and manage costs.

Monitoring will be required of the potential project effects on the canyon rim, and impacts at the beach in the canyon lee, and the beach at and downcoast of the placement site. If monitoring results show no adverse effect to the canyon rim and no threat to Mugu Lagoon from the project, then the breakwater could potentially be extended to block a longer reach of coast and trap more sand for bypassing.

An alternative dredging technology known as the Punaise system could be used at this site. The Punaise system is applied in the Netherlands and is a floating nozzle-shaped unit that is a pin-point removal approach that is effective for mining sand (George Domurat, Personal Communication, March 7, 2007).

Construction costs for this breakwater sand trap concept are estimated to be $45.0 million assuming construction occurs in 2015, with maintenance dredging costs being $10.8 million if done every four years. Table 5 below shows the estimated costs for this concept and the itemized costs are shown in Table A-1 and A-2 in Appendix A. The dredging costs could be reduced if the project is coupled with maintenance dredging of the Channel Islands Harbor location and mobilization costs are shared, thus the project could occur at two- to four-year intervals.

Figure 12 – Upcoast Sand Trap Concept at Mugu Submarine Canyon

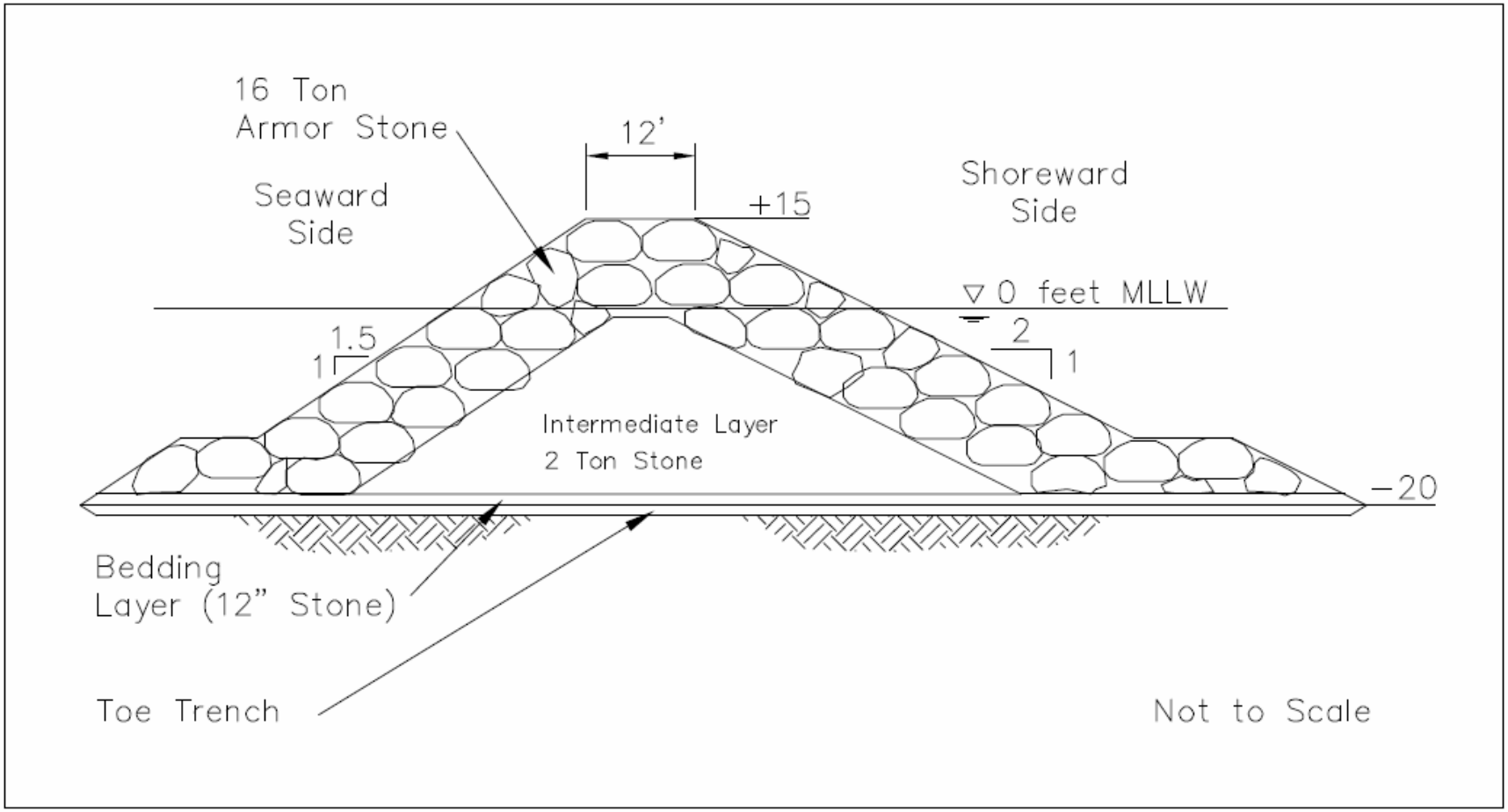

Figure 13 – Typical Section of Upcoast Sand Trap Breakwater Concept at Mugu Submarine Canyon

Item	*Cost*
Breakwater (One Time Cost)	$45,000,000
Dredging (Once Every 4 Years)	$10,800,000
Total of First Time Costs	**$55,800,000**

Table 5 – Costs for a Trap Upcoast With a Breakwater at Mugu Canyon

Trap Upcoast Without A Breakwater

An alternative to the protected sand trap described above is the option of simply using a hopper dredge to create an offshore pit to serve as a physical sand trap for future mining to feed sand downcoast. Figure 14 shows the concept plan for the alternative and Figure 15 shows a conceptual cross-section. The offshore area to be dredged would be just inside (landward) of the depth of closure, in depths between approximately -20 and -30 feet MLLW. Dredging would occur to initially pass a quantity of sand that represents a modest portion of the net longshore sediment transport rate around the canyon. This dredging would essentially create a large depression that would serve as a sand accumulation area over time that could be re-dredged perpetually in the future. As long as the quantity removed does not exceed 200,000 cubic yards per year initially, dredging can occur at whatever frequency is most economical, environmentally acceptable, and otherwise reasonable.

This option requires no new infrastructure and would not be difficult to abandon if it were determined that the project caused adverse impacts to the site. Also, the volume of material to be dredged could readily be modified to reflect conditions identified through monitoring. For instance, if negative impacts to the canyon rim were identified that threatened Mugu Lagoon, the dredge volume could be reduced to a smaller amount that would cause less impact. If no impacts were identified anywhere from the operation, then the dredge quantity could be increased with minimal effort (other than the increased dredging operation).

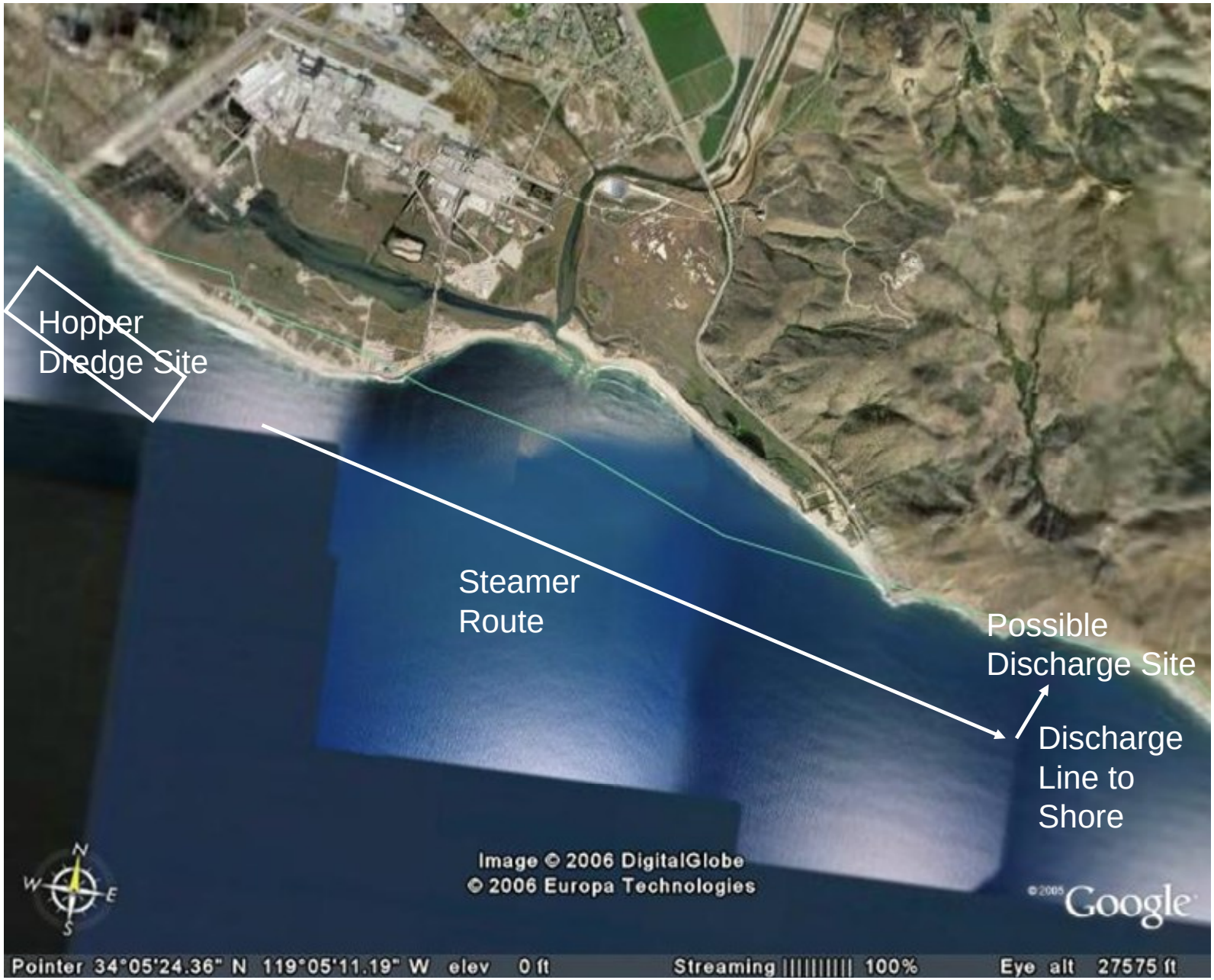

Figure 14 – Upcoast Sand Collection Basin Concept at Mugu Submarine Canyon

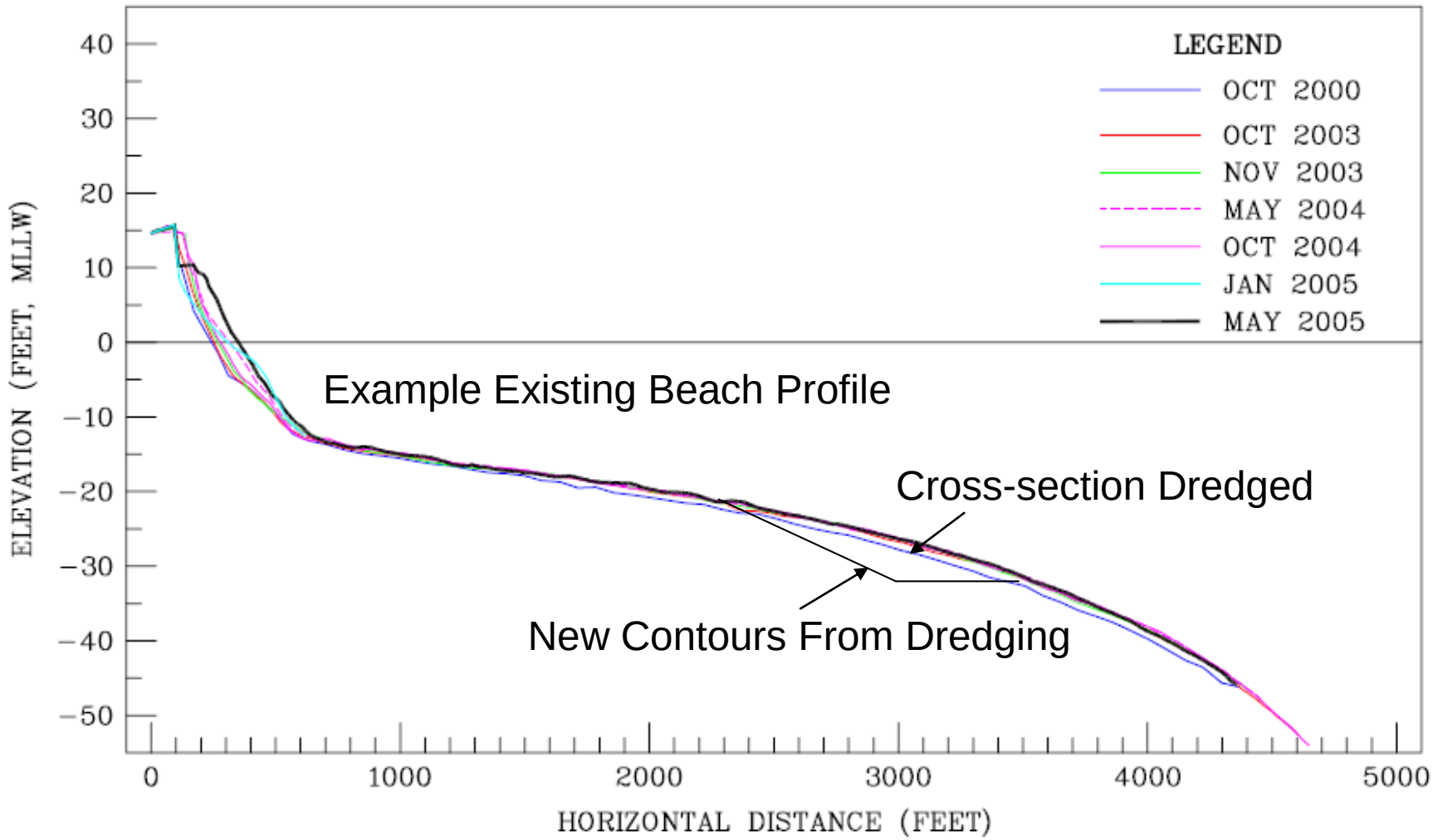

Figure 15 – Typical Section of Upcoast Sand Collection Basin Concept at Mugu Submarine Canyon

Construction costs for this sand collection basin concept are estimated to be $7,500,000 every four years assuming construction occurs in 2010. Table A-3 in Appendix A shows the estimated costs for this concept. The project would likely not be able to be coupled with the Channel Islands Harbor dredging project due to different equipment being used (a hopper dredge versus a hydraulic dredge), thus mobilization costs cannot be shared and would remain as estimated herein. The hopper dredging project is more economical than the structural sand trap project in bypassing sand around Mugu Canyon.

6.2.2 Monterey Submarine Canyon

Monterey Canyon lends itself to a project that captures sand prior to its loss into the canyon, with reuse of the sediment to offset losses at the BECA to the south, and/or at Elkhorn Slough to the east. Three concepts are presented here for consideration consisting of:

1. Intercepting sand along either an array of stationary jet pumps attached to the North Jetty to Moss Landing Harbor or a movable jet pump mounted on a crane moving along the jetty. The jetty would possibly need to be retrofitted with a working platform for any movable jet pump system.
2. Installing and maintaining a sand trap on the south side of the canyon just upcoast of the head.
3. An upcoast sand collection basin concept south of the canyon head without a breakwater.

Without more detailed information on the condition of the canyon walls, it is not certain that the maximum proportion of sand moving toward the canyon from either the north or south could be trapped without causing significant adverse impact to the integrity of the canyon walls. This study assumes that the maximum amount of sand could be removed from the system without harming or destabilizing canyon walls, or causing additional headcutting of the canyon from eliminating this sand from becoming deposited along the canyon rim. Further study of the condition of the canyon walls is warranted prior to implementing an alternative at Monterey Canyon. The other sand management options are not practicable concepts for this site.

North Trap Upcoast Without A Breakwater

The option for sand trapping and redistribution from Monterey Canyon is to intercept sand at the North Jetty upcoast of the north branch and divert it to the beach to the south and/or Elkhorn Slough using jet pumps. An array of stationary jet pumps would be attached to the north face of the jetty, or a movable jet pump would move along the jetty crest on a crane. Sand would be transported to the locations of the jet pumps by the longshore current, and the pumps would hydraulically pump it to a location along the southern beach (within economical reach of the dredge site, such as between 1 to 2 miles) as nourishment and/or to Elkhorn Slough. This action would move the sand into the northern portion of the BECA along this coast, but only over a limited distance for a corresponding limited benefit. Figure 16 shows the concept layout. This concept would likely only be functional during lower wave seasons such as summer and fall to prevent/reduce damage, and would thus work approximately one-half of the year.

Figure 16 – Upcoast North Sand Collection Concept at Monterey Submarine Canyon

Infrastructure from this type of project would be able to be removed without great difficulty if it were determined that the project caused adverse impacts to the site.

Construction costs for this sand collection basin concept are estimated to be between $14,700,000 for stationary pumps and $24,900,000 for a movable crane-mounted pump, assuming construction occurs in 2015. Table A-4 in Appendix A shows the estimated costs for this concept. Annual operations costs could reach $500,000 for energy, labor, and maintenance even with the system only functioning for one-half of the year to avoid seasons of high wave energy.

South Trap Upcoast With A Breakwater

A trap in the lee of an offshore breakwater similar to that proposed at Mugu Canyon, and to the prototype at Channel Islands Harbor is an option for the south side of Monterey Canyon as well. This option is more suitable for the south side of this canyon because limited quality surfing resources exist along the beach south of Moss Landing Harbor as compared to the beach north of the Harbor. Constructing a breakwater would eliminate any surfing resource behind the breakwater on all but possibly the highest wave energy conditions. The breakwater option is also more appropriate for the south side of Monterey Canyon because it would provide protection for an eroding beach at the site of the former pier at Moss Landing Marine Lab (MLML). That pier will eventually be replaced and the breakwater will provide shelter for the structure and any navigation associated with MLML.

Figure 17 shows the bypass concept for the south side of Monterey Canyon. The dredge plant could be a hydraulic cutterhead suction dredge pumping a slurry mixture to south of the Salinas River near the City of Marina. Placement at this site is intended to provide a feeder beach for sand periodically moving south from the river mouth location. The dredge discharge line could be a stationary line placed on the beach. One booster pump would be needed to pump the material from the sand trap to the downcoast discharge point. Infrastructure from this type of project would be difficult and costly to remove if it were determined that the project caused adverse impacts to the site.

To mimic the existing breakwater at the Channel Islands, the breakwater at Monterey Bay would have to be constructed 2,500 feet offshore and be approximately 2,000 feet long, with a crest elevation of +15 feet relative to mean lower low water (MLLW). The objective will be to trap a large portion of the littoral drift, yet allow for a smaller portion of the drift to pass the trap and reach the canyon head to maintain the protective sand cover over the rim. Figure 13 shows a typical cross-section of the breakwater sand trap, the same concept as that proposed for Mugu Canyon. Further analysis needs to be performed to design the breakwater to fit the site conditions. Breakwater elevation and length could be modified as needed to optimize project effects and manage costs. Monitoring will be required of the potential project effects on the canyon rim, and impacts to the canyon walls, and the beach at and downcoast of the placement site.

An alternative dredging technology known as the Punaise system could also be used at this site. As mentioned previously in this report, the Punaise system is applied in the

Figure 17 – Upcoast South Sand Trap Concept With a Breakwater at Monterey Submarine Canyon

Netherlands and is a floating nozzle-shaped unit that is a pin-point removal approach that is effective for mining sand (George Domurat, Personal Communication, March 7, 2007).

Construction costs for this breakwater sand trap concept are estimated to be $45 million assuming construction occurs in 2015, with maintenance dredging costs being $10.9 million if done every two years. Table 6 below shows the estimated costs for this concept and the itemized costs are shown in Table A-6 and A-7 in Appendix A. The dredging costs could be reduced if the project is coupled with maintenance dredging of the Moss Land Harbor and/or entrance channel locations and mobilization costs are shared.

Item	***Cost***
Breakwater (One Time Cost)	$45,000,000
Dredging (Once Every 2 Years)	$10,900,000
Total of First Time Costs	**$55,900,000**

Table 6 – Costs for a South Trap Upcoast With a Breakwater at Monterey Canyon

South Trap Upcoast Without A Breakwater

An alternative to the protected sand trap described above is the option of simply using a hopper dredge to create an offshore pit to serve as a physical sand trap for future mining to feed sand downcoast, similar to the concept suggested for Mugu Canyon. Figure 18 shows the concept plan for the alternative and Figure 15 shows a conceptual cross-section. The offshore area to be dredged would be just inside (landward) of the depth of closure. Dredging would occur to initially pass a quantity of sand that represents a large portion of the net longshore sediment transport rate to the canyon. This dredging would essentially create a large depression that would serve as a sand accumulation area over time that could be re-dredged perpetually in the future. Dredging could occur at whatever frequency is most economical, environmentally acceptable, and otherwise reasonable to remove a quantity equivalent to 400,000 cyy. Sand could be delivered to the southern end of Southern Monterey Bay to directly nourishment a BECA identified near Sand City.

This option requires no new infrastructure and would be simple and cost-free to abandon if it were determined that the project caused adverse impacts to the site. Also, the volume of material to be dredged could readily be modified to reflect conditions identified through monitoring. For instance, if negative impacts to the canyon rim were identified, the dredge volume could be reduced to a smaller amount that would cause less impact. If no impacts were identified anywhere from the operation, then the dredge quantity could be increased with minimal effort (other than the increased dredging operation).

Construction costs for this sand collection basin concept are estimated to be $7,500,000 every two to four years assuming construction occurs in 2010. Table A-8 in Appendix A shows the estimated costs for this concept. The project would likely not be able to be coupled with the Moss Landing Harbor or entrance channel dredging project due to different equipment being used (a hopper dredge versus a hydraulic dredge), thus

Figure 18 – Upcoast South Sand Collection Basin Concept at Monterey Submarine Canyon

mobilization costs cannot be shared and would remain as estimated herein. The hopper dredging project is more economical than the structural sand trap project in backpassing sand around Monterey Canyon, but may experience more frequent weather shut-downs due to more frequent rough sea conditions as compared to conditions in Southern California.

6.3 Considerations of Sand Bypassing

6.3.1 Environmental

Certain elements of project implementation pertaining to the environment and regulatory requirements are addressed below. Considerations common to any canyon sand interception program are issues of canyon geomorphology (headcutting and wall stability), ecology (benthic habitat), effected recreational activities such as surfing, offshore fisheries, and nearshore infrastructure avoidance and protection. The importance of comparing multiple bathymetric data sets to determine headward and lateral canyon head/flank retreat rates, location, and timing should be considered and studies programmed into any project.

Beach profiling and monitoring should occur in the vicinity of project sites either seasonally or annually for a period of years to understand beach behavior so that pre- and post-project morphology can be forecast and compared. Useful historical data of shoreline changes in this area are available in Hapke, et al. (2006). Baseline profile data are needed to monitor change resulting from potential engineering projects. The 1997 and 2005 USGS LIDAR surveys will provide important similar information.

Some type of ecological investigation of sand/canyon ecological interactions should be completed as part of any project as sand may provide benthic habitat near the canyon rim. Surfing should be documented as a resource in the vicinity of the canyon heads, with sensitive surfing resources considered in planning of any concepts that may cause an effect, either positive or negative.

In addition, existing infrastructure in the vicinity of a sand trap project site needs to be carefully mapped for any proposed project, and the project should provide assurance that the proposed sand excavation or interception will not destabilize or erode pre-existing infrastructure. Finally, offshore commercial fishing interests need to be considered for effects of any project. Site specific issues for each recommended project follow.

Mugu Submarine Canyon

Considerations of sand bypassing at Point Mugu include potential environmental impacts to downcoast reef areas in the vicinity of Malibu from sedimentation caused by the project. Some sand transported east from the Mugu State Beach discharge site will likely be deposited along the Malibu coast. Sensitive reefs that exist along this coast are colonized with surfgrass and kelp. Sedimentation could cause significant environmental impacts and the project will have to be assessed in light of the Magnesun-Stevenson Fisheries Act through an Essential Fish Habitat (EFH) Assessment. Bypassing can likely be planned to result in minimal impacts to resources if environmental data are collected and considered in design, and if appropriate monitoring occurs as verification.

Also, the coast downcoast of Point Mugu is designated as an Area of Special Biological Significance (ASBS), indicative of the existence of sensitive biological resources. Any project proposed within this area will have to be reviewed for potential effects and potentially constrained with restrictions on operations to preclude causing adverse impacts.

To address the potential for increased headcutting at this canyon from a project, an investigation should occur of the layer of sediment inferred to protect the canyon rim from erosion. The investigation should consider how it is distributed, its thickness, grain size, mobility, and capacity to protect the rim at a minimum. The issue could be addressed by seafloor mapping, sampling and coring, possible high-resolution seismic reflection, and measuring and modeling sediment transport. Other issues such as the importance of canyon currents in canyon wall erosion, whether they are being undermined, if head/wall erosion is occurring frequently in many small increments, through less common big slope failures, or some combination of conditions, and if head/wall erosion is a fairly constant seasonal process or occurs in response to large but rare events (catastrophies) such as the huge storms of the 1997-98 El Nino winter or strong ground motions associated with earthquakes (e.g., 1994 at Northridge). A study plan should be formulated at the feasibility study stage of the project.

Monterey Submarine Canyon

The most significant constraint to any project within Monterey Bay is that the area is within the Monterey Bay National Marine Sanctuary, thus limiting any dredging and filling activity. Future work would require a permit from the Sanctuary Superintendent after full assessment of potential benefits and impacts. Backpassing or redistributing sediment from Monterey Submarine Canyon should not pose significant, long-term adverse effects to the environment, and should provide significant demonstrable benefits from regional sediment management. Potential small-scale impacts may occur during beach nourishment such as turbidity at the placement site and potential direct and indirect burial of resources with sand. Significant planning work would be needed to secure approvals to implement the proposed concepts.

Any work done in Elkhorn Slough would be assessed for environmental consequences. A Tidal Wetland Project is ongoing at the Slough that is assessing potential concepts to address the erosion problem. Concepts are being prepared and may include a variety of means to arrest the problem of sediment loss, while incorporating measures for sediment gain. That project is on a separate track from this one but the efforts are being coordinated and may become integrated in the future. Impacts could occur from infilling of Elkhorn Slough by a project. Sedimentation could cause environmental impacts to fish and the project will have to be assessed in light of the Magnesun-Stevenson Fisheries Act through an EFH Assessment.

6.3.2 Policy, Procedural, and Regulatory Issues

Regulatory considerations are whether this type of project is consistent with Federal and State laws. Applicable Federal laws include Section 404 of the Rivers and Harbors Act, Section 401 of the Clean Water Act, Section 7 of the Endangered Species Act, and designation of National Marine Sanctuaries. Applicable State laws include the California Coastal Act, and administrative requirements of the State Lands Commission and State Department of Parks and Recreation, and the California Fish and Game Code.

Mugu Submarine Canyon

The project will be required to secure permits, federal consistency determinations, and/or consultations from these agencies to coordinate the activity and to prevent the occurrence of significant impacts to public resources. Required permits/approvals will include:

1. A Section 401 C Water Quality Certification from the Regional Water Quality Control Board;
2. A Coastal Federal Consistency Determination from the California Coastal Commission;
3. A Lease of State Lands from the State Lands Commission; and
4. An Encroachment Permit from the State Department of Parks and Recreation.

The USACE follows a different process from non-USACE applicants. The USACE project process consists of following 404 B(1) Guidelines and issuing a Record of Decision.

Research should investigate the potential increased rate of retreat of the canyon rim to determine whether the removal of some of the capture rate will result in a greater exposure of the canyon headwall if some of the protective sand layer over the rim is effectively removed by the bypassing activity. The research should focus on the rate of sand bypassing that can occur with minimal change to the existing canyon head retreat rate. The rate of extraction is to be defined, dependent on the difference between the sand loss rate into the canyon and the quantity needed along the rim to maintain the position of the canyon head.

Overall, the project could generate significant benefits to recreation and shore protection from providing larger sand volumes to Santa Monica Bay, assuming that Dume Canyon intercepts only a nominal amount of sand over time. If 20% of the sand captured by the canyon reaches beaches downcoast, they could widen increasing recreational beach area by 3 acres per year as far east as Marina del Rey. Over time, this benefit could significantly improve recreational opportunities on the larger beach areas, and increase protection to public and private property along the coast.

Monterey Submarine Canyon

This project will also be required to secure permits, federal consistency determinations, and/or consultations from appropriate resource agencies. Permits/approvals will include:

1. Approval of project activities within the Monterey Bay National Marine Sanctuary;
2. A Section 401 C Water Quality Certification from the Regional Water Quality Control Board;
3. A Coastal Federal Consistency Determination from the California Coastal Commission;
4. A Lease of State Lands from the State Lands Commission; and
5. An Encroachment Permit from the State Department of Parks and Recreation.

The USACE will follow 404 B(1) Guidelines and issue a Record of Determination.

A project in Monterey Bay may be subject to significant restrictions associated with the Monterey Bay National Marine Sanctuary. Restrictions include securing approval from the Sanctuary Superintendent, and may involve preventing impacts within the Sanctuary from possible turbidity or unwanted erosion/sedimentation. It is anticipated that these conditions could occur from this project, so coordination with resource agencies and the Sanctuary Superintendent will be required.

The project will generate significant benefits to the environment from restoring areas of the Southern Monterey Bay BECA and/or Elkhorn Slough progressively over time. Sand deposition may be able to occur at rates sufficient to offset losses along the coastal BECA, and at the Slough and thus cause accretion and restore the natural Southern Monterey Bay shoreline and possibly Slough habitat.

7.0 CONCLUSIONS

The USACE desires to investigate options for regional sediment management in the vicinity of offshore submarine canyons. Their goal is to identify opportunities to capture sand prior to its loss into canyons and contribute it to the littoral zone. Review of existing data of submarine canyons throughout the state indicates that Mugu Canyon and Monterey Canyon are the most appropriate sites for projects.

7.1 Mugu Submarine Canyon

Mugu Canyon traps perhaps as much as 90% of the net longshore transport at that location that equates to approximately 1 million cubic yards of sand lost per year. As such, Mugu Canyon provides great benefits given likely costs. The main adverse effect of a project at Mugu Canyon is the potential to uncover an existing protective sediment layer over the canyon rim leading to an increased rate of headcutting and possible impacts to Mugu Lagoon.

Conceptual-level projects identified for Mugu Canyon with potential to meet the project goals include the following:

1. Construct an offshore breakwater upcoast of the canyon similar to that at Channel Islands Harbor and hydraulically dredge from the behind the structure. The quantities and rates of dredging can vary, but only 20% of the net longshore transport rate should initially be dredged to allow the remaining 80% that bypasses the trap to enter the canyon and preserve its protective sedimentary cover. By dredging 20% of the longshore transport rate per year, a project could occur that consists of dredging up to 400,000 cubic yards of sand from the trap every four years. Sand would be pumped east to Mugu State Beach.

2. Use a hopper dredge to dredge this same quantity every four years from within the closure depth upcoast of the canyon to create a sediment basin that refills naturally and is perpetually re-dredged.

The costs of constructing the trap upcoast with a breakwater are quite high, assuming the project costs extrapolated to the year 2015, reaching $45.0 million for the breakwater and $10.9 million for one dredging event every four years. This is due to the large stone quantity required for the breakwater and the long pump distance (5 miles) that requires a booster pump. Breakwater dimensions of crest elevation and length could be modified to optimize the project effects and reduce costs.

The costs of performing the hopper dredge operation are $7.5 million every four years under the same assumptions of project timing. Costs are reduced because the hopper dredge is efficient to perform this type of operation. The hopper dredge project is more feasible

economically than the sand trap project, while the effect is similar. As such, the hopper dredge sand management area is the concept proposed in this study.

The hopper dredge project could be phased in to address the accelerated canyon headcutting issue by dredging relatively small quantities initially and monitoring the rate of headcutting, then modifying the dredging quantities based on results. The breakwater concept could also be phased and constructed in segments, but this concept would be more expensive due to costs of mobilization and demobilization equipment.

Any project at Mugu Canyon should be followed up by field verification that the existing rate of canyon headcutting does not increase to a point that is unacceptable and threatening to Mugu Lagoon. Other potential environmental impacts to downcoast reef areas should also be proactively investigated during project planning to minimize adverse effects.

7.2 Monterey Submarine Canyon

Monterey Submarine Canyon terminates within an eroding littoral cell and is situated adjacent to a severely eroding sensitive national wildlife refuge, and thus also provides great benefits given likely costs. No adverse effects are identified from one or more projects at Monterey Canyon.

The conceptual-level projects identified for Monterey Canyon with potential to meet the project goals consists of:

1. Constructing either a line of stationary jet pumps along the north face of the North Jetty to Moss Landing Harbor or one movable jet pump there to block sand from reaching the north branch of the canyon. Sand would be naturally transported to the locations of the jet pump(s) by longshore transport. The pump(s) would then intake the sand and pump it hydraulically toward Monterey to the south and/or Elkhorn Slough to the east. The costs of installing the project are between $14,700,000 and 24,900,000, assuming the project costs extrapolated to the year 2015. Annual operating costs could reach $500,000 per year (assuming the system functions for one-half the year) mainly due to energy costs, labor, and maintenance.

2. Construct an offshore breakwater south of the canyon and hydraulically dredge from the behind the structure. The quantities and rates of dredging can vary, but the majority of the net longshore transport rate should initially be dredged to allow the remainder that bypasses the trap to enter the canyon and preserve its protective sedimentary cover. A project could occur that consists of dredging up to 400,000 cubic yards of sand from the trap every two years. Sand would be pumped south of the Salinas River.

3. Use a hopper dredge to dredge this same quantity every two to four years from within the closure depth upcoast of the canyon to create a sediment basin that refills naturally and is perpetually re-dredged.

The costs of installing the trap with a breakwater are quite high, assuming the project costs extrapolated to the year 2015, reaching $45 million for the breakwater and $10.9 million for one dredging event every two years. This is due to the large stone quantity required for the breakwater and the long pump distance (5 miles) that requires a booster pump. Breakwater dimensions of crest elevation and length could be modified to optimize the project effects and reduce costs.

The costs of performing the hopper dredge operation are $7.5 million every two to four years under the same assumptions of project timing. Costs are reduced because the hopper dredge is efficient to perform this type of operation. The hopper dredge project is more feasible economically than the sand trap project, while the effect is similar. As such, the hopper dredge sand management area is the concept proposed in this study at the south side of Monterey Canyon.

Additional future study of the condition of the canyon walls is necessary prior to implementing an alternative at Monterey Canyon. The study is to focus on whether canyon walls are relatively erodible or resistant. The results of the study will help to clarify the amount of longshore sediment transport that can be trapped prior to being backpassed.

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APPENDIX A

CONSTRUCTION COST ESTIMATES

MUGU SUBMARINE CANYON

TRAP UPCOAST WITH A BREAKWATER

TABLE A-1 – BREAKWATER COST ESTIMATE

TABLE A-2 – DREDGING COST ESTIMATE

TABLE A-1
BREAKWATER CONCEPT AT MUGU CANYON
MUGU SUBMARINE CANYON

ITEM NO.	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	BREAKWATER CONSTRUCTION COST				
1	MOB., DEMOB. & PREP. WORK	1	LS	$750,000	$750,000
2	OUTER LAYER (A ROCK)	159,800	TON	$75	$11,985,000
3	INTERMEDIATE LAYER (B ROCK)	149,300	TON	$65	$9,704,500
4	BEDDING LAYER	80,400	TON	$53	$4,261,200
5	TOE TRENCH	1	LS	$260,000	$260,000
6	SUBTOTAL				$26,960,700
7	CONTINGENCY			15%	$4,044,105
8	SUBTOTAL				$31,004,805
9	ENGINEERING, DESIGN, PERMITTING			8%	$2,480,384
10	CONSTRUCTION ENG. & MGMT.			10%	$3,100,481
11	BREAKWATER CONSTRUCTION COST				$36,585,670
12	ESCALATION FOR 7 YEARS (TO 2015)	1	LS	123%	$44,995,759
	BREAKWATER MAINTENANCE				
13	MAINTENANCE @ YEAR 25 (PRESENT CONST. RATES)			20%	$8,999,152
14	FUTURE MAINTENANCE COST WITH INFLATION = Cost*(1+e*n)				$14,173,664
15	PRESENT WORTH OF MAINTENANCE = Future*$(1+i)^{-n}$				$2,533,404

NOTES:
1. Armor & underlayer unit costs time adjusted from recent projects.
2. Annual Interest Rate: i= 7.13%
3. Annual Rate of inflation (From ENR 1977 to 2050): e = 2.30%
4. Project Life (years) = n: n= 50
5. Future Cost = Present Cost * (1+e*n). Amount paid for the same work n years in the future.
6. Present Worth = Future Cost/$(1+i)^n$. Amount placed in a bank account today.

DREDGING

TABLE A-2
DREDGING COST ESTIMATE
800,000 CY SAND BYPASSING EVERY 4 YEARS
HYDRAULIC DREDGE WITH BOOSTER PUMP
MUGU SUBMARINE CANYON

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	SUBTOTAL
1	Mobilization & Demobilization	1	LS.	$2,000,000.00	$2,000,000
2	Dredging and Pumping to the Beach	800,000	CY	$10.1	$8,112,875
	Subtotal Hard Construction Items				**$10,112,875**
	Construction Management	1	LS.	3% of construction	$303,386
	Construction Survey or Inspection	1	LS.	1% of construction	$101,129
	Permits and Environmental Review	1	LS.	$175,000.00	$175,000
	Final Engineering for Construction	1	LS.	$75,000.00	$75,000
	Pre- and Post-Project Monitoring	1	LS.	$150,000.00	$150,000
	Subtotal Soft Costs and Planning Items				**$804,515**
	GRAND TOTAL ALL ITEMS				**$10,917,390**

ASSUMPTIONS:

1. Mobilization and Demobilization assumes use of a hydraulic dredge with discharge lines available somewhere on the west coast of North America at the time of the project.

2. Dredging and Pumping includes construction of containment dikes and final grading, and use of a booster pump for discharging 5 miles east to Mugu State Beach.

3. Costs for permits and environmental review assume an Environmental Impact Report/Statement.

4. Costs of final engineering is an extremely rough estimate and needs verification.

5. Monitoring of beach profiles and marine biology is required before construction, turbidity monitoring is required during construction, and beach profiles and biology are also monitored for two years after construction as was done recently for other similar projects (Goleta Beach).

MUGU SUBMARINE CANYON

TRAP UPCOAST WITHOUT A BREAKWATER

TABLE A-3
CONSTRUCTION COST ESTIMATE
800,000 CY SAND BYPASSING EVERY 4 YEARS
ASSUMES USE OF A HOPPER DREDGE
MUGU SUBMARINE CANYON

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	SUBTOTAL
1	Mobilization & Demobilization	1	LS.	$1,000,000.00	$1,000,000
2	Dredging and Pumping to the Beach	800,000	CY	$7.2	$5,793,226
	Subtotal Hard Construction Items				**$6,793,226**
	Construction Management	1	LS.	3% of construction	$203,797
	Construction Survey or Inspection	1	LS.	1% of construction	$67,932
	Permits and Environmental Review	1	LS.	$175,000.00	$175,000
	Final Engineering for Construction	1	LS.	$75,000.00	$75,000
	Pre- and Post-Project Monitoring	1	LS.	$150,000.00	$150,000
	Subtotal Soft Costs and Planning Items				**$671,729**
	GRAND TOTAL ALL ITEMS				**$7,464,955**

ASSUMPTIONS:

1. Mobilization and Demobilization assumes use of a hopper dredge with discharge lines available somewhere on the west coast of North America at the time of the project.

2. Dredging and Pumping includes construction of containment dikes and final grading.

3. Costs for permits and environmental review assume an Environmental Impact Report/Statement.

4. Costs of final engineering is an extremely rough estimate and needs verification.

5. Monitoring of beach profiles and marine biology is required before construction, turbidity monitoring is required during construction, and beach profiles and biology are also monitored for two years after construction as was done recently for other similar projects (Goleta Beach).

MONTEREY SUBMARINE CANYON

STATIONARY JET PUMP ARRAY ATTACHED TO THE NORTH HARBOR JETTY

TABLE A-4
CONSTRUCTION COST ESTIMATE
STATIONARY JET PUMP ALTERNATIVE
MONTEREY SUBMARINE CANYON

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	SUBTOTAL
1	Mobilization & Demobilization	1	LS.	$500,000.00	$500,000
2	Install Working Platform on Jetty	10,000	SF	$75.00	$750,000
3	Jet Pumps and Anchors	3	EA	$1,000,000.00	$3,000,000
4	Discharge Line (HDPE)	18,000	LF	$20.00	$360,000
5	Temporary Booster Station	3	EA	$1,500,000.00	$4,500,000
6	Dredging and Pumping to Receiver Site	160,000	CY	$8.00	$1,280,000
	Subtotal Hard Construction Items				**$10,390,000**
7	Escalation for 7 Years (to 2015)	1	LS.	123%	$12,779,700
8	Construction Management	1	LS.	3% of construction	$383,391
9	Construction Survey or Inspection	1	LS.	1% of construction	$127,797
10	Permits and Environmental Review	1	LS.	$500,000.00	$500,000
11	Final Engineering for Construction	1	LS.	$500,000.00	$500,000
12	Pre- and Post-Project Monitoring	1	LS.	$400,000.00	$400,000
	Subtotal Soft Costs and Planning Items				**$1,911,188**
	GRAND TOTAL ALL ITEMS				**$14,690,888**

ASSUMPTIONS:

1. Mobilization and Demobilization assumes use of cranes and trucks.

2. Dredging and Pumping includes construction of containment dikes and final grading.

3. Length of discharge line assumes the material is delivered to Southern Monterey beaches and/or Elkhorn Slough (Parsons Slough).

4. Costs for permits and environmental review assume an Environmental Impact Report/Statement.

5. The cost of final engineering is an extremely rough estimate and needs verification.

6. Monitoring of beach profiles/Slough grades and marine biology is required before construction, turbidity monitoring is required during construction, and beach profiles/Slough grades and biology are also monitored for two years after construction as was done recently for other similar projects (Goleta Beach).

MONTEREY SUBMARINE CANYON

MOVABLE JET PUMP ARRAY ATTACHED TO THE NORTH HARBOR JETTY

TABLE A-5
CONSTRUCTION COST ESTIMATE
MOVABLE JET PUMP ALTERNATIVE
MONTEREY SUBMARINE CANYON

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	SUBTOTAL
1	Mobilization & Demobilization	1	LS.	$1,000,000.00	$1,000,000
2	Install Working Platform on Jetty	10,000	SF	$75.00	$750,000
3	Mobile Crane With Movable Arm	1	EA	$8,500,000.00	$8,500,000
4	Jet Pump Assembly With Hoses	1	EA	$1,000,000.00	$1,000,000
5	Discharge Line (HDPE)	18,000	LF	$20.00	$360,000
6	Temporary Booster Station	3	EA	$1,500,000.00	$4,500,000
7	Electrical Power Source Station	1	EA	$1,000,000.00	$1,000,000
8	Dredging and Pumping to Receiver Site	160,000	CY	$8.00	$1,280,000
	Subtotal Hard Construction Items				**$18,390,000**
9	Escalation for 7 Years (to 2015)	1	LS.	123%	$22,619,700
10	Construction Management	1	LS.	3% of construction	$678,591
11	Construction Survey or Inspection	1	LS.	1% of construction	$226,197
12	Permits and Environmental Review	1	LS.	$500,000.00	$500,000
13	Final Engineering for Construction	1	LS.	$500,000.00	$500,000
14	Pre- and Post-Project Monitoring	1	LS.	$400,000.00	$400,000
	Subtotal Soft Costs and Planning Items				**$2,304,788**
	GRAND TOTAL ALL ITEMS				**$24,924,488**

ASSUMPTIONS:

1. Mobilization and Demobilization assumes use of cranes and trucks.

2. Dredging and Pumping includes construction of containment dikes and final grading.

3. Length of discharge line assumes the material is delivered to Southern Monterey Bay beaches and/or Elkhorn Slough (Parsons Slough).

4. Costs for permits and environmental review assume an Environmental Impact Report.

5. The cost of final engineering is an extremely rough estimate and needs verification.

6. Monitoring of beach profiles and marine biology is required before construction, turbidity monitoring is required during construction, and beach profiles and biology are also monitored for two years after construction as was done recently for other similar projects (Goleta Beach).

MONTEREY SUBMARINE CANYON

TRAP UPCOAST WITH A BREAKWATER

TABLE A-6 – BREAKWATER COST ESTIMATE

TABLE A-7 – DREDGING COST ESTIMATE

TABLE A-6
BREAKWATER CONCEPT AT MONTEREY CANYON
MONTEREY SUBMARINE CANYON

ITEM NO.	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	BREAKWATER CONSTRUCTION COST				
1	MOB., DEMOB. & PREP. WORK	1	LS	$750,000	$750,000
2	OUTER LAYER (A ROCK)	159,800	TON	$75	$11,985,000
3	INTERMEDIATE LAYER (B ROCK)	149,300	TON	$65	$9,704,500
4	BEDDING LAYER	80,400	TON	$53	$4,261,200
5	TOE TRENCH	1	LS	$260,000	$260,000
6	SUBTOTAL				$26,960,700
7	CONTINGENCY			15%	$4,044,105
8	SUBTOTAL				$31,004,805
9	ENGINEERING, DESIGN, PERMITTING			8%	$2,480,384
10	CONSTRUCTION ENG. & MGMT.			10%	$3,100,481
11	BREAKWATER CONSTRUCTION COST				$36,585,670
12	ESCALATION FOR 7 YEARS (TO 2015)	1	LS	123%	$44,995,759
	BREAKWATER MAINTENANCE				
13	MAINTENANCE @ YEAR 25 (PRESENT CONST. RATES)			20%	$7,317,134
14	FUTURE MAINTENANCE COST WITH INFLATION = Cost*(1+e*n)				$11,524,486
15	PRESENT WORTH OF MAINTENANCE = Future*$(1+i)^{-n}$				$2,059,890

NOTES:
1. Armor & underlayer unit costs time adjusted from Batiquitos & CBC Rifle Range.
2. Annual Interest Rate: i= 7.13%
3. Annual Rate of inflation (From ENR 1977 to 2050): e = 2.30%
4. Project Life (years) = n: n= 50
5. Future Cost = Present Cost * (1+e*n). Amount paid for the same work n years in the future.
6. Present Worth = Future Cost/$(1+i)^n$. Amount placed in a bank account today.

DREDGING

TABLE A-7
DREDGING COST ESTIMATE
800,000 CY SAND BYPASSING EVERY 2 YEARS
HYDRAULIC DREDGE WITH BOOSTER PUMP
MONTEREY SUBMARINE CANYON

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	SUBTOTAL
1	Mobilization & Demobilization	1	LS.	$2,000,000.00	$2,000,000
2	Dredging and Pumping to the Beach	800,000	CY	$10.1	$8,112,875
	Subtotal Hard Construction Items				**$10,112,875**
	Construction Management	1	LS.	3% of construction	$303,386
	Construction Survey or Inspection	1	LS.	1% of construction	$101,129
	Permits and Environmental Review	1	LS.	$175,000.00	$175,000
	Final Engineering for Construction	1	LS.	$75,000.00	$75,000
	Pre- and Post-Project Monitoring	1	LS.	$150,000.00	$150,000
	Subtotal Soft Costs and Planning Items				**$804,515**
	GRAND TOTAL ALL ITEMS				**$10,917,390**

ASSUMPTIONS:

1. Mobilization and Demobilization assumes use of a hydraulic dredge with discharge lines available somewhere on the west coast of North America at the time of the project.

2. Dredging and Pumping includes construction of containment dikes and final grading, and use of one booster pump for discharging 5 miles east to south of the Salinas River Mouth.

3. Costs for permits and environmental review assume an Environmental Impact Report/Statement.

4. Costs of final engineering is an extremely rough estimate and needs verification.

5. Monitoring of beach profiles and marine biology is required before construction, turbidity and possibly biology monitoring is required during construction, and beach profiles and biology are also monitored for two years after construction as was done recently for other similar projects (Goleta Beach).

MONTEREY SUBMARINE CANYON

TRAP UPCOAST WITHOUT A BREAKWATER

TABLE A-8
CONSTRUCTION COST ESTIMATE
800,000 CY SAND BYPASSING EVERY 2 to 4 YEARS
ASSUMES USE OF A HOPPER DREDGE
MONTEREY SUBMARINE CANYON

ITEM NO.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	SUBTOTAL
1	Mobilization & Demobilization	1	LS.	$1,000,000.00	$1,000,000
2	Dredging and Pumping to the Beach	800,000	CY	$7.2	$5,793,226
	Subtotal Hard Construction Items				**$6,793,226**
	Construction Management	1	LS.	3% of construction	$203,797
	Construction Survey or Inspection	1	LS.	1% of construction	$67,932
	Permits and Environmental Review	1	LS.	$175,000.00	$175,000
	Final Engineering for Construction	1	LS.	$75,000.00	$75,000
	Pre- and Post-Project Monitoring	1	LS.	$150,000.00	$150,000
	Subtotal Soft Costs and Planning Items				**$671,729**
	GRAND TOTAL ALL ITEMS				**$7,464,955**

ASSUMPTIONS:

1. Mobilization and Demobilization assumes use of a hopper dredge with discharge lines available somewhere on the west coast of North America at the time of the project.

2. Dredging and Pumping includes construction of containment dikes and final grading.

3. Costs for permits and environmental review assume an Environmental Impact Report/Statement.

4. Costs of final engineering is an extremely rough estimate and needs verification.

5. Monitoring of beach profiles and marine biology is required before construction, turbidity and possibly biology monitoring is required during construction, and beach profiles and biology are also monitored for two years after construction as was done recently for other similar projects (Goleta Beach).