Nearshore Berms - Update of the United States Experience

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ABSTRACT

Cost effective, beneficial use of dredged material is being implemented by construction of nearshore berms for shoreline protection. The U.S. Army Corps of Engineers (USACE) has built several nearshore berms to attenuate wave activity and to introduce clean sediment into the littoral zone. Nearshore berms are generally divided into two categories, "feeder" and "stable" berms. A new concept, a "sacrificial" berm is also being explored. In 1987, a National Nearshore Berm Demonstration project evaluating both a stable and a feeder berm near Mobile, Alabama was initiated. More recently, additional berm projects have included South Padre Island, Texas, Silver Strand Park, California, and Morro Bay, California. Construction details, contour evolution of the berms and adjacent shores, and wave attenuation in the lee of the berm have been monitored and evaluated for these berms. Beneficial effects are substantiated by these results.

INTRODUCTION

The US Army Corps of Engineers (USACE) has long been a proponent of the constructive use of clean dredged material. Maintenance dredging of coastal channels and harbors creates significant amounts of clean material that is valuable to the littoral system. A common, but often expensive use of this dredged sand, is for beach nourishment. In recent years, the concept of using hopper dredges to place dredged material in shallow water as shore-parallel subaqueous berms has gained acceptance as a method of enhancing the beach profile at lower costs. Benefits to the nearshore zone include providing material to the littoral system and reducing erosive wave action on beaches.

The USACE has built a number of nearshore berms for beneficial uses with a variety of materials. The most recent efforts include berms constructed of sand dredged as part of channel maintenance during: a) 1987, off Dauphin Island, Alabama, as part of the National Nearshore Berm Demonstration project (Hands and Bradley, 1990); b) 1988, at Silver Strand, California (Andrassy, 1990, USACE, 1990); c) 1989, off South Padre Island, Texas (McLellan and Burke, 1988, McLellan, 1990); and d) 1990, at Morro Bay, California (Shak, 1991). Also included is the National Nearshore Berm Demonstration project's stable berm, constructed in 1988-1989 of 11.2 million cubic metres of silt, clay, and sand off Dauphin Island, Alabama (McLellan, 1990).

To date "feeder" berms have been constructed of 230,000 to 300,000 m^3 of sand placed in 3 to 12 m of water with 1.5 to 4.5 m relief forming long, linear, shore parallel, subaqueous seabed features. By placing material directly in the active littoral system it is available to move along and onshore as part of natural beach building processes. In addition, the feature's relief will induce wave shoaling and cause larger waves to break in shallow water. Steep, short period waves generally associated with erosion are more likely to break at the berm site. Longer period waves generally associated with beach building processes often pass over the berm unhindered. Thus, the berm may act as a wave filter, damping erosive waves (Zwamborn, Fromme and Fitzpatrick, 1970). The larger, fine grained, "stable" berm was constructed to attenuate wave energy and provide a fisheries habitat. Its material is not intended to reach the beach.

Background on berm construction and interim contour evolution for all berms except Morro Bay have been previously documented and are summarized here. The paper focuses on recent details of berm movement, elevation and volume changes at these berms. Details on the Morro Bay berm, including water depth, volume of material placed, berm elevations, and construction details are also provided.

NEARSHORE BERM CONCEPT

Nearshore berms use clean dredged material removed from harbors or channels to construct submerged, high relief shore parallel features. Nearshore berms have the potential for decreasing adjacent shoreline erosion and providing a placement area for dredged materials at the same time. Thus, beneficial use is being made of the dredged resources in an economical way.

Feeder Berm

Feeder berms are constructed of clean sand placed in relatively shallow water. By strategically mounding this material, adjacent beaches

and nearshore areas are enhanced in two ways. First, erosive hydrodynamic conditions are altered. Waves in the lee of the berm are attenuated and less energy is expended upon the adjacent coastline, reducing beach erosion. Second, a suitable sediment source is introduced into the nearshore where natural recovery processes can transport material into the littoral zone. The term "feeder" comes from the intent that the material will move out of the berm area and become part of the nearshore sand system, contributing to the total volume of material available for natural beach building and recovery processes.

Wave attenuation is accomplished by effectively "tripping" the waves that have high erosion potential. These waves are typically steep waves generated by local storms, and are associated with offshore transport and beach erosion. Wave breaking is a function of wave height, wave steepness and water depth. As storm waves travel over the berm, the elevation of the berm above the surrounding bottom will cause the steeper waves to shoal (to increase in wave height and steepness and to reduce in phase velocity) as they migrate up the berm face. If the wave becomes too steep it breaks, reducing its erosion potential. In this scenario the berm would be sacrificial, reducing erosion along the beach by providing an additional sand source for one high energy event. Summer (swell type) waves are typically flatter, long period waves associated with periods of onshore transport and beach restoration. Shoaling of these waves usually does not increase their relative steepness enough to initiate breaking on most nearshore berms. Thus, the berm could act as a selective wave filter causing large steep waves to break, reducing their energy, and allowing long waves to pass unhindered. As a result, favorable beach building conditions develop in the lee of the mound (Zwamborn, Fromme, and Fitzpatrick, 1970).

Stable Nearshore Berm

Stable berms are intended to remain as relatively permanent bottom features. Generally placed further offshore in deeper water, their major function is to attenuate storm waves. Since they are in deeper water and their material is not expected to be transported onto the beaches, stable berm can be constructed of a wider range of materials. If clean sand is used, the berm could be a stock pile for future beach nourishment projects. In addition to wave attenuation, stable berms show potential for fisheries habitats (Clark, Fredette, and Imsand, 1988).

Sacrificial Nearshore Berm

A third type of berm may provide an additional nearshore alternative, a "sacrificial" berm. This new type of berm placed in shallower waters, would differ from a feeder berm in that it would be constructed of finer grain material, which would likely be carried offshore by waves, possibly nourishing the offshore profile, and flattening its slope. This is in contrast to a feeder berm, which may nourish the beach. The intent of the sacrificial berm would be to expend incident wave energy on the berm thus benefiting the shorelines in the lee of the berm by preventing or reducing wave energy destined for that area from reaching the shore and potentially causing erosion. The sacrificial berm will expend wave energy, sparing the shoreline for as long as the berm remains in place. The life of the berm will be a function of the local wave climate after placement, grain size, type of material placed and the dredging and placement technique used.

NATIONAL NEARSHORE BERM DEMONSTRATION PROJECT, MOBILE, ALABAMA

To fully document the environmental and physical aspects of nearshore berm construction, a National Demonstration Project was established in 1986 by the USACE Director of Civil Works. Approval was accomplished after endorsement of the project by several agencies including the Environmental Advisory Board, Coastal Engineering Research Board and the National Marine Fisheries Service. Mobile Harbor was chosen as the National Demonstration Site where both feeder and stable berms could be demonstrated.

Both berms are located west of the navigation channel within the Gulf of Mexico, Figure 1. The Gulf Coast off Alabama is a complex hydrographic area influenced mainly by discharges from Mobile Bay, tides, late fall and early winter storms, and hurricanes. The feeder berm was placed less than 2.4 km from the channel and the stable berm is about 4 km from the channel and about 4 km farther offshore (McLellan and Langan 1990).

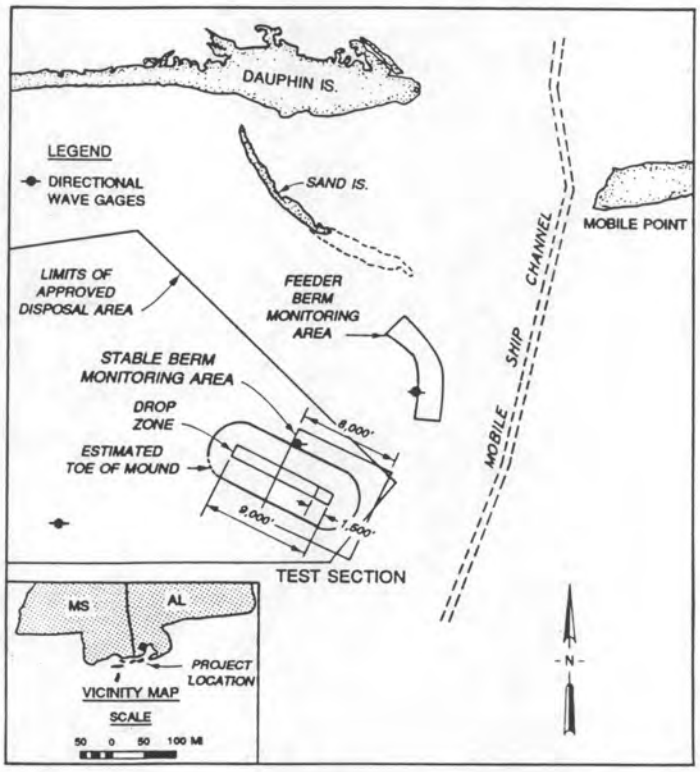

Figure 1. Location map of stable and feeder berms, Mobile, AL

Monitoring elements are similar for both berms including wave gaging, hydrographic surveys, sediment sampling, and current measurements. The principal objectives of the monitoring are to measure the physical characteristics of both berms and how these characteristics change with time. The monitoring program is also designed to measure some of the overall physical forces that cause these changes and any fisheries benefits that may accrue due to the stable berm. The extensive monitoring program was designed in part so that results of the National Demonstration can then be applied to other coastal areas of the United States.

National Demonstration Project Stable Berm, Mobile, Alabama

Construction of the stable berm began in February 1988 and was completed in May 1990 placing about 11.2 x 10^6 m^3 of widely varying new work material in 10.5 to 15 m of water. The berm was constructed to 6 m in height with design crest dimensions of 300 by 2750 m. The exterior slopes resulted in a berm about 1.6 km by 4 km at its base, making it the largest underwater feature ever constructed in the United States. The placement resulted in some disposal costs savings by concentrating the material in the extreme eastern limits of the designated disposal area, reducing the average haul distances. The berm was constructed by Great Lakes Dredge and Dock Company's clamshell dredge CHICAGO, and 4,600 m^3 dump scows which transported the material to the berm construction site from the bay channel deepening project. The approach channel was dredged by split-hulled hopper dredges.

For the stable berm demonstration, the entire berm is not being monitored, but only a test section that was the first part of the berm constructed (see Figure 1). After the test section was completed, the dredging contractor was required to place material at the other end of the berm feature and begin working back towards the test section. After an initial period of adjustment the test area has been relatively stable since January 1989. Repetitive surveys of the test berm, figure 2, have shown the long-term stability of the material. Figure 2 shows the pre-construction, two post-construction, and the most recent survey. Four other surveys, not shown on figure 2, were conducted in between these surveys. No significant change in the profile occured during this time. There is no doubt that the material that was new work, clamshell dredged, and placed in such large volumes, helped increase the berm stability.

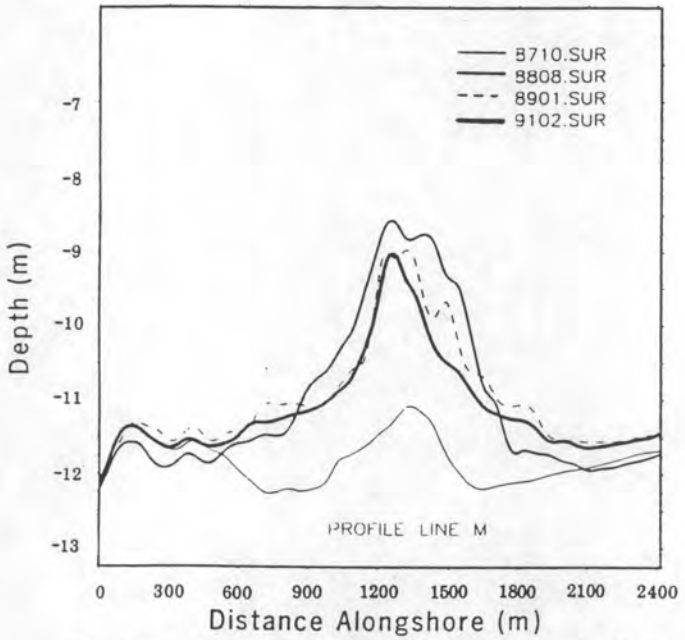

Figure 2. Mobile stable berm profiles

One of the main goals of the stable berm was to reduce wave energy in its lee. Directional wave data were collected offshore and inshore of the stable berm to measure changes in energy across the berm. Analysis of data to date has shown the stable berm's ability to filter wave energy allowing low energy waves to pass while reducing storm wave energy up to 70% (McLellan, Pope, and Burke 1990).

National Demonstration Project Feeder Berm, Mobile, Alabama

The feeder berm was built in February 1987 by two Gulf Coast Trailing Company hopper dredges, the ATCHAFALAYA and MERMENTAU, placing 137,000 m^3 of sand in 5.5 m of water. Considerable time was spent by the contractor in following a precise alignment in an effort to build the berm to a maximum height above the bottom, some portions as great as 2.5 m.

Monitoring on the feeder berm began in December 1986 with surveys to characterize pre-berm bathymetry and native bottom sediment. The first post-construction survey was conducted after completion of the feeder berm in March of 1987. The berm was constructed on the 6 m contour and was 2 m in height, about 1.6 km long, and contained about 343,000 m^3 of sand. The depth near the drop zone was reduced to a minimum of 2.5 m with an average depth of 4.0 to 4.5 m. By the January 1988 survey, the berm had begun to move west and minimum depths increased to approximately 3.5 m (Hands and Bradley 1990). By August 1989, some sections of the monitored berm had moved 87 m to the northwest (shoreward).

OTHER RECENTLY CONSTRUCTED USACE NEARSHORE BERMS

Brazos-Santiago Pass, South Padre Island, Texas

Brazos-Santiago Pass (BSP) Inlet is located just north of the United States-Mexico border on the southern tip of Padre Island, Texas (Figure 3). The entrance channel is maintained at 11.5 m depth and 91 m width.

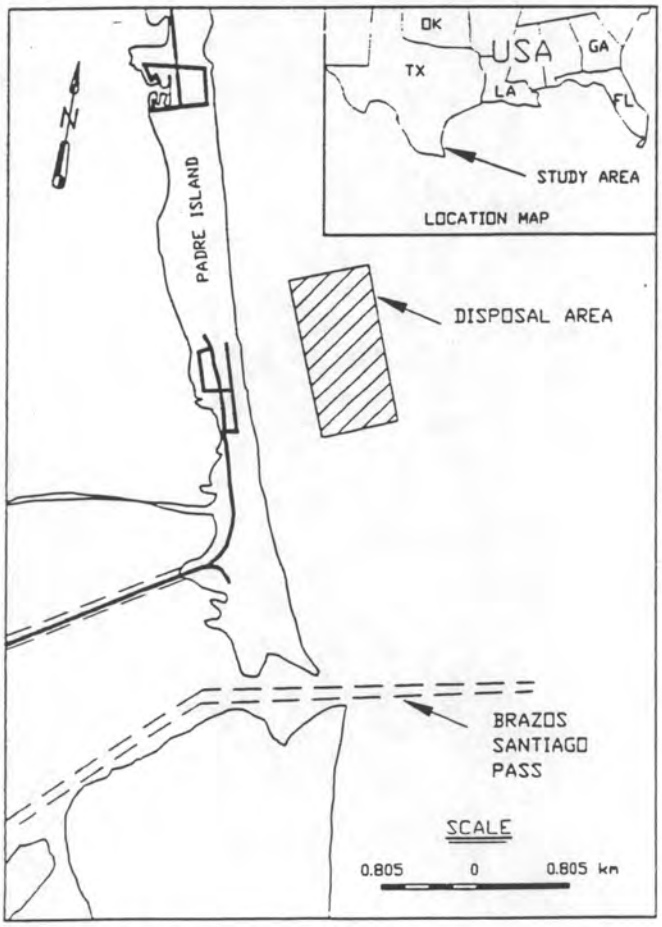

Figure 3. Location map of Brazos-Santiago Pass Inlet, South Padre Island, TX

The area of South Padre Island has a history of erosion with the exception of the extreme southern tip located next to the BSP jetties. Historical evidence shows that the predominant littoral drift in this area is to the north but indicates seasonal reversals during the winter months, October through February. To better define a berm construction location for Brazos-Santiago Pass, a field study was designed and conducted for the downdrift side of the jetties (McLellan and Burke 1988). The December 1987 field study utilized seabed drifters (SBDs), supplemented by additional instrumentation and procedures to delineate nearshore flow patterns. The SBD returns from potential construction locations suggested that the berm needed to be constructed at least 1.6 km north of the jetties to reduce the chance of sediments returning to the channel or being trapped by the jetty. In addition the hindcast wave data indicated that the berm should be shoreward of the 8.5 m contour and that late winter/early spring was the best time for construction to take advantage of seasonal littoral drift away from the entrance channel.

North American Trailing Company's hopper dredge MANHATTAN ISLAND placed approximately 168,000 m^3 of sandy material on the 8 m contour in December 1988. To ensure beach quality material was placed into the berm site, periodic samples were collected from the hopper dredge. Mean sizes of beach samples collected, ranged from 2.40 to 2.62 phi, a fine sand typical of Texas beaches. Samples from the hopper ranged from 3.08 to 3.15 phi, very fine sand. After placement, grain sizes increased to 2.6 phi in the vicinity of the berm. This shift to a coarser grain size was not evident in other samples collected in the berm's vicinity offshore, but outside of its influence. The higher quality beach material in the vicinity of the berm is most likely due to winnowing of finer grained fraction of the sediments during placement of the material.

Comparisons of the pre- and post-construction surveys indicate the berm rose 1.2 m above the natural bottom and is approximately 1070 m long (McLellan 1990). Figure 4 shows that during the winter months following

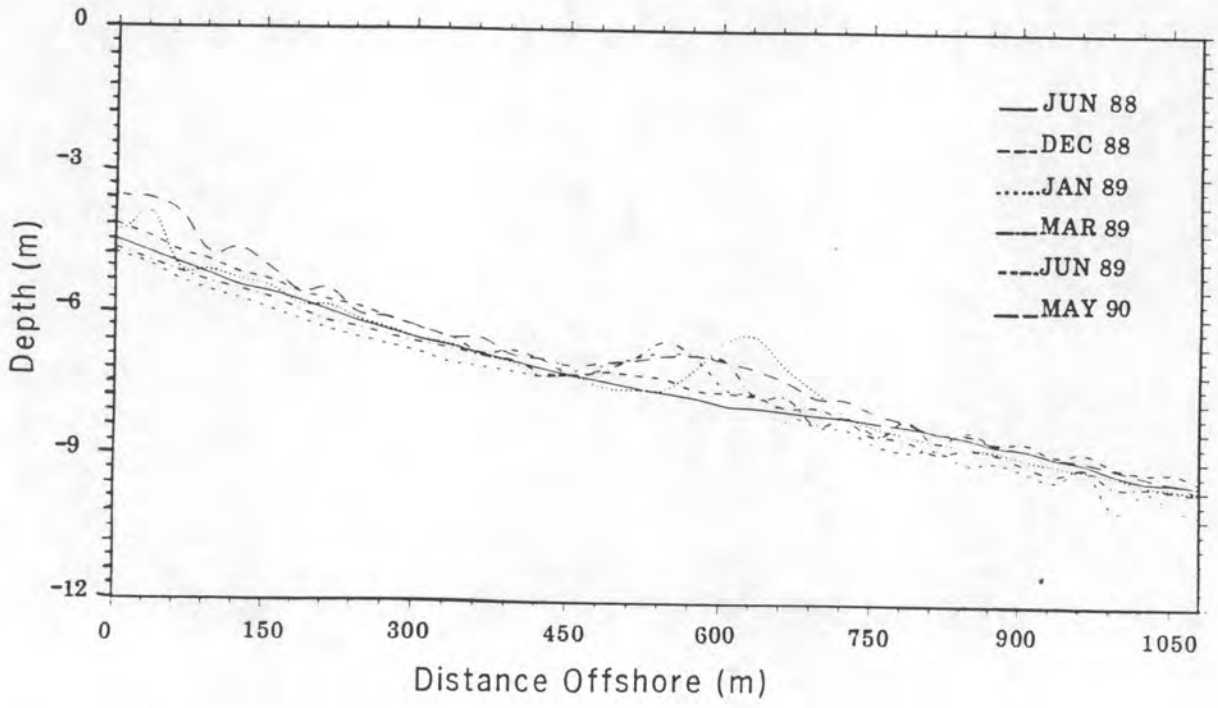

Figure 4. Survey profiles for Brazos-Santiago Pass Inlet

placement the berm moved approximately 91 m shoreward from January to March 1989. Historically, this is the most energetic time period for the area and the maximum movement can be expected. From March to June, with less energy in the environment, the berm had little to no movement. Preliminary indications are that the berm is moving as a bar directly towards shore, with little or no movement alongshore. There has been some erosion of the peak elevations, but there is still a well defined feature evident. The berm is expected to continue migrating towards shore as a bar, until it encounters the naturally forming bar, between -4.5 to -5.5 m. It is likely that the berm will then become assimilated into the littoral system and, from a monitoring standpoint, become indistinguishable from the natural system.

Silver Strand Park, California

From December 1988 through January 1989 the USACE Los Angeles District constructed the first recent nearshore berm project on the west coast of the United States. San Diego Harbor is the southernmost harbor on the West Coast of the Continental United States, and Silver Strand Park is located approximately ten km to the southeast (Figure 5). The berm was constructed of 110,000 m^3 of medium sand removed during maintenance of San Diego Harbor. Placed parallel to the Silver Strand shoreline, the berm's final dimensions were 370 m long by 180 m wide. The hopper dredge NEWPORT performed the dredging, and constructed a feeder berm between 230 m to 460 m offshore, corresponding approximately to the -3 m and -9 m mean lower low water (MLLW) contours. Immediately after construction, the berm crest elevation was recorded as high as -3 m MLLW at some locations (Juhnke, Mitchell, and Piszker, 1989 and USACE, 1990).

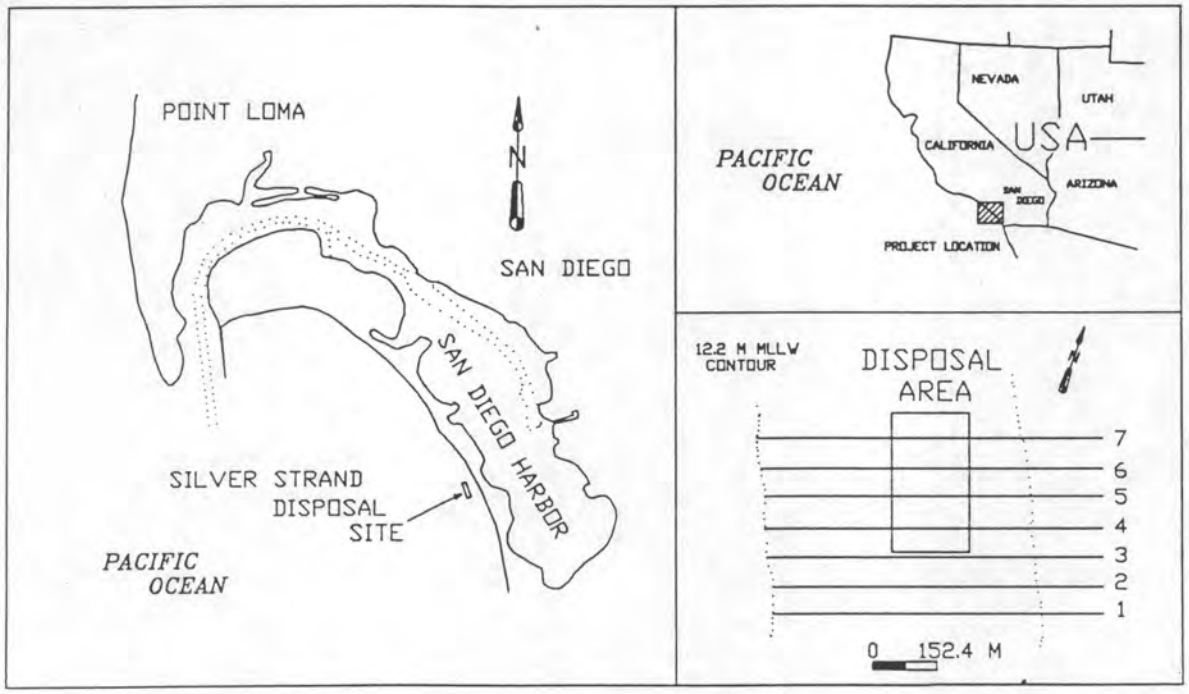

Figure 5. Location map of Silver Strand, CA

Seven survey profiles on 76 m intervals, extending from -12.2 m MLLW across the berm site and up the beach to the 1 m MLLW contour, were

surveyed 8 times at regular intervals between December 9, 1988 and February 21, 1990 (USACE Los Angeles District, 1990). Because the adjacent beach was included in the surveys, these profiles provide information previously undocumented for other USACE berms. From these profiles, the impact of the berm on the beach can be measured. Figure 6 shows pre-construction and post-construction surveys for profile five across the center of the berm. By comparing the December 8-9, 1988 survey to the August 14-15, 1989 survey it can be seen that eight months later the berm has flattened out, nourishing the profile, and the MLLW shoreline has moved nearly 60 m seaward, creating a wider dry beach. Examination of all profiles for the 14 month study revels a trend of onshore migration of the berm. Reworking of the berm material by the hydraulic regime reduces it's relief, and nourishes the profile as the profile approaches equilibrium.

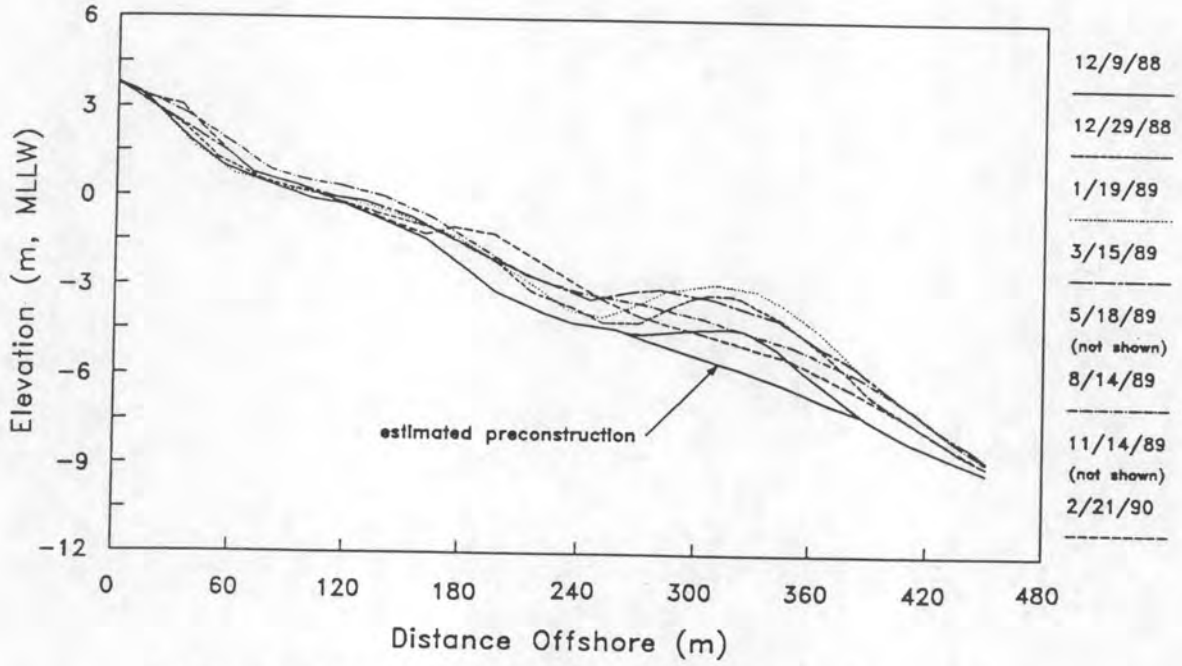

Figure 6. Surveys of profile 5 for Silver Strand, CA

Figures 7, 8 and 9 show migration of the berm crest, the MLLW shoreline, and the +1.5 m contour vs. time for five of the profile lines. From these figures it is clear that the berm migrated onshore, and at the same time the beach increased in width. According to the USACE Los Angeles District (1990), between the first post-construction survey 29 December, 1989 and the 15 March, 1989 survey, average onshore movement of the crest position was 34 m. Maximum shoreward movement was 54 m near the southern end of the berm, and minimum shoreward movement was 18 m.

To quantify volumetric changes in the nearshore caused by the berm, the USACE Los Angeles District (1990) sectioned the profiles into three regions referenced to pre-construction depths and compared the profiles through time. A summary of their findings follows. The three regions, +3 m to 0 m, 0 m to -3 m, and -3 m to -9 m MLLW, delineate the visible beach, the foreshore, and the berm construction area. Between the pre-construction survey and the first post-construction survey, the volume of material within the survey area increased 118,500 m^3. Placed dredge material accounts for 110,000 m^3 of this increase, 8,500 m^3 resulted from transport of material from outside of the survey region. Over the next four month period between January 19, 1989 and May 18, 1989, there was no

significant change in the total volume of material within the survey area; however, approximately 23% of the volume of material was redistributed from the berm area to the foreshore region. No significant longshore changes were observed for this time frame. During the summer and into the fall, between surveys May 18, 1989 and August 14, 1989, the total volume within the survey area increased by approximately 26,000 m^3.

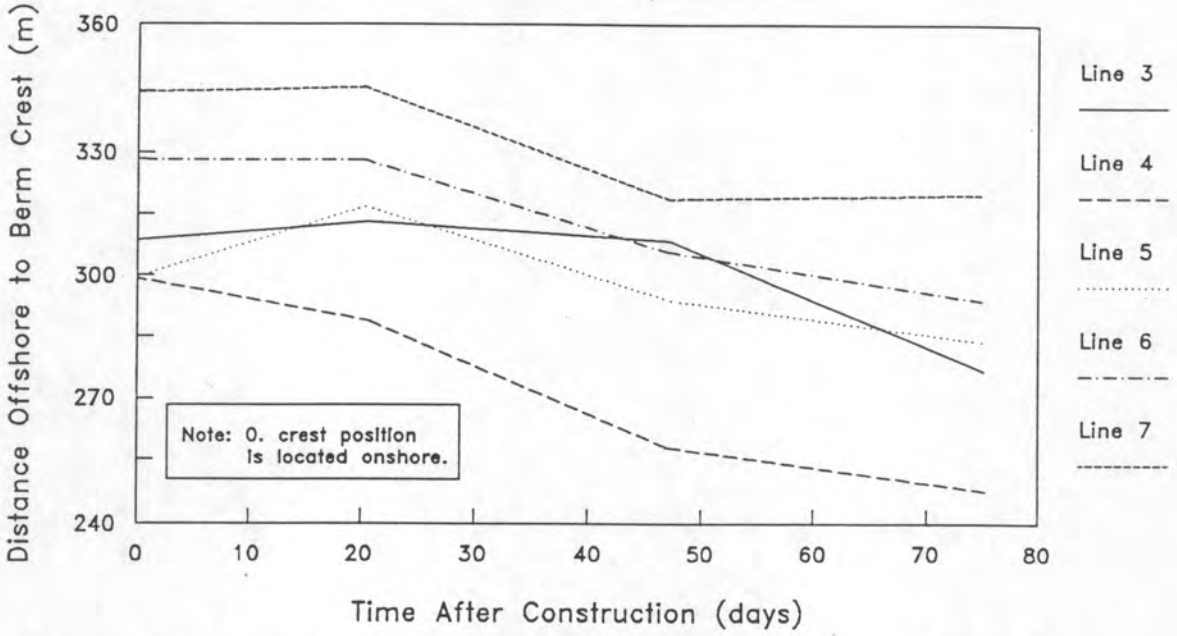

Figure 7. Migration of berm crest shoreward at Silver Strand, CA

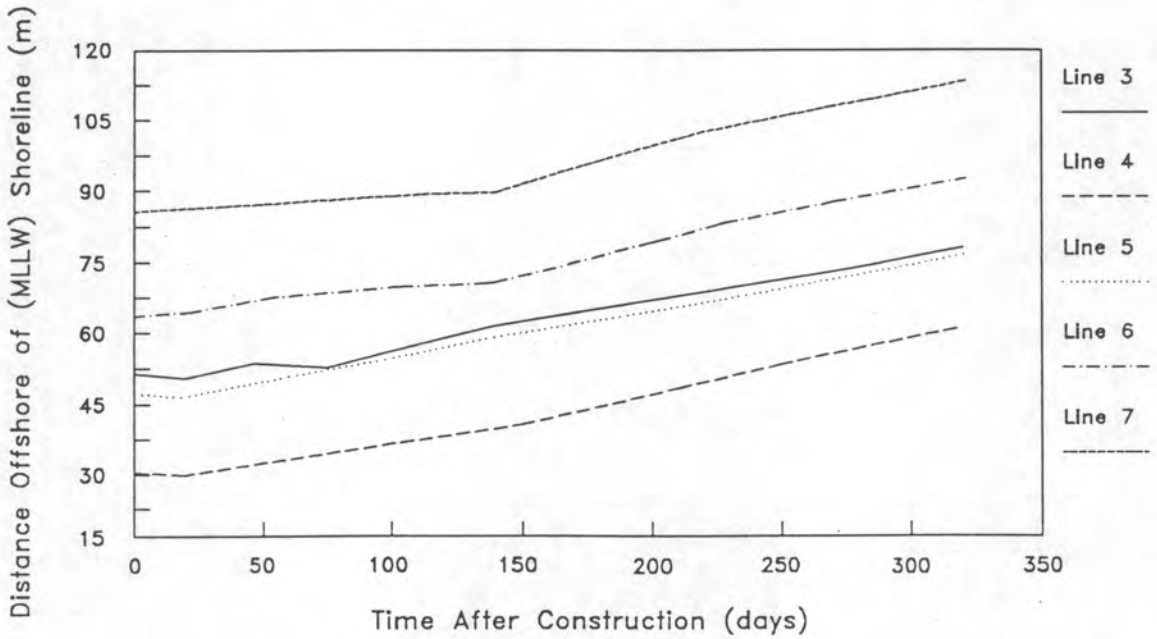

Figure 8. Migration of MLLW shoreline seaward at Silver Strand, CA

The increased volume was concentrated within the beach and foreshore regions. The source of this material may have been littoral drift moving alongshore and impounding in the lee of the berm due to a modified hydraulic regime (USACE Los Angeles District, 1990). Volumes from surveys taken on November 14, 1989 and February 21, 1990 indicate

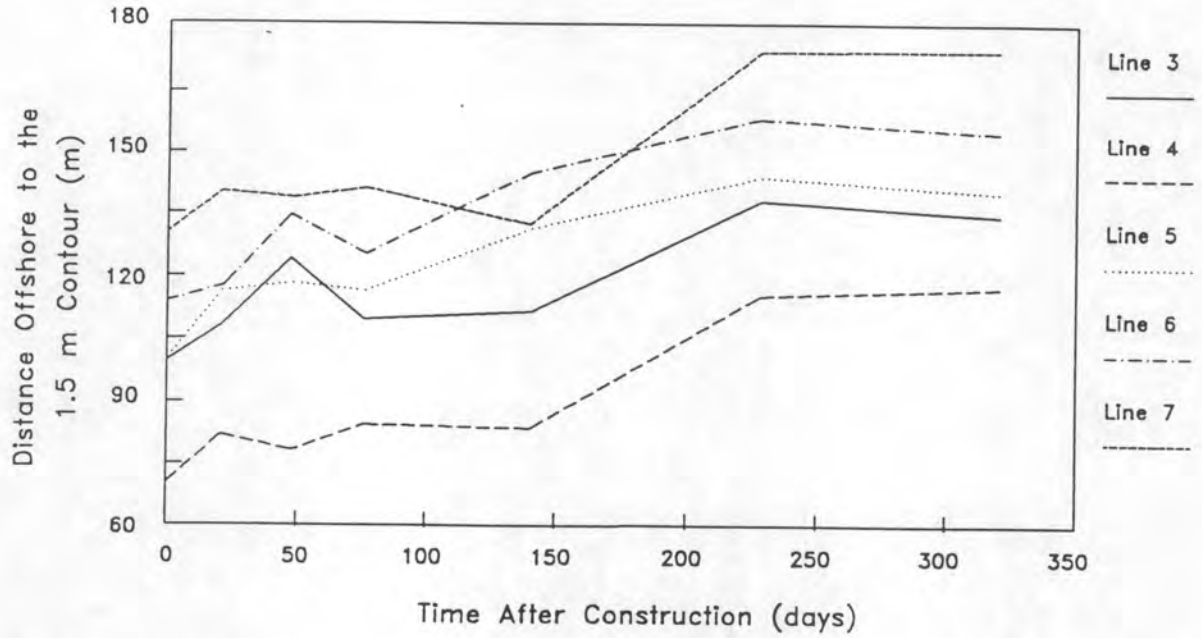

Figure 9. Migration of the +1.5 m contour seaward at Silver Strand, CA

seasonal effects. Approximately the same volume that accreted in the foreshore during summer, eroded from the entire survey area during the winter, returning the volume within the survey area to the first post-construction survey level. The volume of dredged material that was placed and the additional volume that accreted immediately prior to the first post construction survey remained within the survey area through the first year of the monitoring.

The Silver Strand Park berm seems to be an unquestionable success. The nearshore profile has been reworked. Berm material has dispersed into the profile and equilibrium has been reached. Due to both direct and indirect effects of the berm, the beach is much wider and the entire profile has shifted offshore. At the end of one year, the volume of material contained within the survey area, accounting for seasonal changes, has remained nearly the same as the volume at the time of the first post-construction survey.

Morro Bay, California

Morro Bay is located on the Central California coast approximately 240 km north of Los Angeles, nearly half the distance to San Francisco. The Morro Bay feeder berm was built in 1990 by the USACE Los Angeles District with maintenance material dredged from the Morro Bay entrance channel. Dredging and berm construction were performed by the USACE Portland District's dredge Yaquina, a 630 m^3 hopper dredge, drafting 4.3 m when loaded. Two sites were used (Figure 10), but the north site received only 38,200 m^3 and was surveyed pre- and post-construction. Continued monitoring was not performed. The south site received 329,000 m^3 of medium sand and some silt and is discussed here. The operation took place between September 3, 1990 and November 15, 1990 (Anderson, 1991).

South site monitoring included pre-, during, and post-construction surveys, sediment samples, and wave data. Survey profiles extended across the berm site and up onto the beach. Additional profiles north and south of the site were surveyed as controls. Profiles extended from the -18 m MLLW contour approximately 1200 m offshore up to the +3 m MLLW elevation on the beach (Shak, 1991).

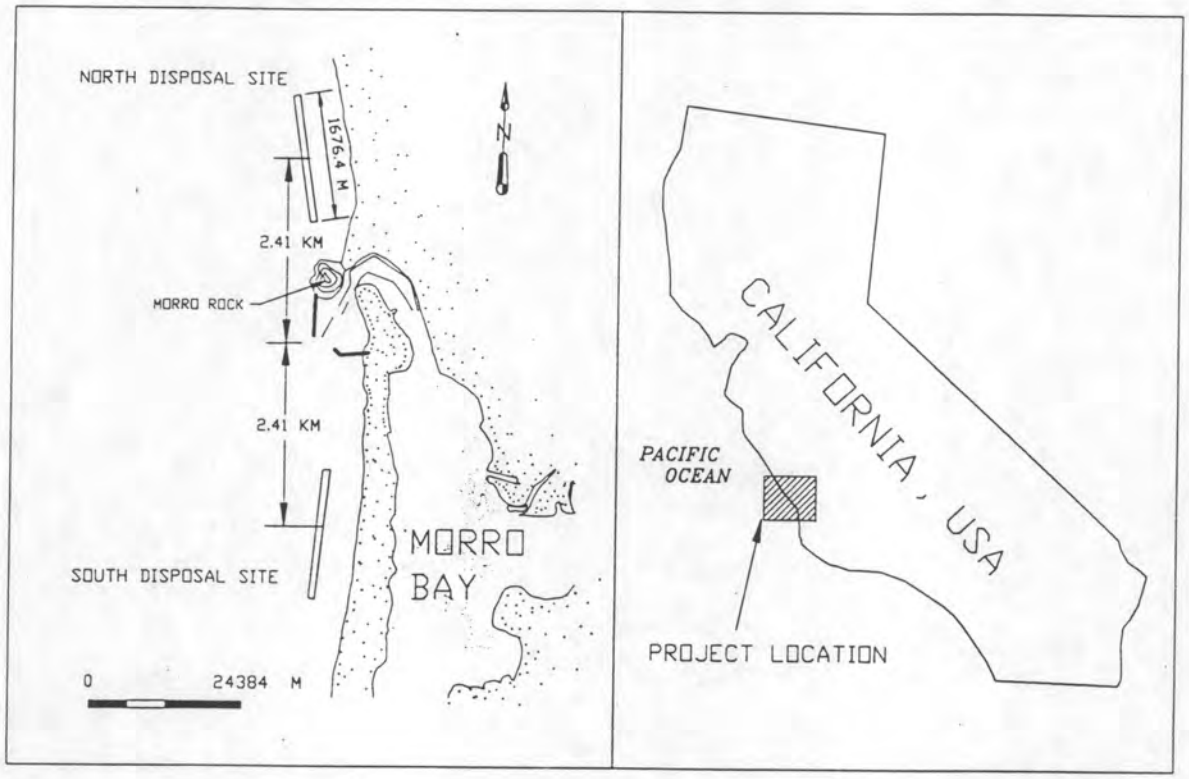

Figure 10. Location map of Morro Bay, CA

Construction at the southern site resulted in a 760 m long, linear subaqueous feature with two bulbous regions. These bulbous regions contain large percentages of the material, creating areas of relatively high relief peaks. These peaks may focus wave patterns in their lee. Figure 11 displays a footprint of the berm and the relative alignment of the berm crest from the November 17, 1990 survey.

Placement of the material in the south site ranged between the -8 m and -13 m MLLW contours, at a distance of 610 m to 910 m offshore. The berm crest of the southern two-thirds of the feature is centered approximately on the pre-construction -11 m MLLW contour, approximately 760 m offshore. At the southern tip, the berm curves slight shoreward to the -9 m MLLW contour, 670 m offshore. The northern one-third of the berm formed in slightly deeper water, with the crest at a pre-construction depth of -12 m MLLW and 820 m offshore. At its widest point, the berm measured 260 m wide perpendicular to the shoreline and averaged 175 m in width (Figure 11).

To provide a visual interpretation of the post construction alongshore berm geometry, Figure 12 shows the water depth at the berm crest from the November 17, 1990 survey and the depth of the base of the berm directly under the crest from the pre-construction September 1, 1990 survey. Comparison of the two values shows the variance in relief of the berm along shore. The berm's maximum crest elevation from the November 17, 1990 survey was -7 m, the second highest crest peak elevation was -8 m. Relief of the berm in these regions was also greatest, 4.3 m and 3.4 m respectively. Berm crest average elevation was -9.5 m and average relief of the berm was 2 m.

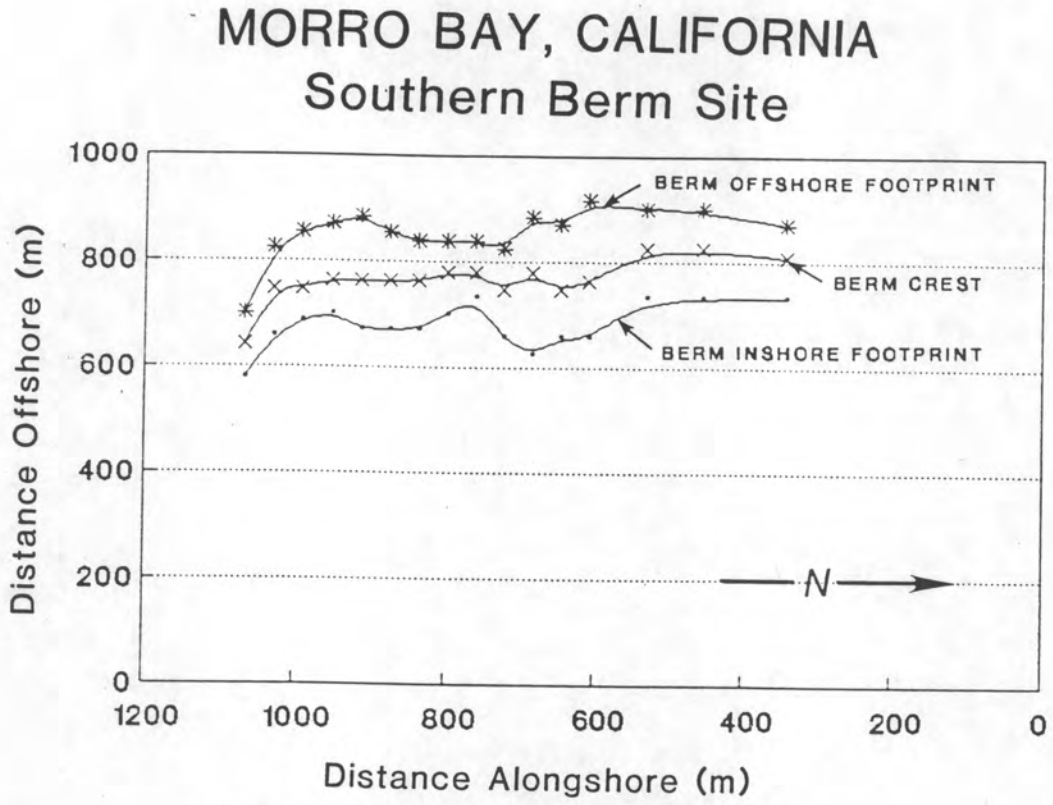

Figure 11. Morro Bay berm footprint

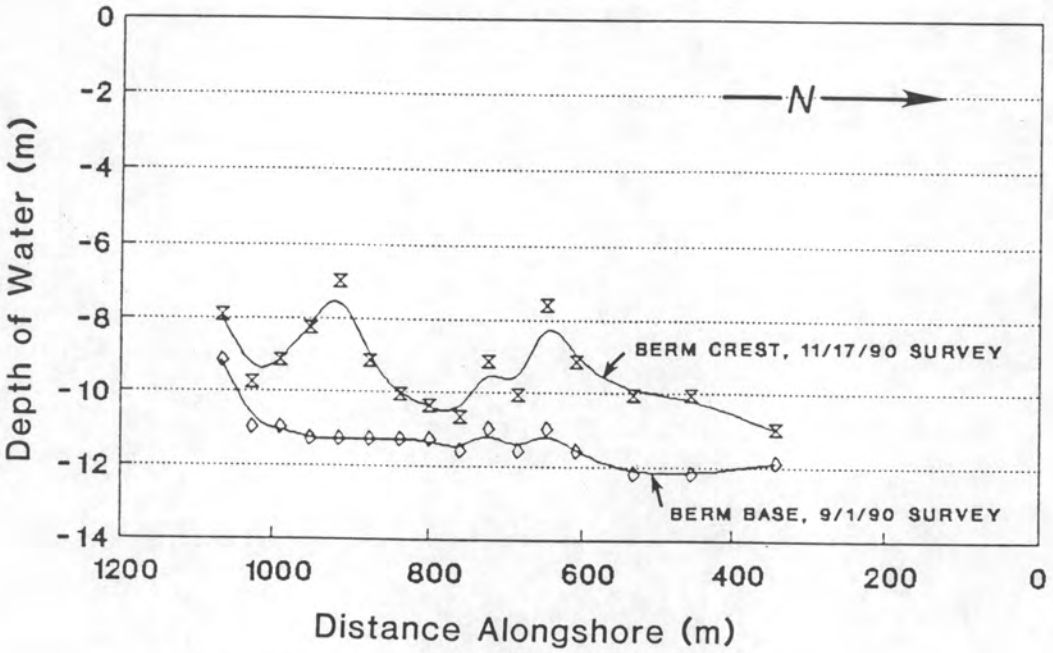

Figure 12. Morro Bay berm crest and base

DESIGN GUIDANCE

A primary goal of the research associated with nearshore berms has been to provide design guidance. Design guidance includes information on berm siting, geometry, placement techniques, and berm functions. Initial guidance can be found in McLellan (1990), and McLellan, Kraus, and Burke (1990).

SUMMARY

Between 1987 and 1990, the USACE has been responsible for constructing several nearshore berms. Each of these berms has been monitored to some degree providing strong evidence that the berms are functioning as designed to either provide additional material to the littoral zone or to remain stable features to reduce wave energy. Results from the monitoring efforts at these berms are being used to improve design guidance. As the experience base enlarges, design guidance becomes more sophisticated, and more local and regional resource agencies realize the benefits and cost effectiveness of nearshore berms, their use should increase.

ACKNOWLEDGEMENTS

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