# City of Oceanside Beach Sand Replenishment and Retention Device Project

Feasibility Analysis of Project Alternatives

(Photo: SANDAG 2020)

Prepared for:

City of Oceanside
Public Works Department

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# ES.1 Executive Summary

Since construction of the Oceanside Harbor complex 80 years ago, the City of Oceanside and U.S. Army Corps of Engineers (USACE) have struggled to offset the erosional impacts to downdrift beaches. The effect was described as an “erosional wave” that could be seen moving down the Oceanside Littoral Cell, which spans from the harbor to La Jolla submarine canyon to the south (Jenkins and Inman 2003). During this time, the City placed over 21M cubic yards (cy) of sand on their beaches from both the USACE’s harbor dredging program (13.5M cy) and one-off, local or regional nourishment events (7.5M cy). This also includes a limited volume of sand from the City and USACE’s Experimental Sand Bypass System that was constructed in the 1980s in efforts to restore the natural transport pathway that was broken when the harbor was constructed. All of these efforts have fallen short of providing the City with a sustained, dry sand beach for recreational, ecological and coastal storm damage protection purposes.

The current condition of many City beaches is dismal for beach recreation, with many areas having little to no dry beach during the majority of the tidal cycle. Wave events are impacting coastal infrastructure with greater frequency and severity, resulting in the need for repairs and improvements to shoreline protection systems. Projected sea level rise threatens to make these conditions worse.

Many factors contribute to the state of Oceanside beaches, but the most significant are the volume and type of sand delivered to City beaches. The USACE’s harbor dredging program places silty sand from the navigational channels on the beaches. This sand is easily mobilized by waves and forms a submerged beach of little value for recreation and storm damage benefits. Coarse-gradation sand remains higher on the upper beach profile and is required to form and sustain a dry beach area. Unfortunately, the primary supply of coarse-gradation sand (littoral drift) is blocked by the Oceanside Harbor breakwater and impounded in the upcoast fillet which has formed a 400-500 foot wide dry beach along Camp Pendleton’s Del Mar Beach Resort.

Four alternatives were developed to meet the City’s desire to protect beaches from long-term shoreline erosion in an environmentally sensitive and financially feasible way. To this end, the Project approach is to pilot the selected alternative in combination with a robust scientific monitoring program, as led by the Scripps Institution of Oceanography. The pilot would be closely monitored for its performance in retention of a beach as well as potential impacts to downdrift beaches and recreational resources.

The four alternatives analyzed in this report are as follows:

- **No Project** assumes continuation of the status quo in which Harbor maintenance dredging is the only program adding sand to the City beaches on a regular basis. The City would continue to participate in regional nourishment efforts similar to RBSP I and II on an ad-hoc basis.
- **Alternative 1: Beach Nourishment** assumes a more frequent beach nourishment program is carried out by the City to deliver 300,000 CY of sand once every five years, approximately doubling the frequency of prior RBSP efforts.
- **Alternative 2: Groins** assumes construction of four, 600-foot long, rubble mound groins spaced 1,000 feet apart along the Pilot Reach. The proposed groins are shore-perpendicular and would extend seaward from the existing rock revetment with a crest elevation of 10' MLLW. A 300,000 cy initial nourishment was included to pre-fill the groin field with subsequent nourishment volumes reduced by about 50%.
- **Alternative 3: San Luis Rey Groin Extension** assumes construction of a 350-foot extension of the existing groin to capture sand moving north toward the harbor. The sand trapped in this fillet could possibly be used as a source for downcoast receiver beaches. This alternative includes a beach nourishment component identical to Alternative 2.
- **Alternative 4: Multi-purpose Artificial Reefs** assumes construction of two 1,000-foot long, rubble mound reefs spaced 1,200 feet apart along the Pilot Reach. Each reefs would have emergent and submergent crest sections along their lengths to dissipate wave energy and potentially create a surfable wave on each end of the reef. A 300,000 cy initial nourishment was included to pre-fill the reef salients with subsequent nourishment volumes reduced by about 50%.

A multi-criteria analysis (MCA) was performed to compare alternatives based on a wide range of criteria that reflects the diversity of opinions and input received from the outreach activities. Each alternative was evaluated against 11 criteria, organized into three categories of Technical Performance, Financial, and Environmental. The results of the MCA indicated the highest ranked alternative was Groins, followed by Multi-purpose Reefs as illustrated in Figure ES-1. These top two alternatives were separated by 8% from one another in total score, which was meaningful when considering the sensitivity of the scoring and weighting system. Beach Nourishment ranked third, about 17% lower than the Groins and 9% lower than Multi-purpose Reefs. The No Project alternative ranked last with very low scores in the Technical Performance and Environmental categories.

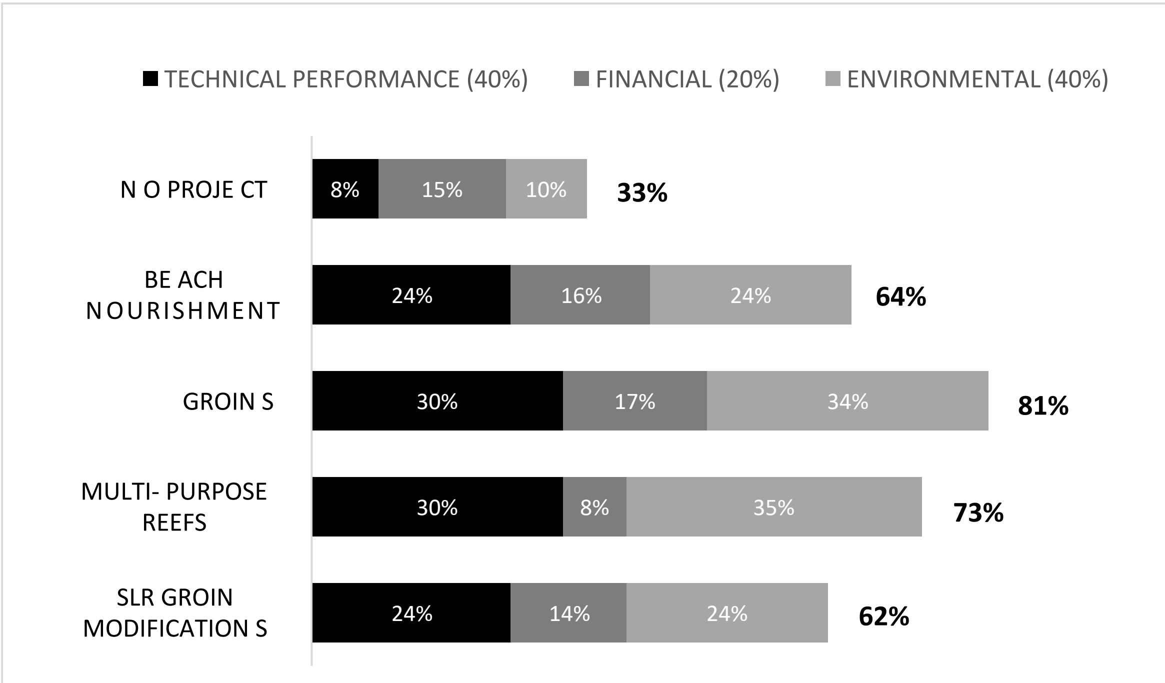


**Figure ES-1: Summary of Multi-Criteria Analysis Scoring for Alternatives**

The findings of this analysis are consistent with numerous prior studies that found groins to be a preferred option for erosion protection in the City. Many of these studies discounted groins for social, political or regulatory reasons. Studies with consistent findings are as follows:

- USACE (1980) – Design of Structures for Harbor Improvements and Beach Erosion Control. Oceanside Harbor and Beach, CA.
- Noble and Associates (1983) – Report of proposed groin field in Oceanside
- USACE (1994) – Reconnaissance Report of Oceanside Shoreline
- Gary Griggs et al. (2020) "Groins, Sand Retention and the Future of Southern California Beaches"
- USACE (Ongoing) – Special Shoreline Study for San Diego.

The life-cycle costs for each of the alternatives is presented in Figure ES-2. Beach Nourishment has a lower lifecycle cost than the Groins due to the initial cost of building the groin structures. The Groins alternative has lower maintenance costs since less volume of nourishment is required over the project duration. Multi-purpose Reefs was estimated to have the highest lifecycle cost due to the significant volume of material required to build the artificial reef structures. Inclusion of a sand bypass option into any of the proposed alternatives has the potential to significantly reduce beach renourishment costs after the initial capital expenditure to construct the system.

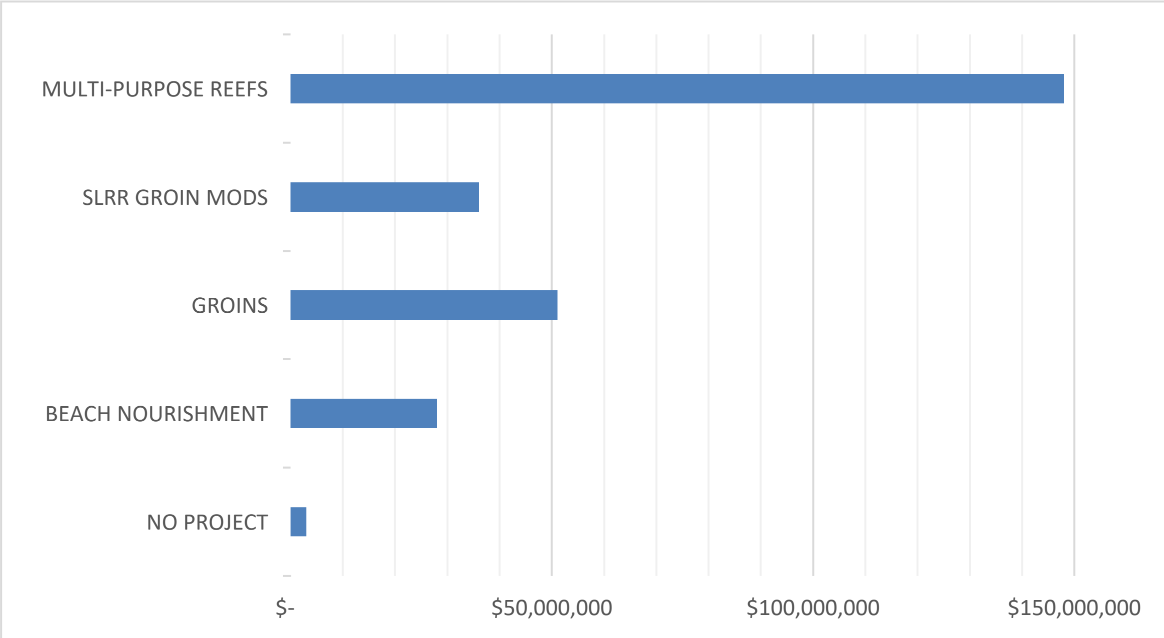


**Figure ES-2: Estimated Lifecycle Costs for Alternatives**

The beach area generated over the lifecycle of each alternative provides a useful metric for comparing the benefit or value of each alternative. Modeling results of the pilot-scale sand retention alternatives indicate they could potentially retain up to 18 acres of beach area, over three times larger than the beach area generated within the initial placement area after RBSP II. While Beach Nourishment has a significantly lower lifecycle cost, the area of beach generated is also significantly lower. Groins require a larger capital expense but offer the highest return on the investment with the best chance of success in providing a stable dry beach along the pilot reach. A comparison of the value in terms of cost per acre of beach area generated for each alternative is provided in Figure ES-3.

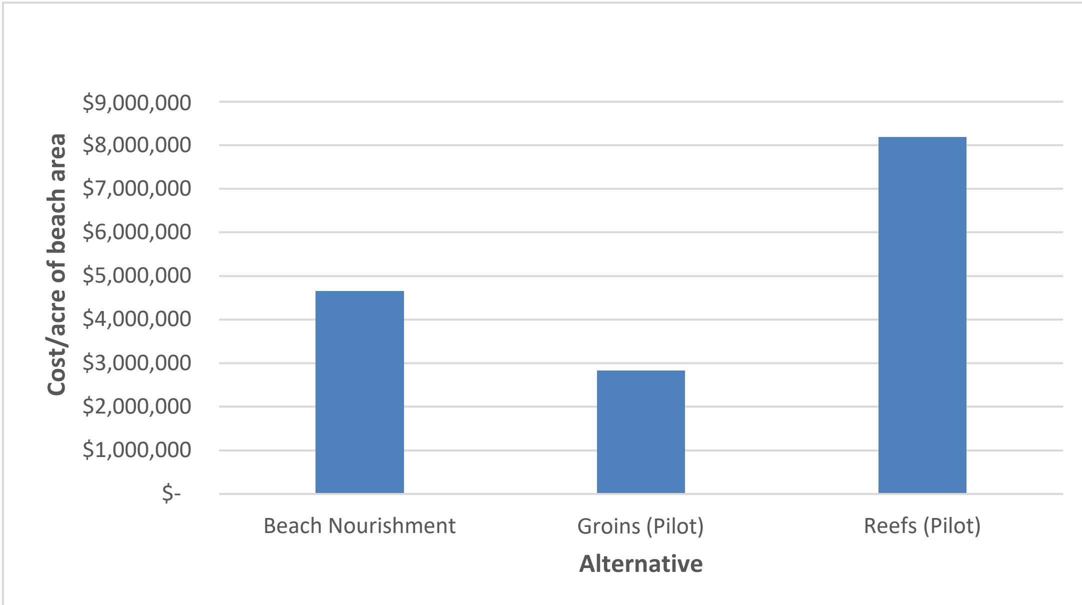


**Figure ES-3: Value Comparison for each Alternative**

The findings of this analysis give the Project team high confidence that Groins have the best chance to protect against long-term shoreline erosion based on consideration of Technical Performance, Financial and Environmental criteria. GHD recommends the Groin pilot-scale concept be advanced for further analysis, additional public/agency outreach and preliminary design to prepare for the environmental review and permitting process. Additional analysis of the Groin alternative would involve sensitivity analyses on groin length and spacing, the pre-fill volumes and sand management systems required to mitigate potential impacts.

Recognizing that any of the alternatives considered within this study require a long-term, high-quality source of sand, a number of sediment management systems were evaluated in this study. The systems evaluated include the following:

- **Fixed Trestle Bypass:** Construction of a fixed trestle (pier type structure) on Camp Pendleton with a series of intake pumps extending into the surfzone/nearshore. The structure would act to capture sand moving in the longshore direction and would transport large quantities of sand (i.e. 100 to 300k cy per year) to City beaches via a network of shallow and deep underground pipelines with multiple outlet locations.
- **Semi-fixed Sand Bypass:** Construction of a smaller bypass system (capable of moving 50 to 100k cy of sand per year) that could be moved relatively easily to accommodate changes in the sand source location. Similar to the fixed system, this option would entail construction of sand distribution pipelines transport sand within the City. This system could be manipulated to source sand from the Camp Pendleton fillet, Harbor Beach or the San Luis Rey River mouth.

- **Piggyback on USACE Harbor Dredging Program:**
  This option assumes the City would "piggyback" on the USACE's annual harbor dredging program (with or without the construction of fixed sand distribution pipelines) to bypass sand from the MCB Camp Pendleton fillet or other high-quality sand source. Piggybacking on other dredging operations is a common practice to save on contractor mobilization/demobilization costs. Logistics surrounding how to access and dredge the fillet or other high-quality sand source would require further coordination with the dredge contractor and the MCB Camp Pendleton.

Without having secured a significant source of high-quality sand for the City, there is limited benefit to furthering the design and analysis of a sand bypass system. The ideal sand source for a sand bypass system is the MCB Camp Pendleton fillet despite the significant political and jurisdictional obstacles that exist. Should that sand source become available, the Semi-fixed Sand Bypass or USACE Piggyback option should be evaluated more closely to determine the most cost-effective solution.

Recommended next steps are as follows:

1. **Agency and Stakeholder Coordination & Engagement:**

   a. Overcoming the social, political and regulatory challenges surrounding the use of sand retention structures is going to require continued coordination with key agencies and stakeholders to address concerns surrounding downdrift impacts, recreational impacts and precedent-setting type concerns. Key agencies to continue to engage include the California Coastal Commission, Surfrider Foundation and other non-government agencies that have expressed concern during this first phase.

   b. Access to the sand source along the northern fillet is also a critical element in making any sand bypassing option viable. Engagement with the MCB Camp Pendleton at the appropriate level is also a key next step to securing a sustainable, high-quality source of sand and progressing sand bypassing options.

   a. Further engineering analysis and design of the Groin concept is needed to refine the length, spacing, location, and structural details of these structures. The volume and distribution of the initial nourishment will also depend on this additional analysis and design effort.

   b. Development adaptive management plan to address public, agency and stakeholder concerns about potential impacts. The plan will identify triggers where action would be taken to remedy an impact, if realized. The plan would be informed by the scientific monitoring program.

3. **Enhance Beach Data Monitoring Efforts**: Beach width data is important to understand changes and base management decisions on. Establishing a baseline of data will also be useful should a sand retention pilot be constructed. The following monitoring actions are recommended:

a. Continue to support tracking of subaerial beach widths (dry beach) with the citizen science program conducted by Save Oceanside Sand (SOS) and others in coordination with the Scripps Institution of Oceanography (SIO).

b. Annual to bi-annual, high-resolution beach and nearshore SIO "Jumbo Surveys" are recommended to track the spatial and temporal changes in sand in the City. These surveys supplement the subaerial surveys and provide a greater level of detail than the existing regional transect monitoring program.

4. **Develop Project Financing Strategy**: Any of the alternatives considered will require a significant amount of capital and operational expenditure. Financing strategies should be considered in concert with seeking state and federal grant funds for the Project.

5. **Stay Actively Engaged in Local and Regional Sediment Management Activities:** The City should remain actively engaged in ongoing management activities and seek new sources of sand, as they become available. This recommendation works in concert with the sediment retention project as local sediment management activities alone will lack the magnitude or quality to sustain beaches in the city.

    a. Continue to engage with the USACE on annual harbor dredging program activities. The timing, placement methods and locations should be discussed to see if they can be modified to increase local benefits.

    b. Continue to seek opportunistic sources of sand (i.e. San Luis Rey River, Buena Vista Lagoon Restoration, etc.) for beach nourishment. Maintain City's permits for the Opportunistic Beach Fill Program to streamline approval of these sand sources as they become available.

    c. Continue to participate in future regional beach sand projects with consideration for different placement locations, quantities or timing within the City to increase local benefits.

# 1. Introduction

Despite existing sediment management and planning efforts, City of Oceanside (City) beaches are in severely eroded condition leaving many areas with limited or no dry beach. The City understands the importance of sandy beaches for protection of coastal infrastructure, recreation and the local economy. The City seeks to identify feasibility solutions to protect and restore their shoreline by either utilizing re-nourishment projects or construction of sand retention devices, or a combination of both.

Sand retention structures (e.g. groins, breakwaters) act to retain/reduce the loss of sand on an eroding shoreline by altering the effects approaching waves. The City acknowledges the potential regulatory and funding challenges with the solutions being considered and wishes to identify strategies that are environmentally sensitive, financially feasible and have a reasonable chance of being approved through the regulatory permitting process.

The City retained GHD Inc. (GHD) to undertake a preliminary engineering evaluation of feasible options for the Beach Sand Replenishment and Retention Device Project (Project). The scope of this study included the following major tasks:

- **Coastal Data & Project Review**: Gather and assimilate existing coastal data and data on similar, global project examples in order to understand the City problem and bring forward viable solutions.
- **Concept Design**: Develop beach nourishment and sand retention concepts to be evaluated within the study. Concepts to be evaluated through a multi-criteria decision matrix.
- **Numerical Modeling of Concepts**: Develop and validate a coastal numerical model to evaluate the performance of beach nourishment and sand retention concepts.
- **Estimate Future Costs**: Develop soft (i.e. design, permitting, outreach) and hard (i.e. construction and adaptation) cost estimates for the concepts being considered.
- **Scientific Baseline & Monitoring Plan:** Develop a scientific baseline for the Study Area and a robust monitoring plan that can be implemented to test any of the nourishment or sand retention options once constructed. Scripps Institution of Oceanography (SIO), working under a subcontract with GHD, led this work.
- **Resource Agency, Stakeholder and Coastal City Coordination Meetings:** Early coordination with each of these groups to receive feedback of options being considered.

Figure 1-1). The Project Area, or area of focus, for the study includes the City's southern shoreline from about the Oceanside Pier to Buena Vista Lagoon (Figure 1-2). The Project Area is severely eroded and has little sustained dry beach for the last 10 years compared to beaches north of the pier.

**Figure 1-1. Project Location**


**Figure 1-2. Project Area**

# 2. Coastal Setting

Oceanside is the northernmost city of the Oceanside Littoral Cell. A littoral cell is a segment of coastline with unique sediment sources, pathways and sinks that all impact or benefit the shorelines within it. The cell is bounded to the north by the Dana Point Harbor and to the south by La Jolla submarine canyon. Primary sediment sources to the cell include rivers, bluff erosion, gully/terrace erosion and beach nourishment. Natural sediment delivery to the coastline has generally declined over time within the cell as a result of various forms of development impeding their flow.

The majority of the City's shoreline is protected by seawalls and rock revetments. The City's bluffs are setback behind these protection devices in many locations. Other parts of the shoreline are modified by shore-perpendicular coastal structures, including a rock groin at the San Luis Rey River, the Oceanside Harbor breakwaters and the Oceanside Pier.

The wave climate within the City is characterized by seasonal long-period swells generated by distant storms in the North Pacific and Southern Oceans. Southern swell arrives at Oceanside from the southwest through the spring and summer months and transports sand to the north (Figure 2-1). Larger North Pacific swell approaching from the northwest and west during the fall and winter months transports sand to the south (Figure 2-2). Locally generated short-period wind waves can occur any time during the year and typically come from the west.

Waves are the dominant driver of sediment transport along Oceanside beaches. The net longshore sediment transport patterns for Oceanside are accepted to be southern, although seasonal variations are common and depend on the swell direction. There are numerous estimates of the longshore sediment transport for Oceanside and within the Oceanside Littoral Cell, as shown in Table 2-1. These estimates are based on historic studies and have not been updated or field verified recently. However, amongst these studies there is general agreement that Oceanside experiences a net sediment transport to the south of 100,000 to 200,000 cubic yards (cy) per year.

Sediment also moves in the cross-shore direction within the Oceanside Littoral Cell and is estimated to range from 26,000 to 113,000 cy/year (USACE, 1991). Cross-shore transport predominantly occurs during high energy wave events and are most likely be concentrated at creek mouths and around structures (USACE, 1994).

**Table 2-1. Longshore Sediment Transport Estimates**

<table>
<tr><th>Location</th><th>Estimated Gross Northern Transport Rate (cy/yr)</th><th>Estimated Gross Southern Transport Rate (cy/yr)</th><th>Estimated Net Longshore Transport Rate (cy/yr)</th><th>Direction</th><th>Source</th></tr>
<tr><td rowspan="3">Oceanside Littoral Cell</td><td>545,000</td><td>760,000</td><td>215,000</td><td>South</td><td>Marine Advisors (1961)</td></tr>
<tr><td>NA</td><td>NA</td><td>250,000</td><td>South</td><td>Inman (1976)</td></tr>
<tr><td>550,000</td><td>740,000</td><td>194,000</td><td>South</td><td>Hales (1979); Inman & Jenkins (1985); Dolan et al. (1987)</td></tr>
<tr><td>Oceanside Harbor Southside</td><td colspan="2">934,000</td><td>106,000</td><td>South</td><td>USACE, (1991); Tekmarine, Inc., (1978)</td></tr>
<tr><td>Oceanside</td><td>NA</td><td>NA</td><td>146,000</td><td>South</td><td>Patsch & Griggs, 2006</td></tr>
<tr><td>Oceanside</td><td>553,000</td><td>807,000</td><td>254,000</td><td>South</td><td>Inman & Jenkins (1983)</td></tr>
<tr><td>Oceanside</td><td>541,000</td><td>643,000</td><td>102,000</td><td>South</td><td>Hales (1978)</td></tr>
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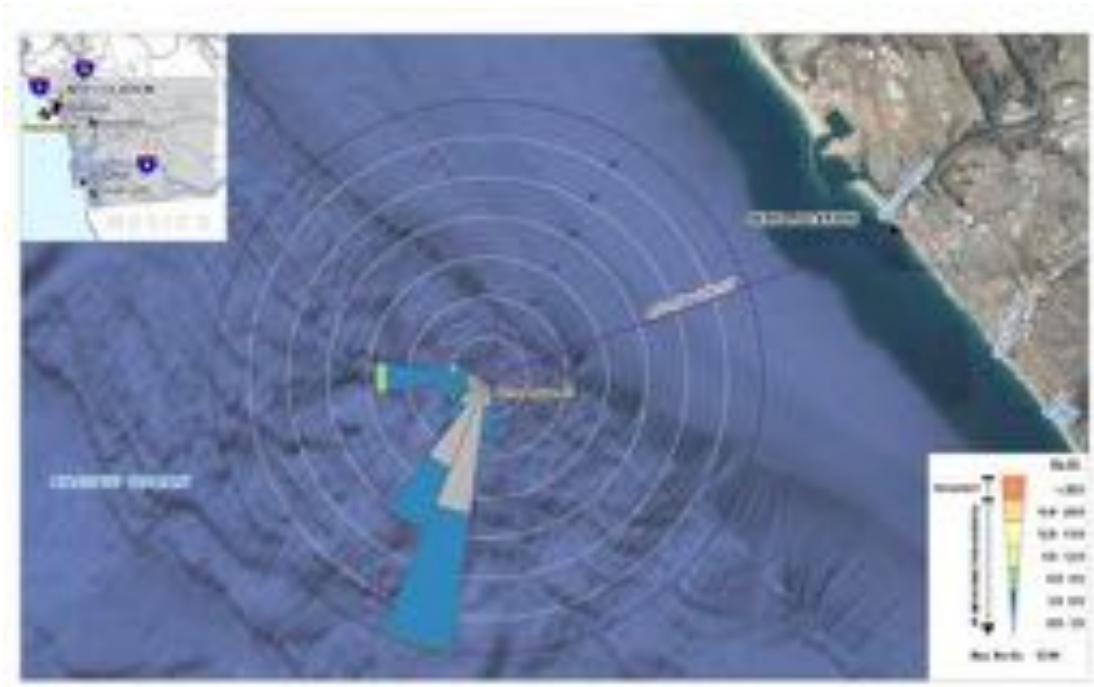

**Figure 2-1. Summer Wave Height and Approach Direction (CDIP Station 045 2000-2020)**

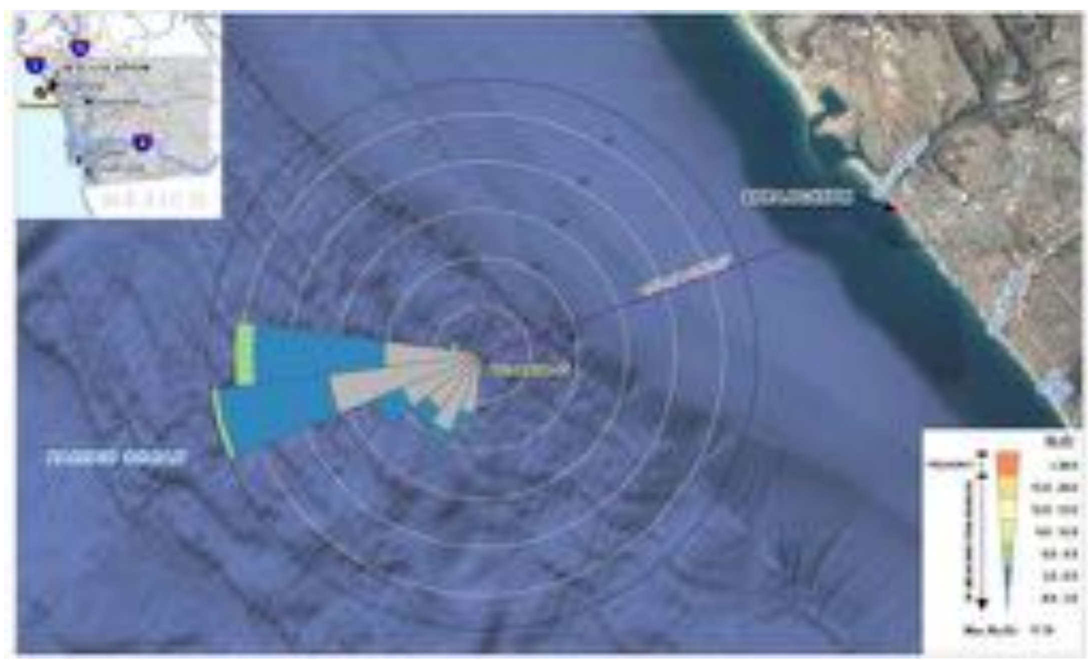

**Figure 2-2. Winter Wave Height and Approach Direction (CDIP Station 045 2000-2020)**

# 3. Historical Perspective

## 3.1 Chronology of Coastal Development & Human Interventions

The U.S. Marine Corps constructed the Del Mar Boat Basin in 1942 to support amphibious training efforts for WWII (USACE, 2016). The original construction consisted of two shore-perpendicular jetties and dredging of a rectangular basin between the mouths of the Santa Margarita and San Luis Rey Rivers. The harbor jetties were extended in 1950. In 1963 the Boat Basin was expanded to include Oceanside Small Craft Harbor. Sand from the construction of these harbor improvements were placed on City beaches.

Despite the addition of sand from harbor construction, increased erosion was observed on City beaches after the harbor improvements were completed. As early as 1956, the government stipulated in a House Document (399/84/2) that Camp Pendleton Harbor was primarily responsible for the Oceanside beach erosion problem (USACE, 2016). Since the early 1940s, additional sand fill has been placed on City beaches. Sand replenishment efforts have been insufficient and have not had a long term, lasting impact as the beaches continue to recede (USACE, 2016).

In response to the heightened sediment deficiency on City beaches and desire for a long-term fix, a fixed sand bypassing pilot project was constructed in the 1980's within Oceanside Harbor (Figure 3-1). This system operated from 1989 to 1992 and was designed to pump 150,000 CY of sand from northern harbor fillet in the winter months and 200,000 CY from the channel entrance in the summer months (USACE, 1995; USACE, 1996).

The project had a multitude of issues revolving around maintenance of the pumps, sand recharge within sand collection areas and inadequate federal funding. With an estimated total cost of $5 million and an actual cost of $15 million, only the first two phases of the project were completed (Boswood & Murray, 2001). This system only bypassed around 124,000 CY of sand from 1989 to 1992 before becoming ultimately decommissioned.

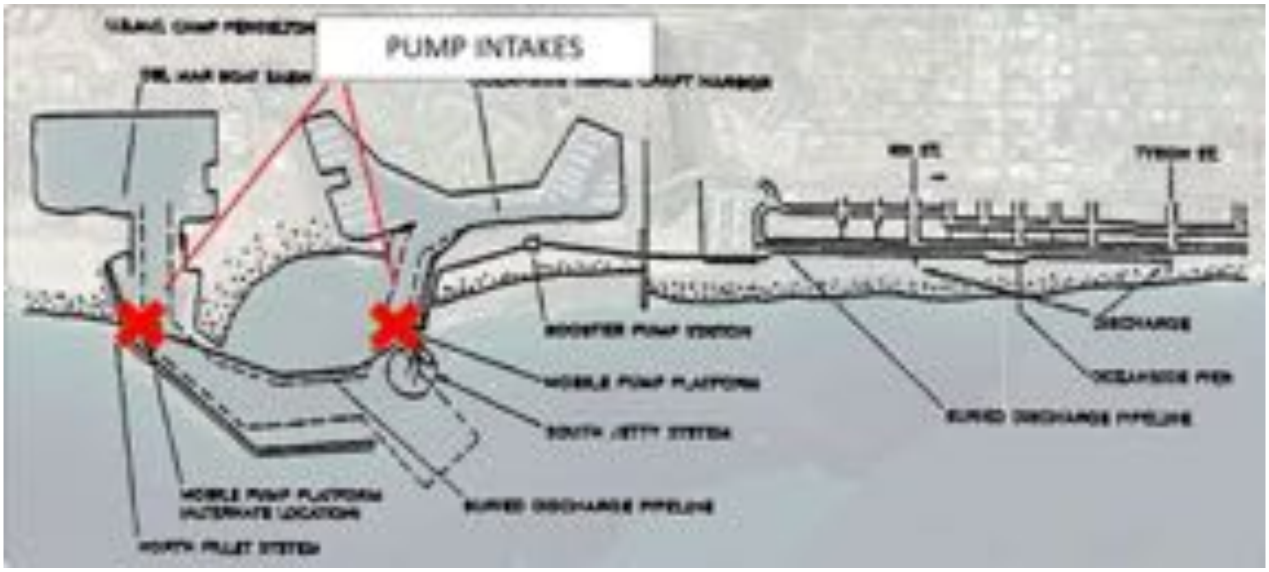


**Figure 3-1. Fixed Sediment Bypass Pilot**

## 3.2 Oceanside Harbor Maintenance Dredging Program

Since 1942, sand has been dredged annually from the Oceanside Harbor federal navigational channels and placed in the City within four designated sites (Figure 3-2). Decisions around how much sediment is placed at each of the four sites is made by the USACE, the dredging contractor and City staff. The decision is contingent on a variety of factors including beach conditions and need, volume to be dredged, environmental factors (i.e. grunion, least terns) and safety. In recent years, the dredging contractor has cited the need to place enough sand in front of the North Coast Village and Oceanside Pier Lifeguard Headquarters revetments in order to have adequate beach to laydown the dredge pipeline.

Dredging occurs every year in the spring over a period of about two to four weeks. However, a number of emergency dredging events have occurred in the fall as a result of the harbor shoaling after significant south swell events. The harbor dredging program is cost-shared by the USACE and Navy. However, the City will commonly pay additional money into the program to receive additional sand.

In total, approximately 18 million CY of sand has been bypassed from the harbor since the construction (Table 3-1 and Figure 3-3). The total volume of dredged sediment from the harbor has decreased since the dredging program began. From 1945 to 1981, the average volume of sediment dredged was approximately 412,000 CY. From 1994 to 2020, the average volume of dredged sediment was 253,000 CY. Dredged sediment from the harbor consists mainly of fine sands, with a mean median grain size ($D_{50}$) between 0.1 mm and 0.2 mm (data average between 2012 and 2020), which is unlikely to remain on the upper beach profile to form a dry beach as discussed in Section 4.2.

Over the last decade or more, sediment has been recovered using a cutterhead suction dredge, transported south in a 24" HDPE slurry pipe, and discharged onto intertidal portions of the beach. Dozers then scrape material up from the intertidal to the foreshore or dry beach downdrift of the discharge pipe. Training dikes are not currently used to capture sand from the slurry on the beach, as is typical for beach nourishment projects.

**Table 3-1. Chronology of Coastal Development and Interventions in Oceanside**

| Year | Activity Type | Description | Reference |
|---|---|---|---|
| 1942-1944 | Harbor Construction & Beach Nourishment | Del Mar Boat Basin Construction. 1.5 mcy of sand placed on City beaches. | Moffatt and Nichol, 1982 |
| 1952 | Groin Construction | Two, 50-foot groins constructed at Wisconsin Avenue and 1,000 feet south (vicinity of Marron Street). | USACE |
| 1958 | Harbor Construction & Beach Nourishment | Del Mar Boat basin and Harbor Improvements. About ~800,000 cy of sand placed on City beaches. | Moffatt and Nichol, 1982 |
| 1962-1963 | Harbor Construction & Beach Nourishment | Recreational and Small Craft Harbor construction. 3.4 mcy of sand placed on City beaches. | USACE, 1994 |
| 1966 | Beach Nourishment | 684,000 CY placed on City beaches. | USACE, 1994 |
| 1968 | Groin Construction | San Luis Rey River Groin Constructed | USACE, 1994 |
| 1981 | Beach Nourishment | 863,000 placed in Oceanside | USACE, 1994 |
| 1982 | Beach Nourishment | 922,000 CY placed in Oceanside | USACE, 1994 |
| 1982 | Beach Nourishment | 1.3 mcy of sand placed on City beaches from San Luis Rey River dredging. | Flick, R.E., 1993 |
| 1985 | Sand Bypassing System Construction | Sand Bypass Discharge Line constructed within Oceanside Harbor. | O'Hara & Graves, 1991 |
| 1989-1992 | Sand Bypassing | Sand bypass operation begins 1989. Bypassed a total of 124,300 CY of sand between 1989 to 1992 | Boswood & Murray, 2001 |
| 1992 | Sand Bypass System Decommissioned | | |
| 2001 | Beach Nourishment | 421,000 cy placed in Oceanside as part of RBSP I | Coastal Frontiers Corp, 2020 |
| 2012 | Beach Nourishment | 293,000 cy placed in Oceanside as part of RBSP II | Coastal Frontiers Corp, 2020 |

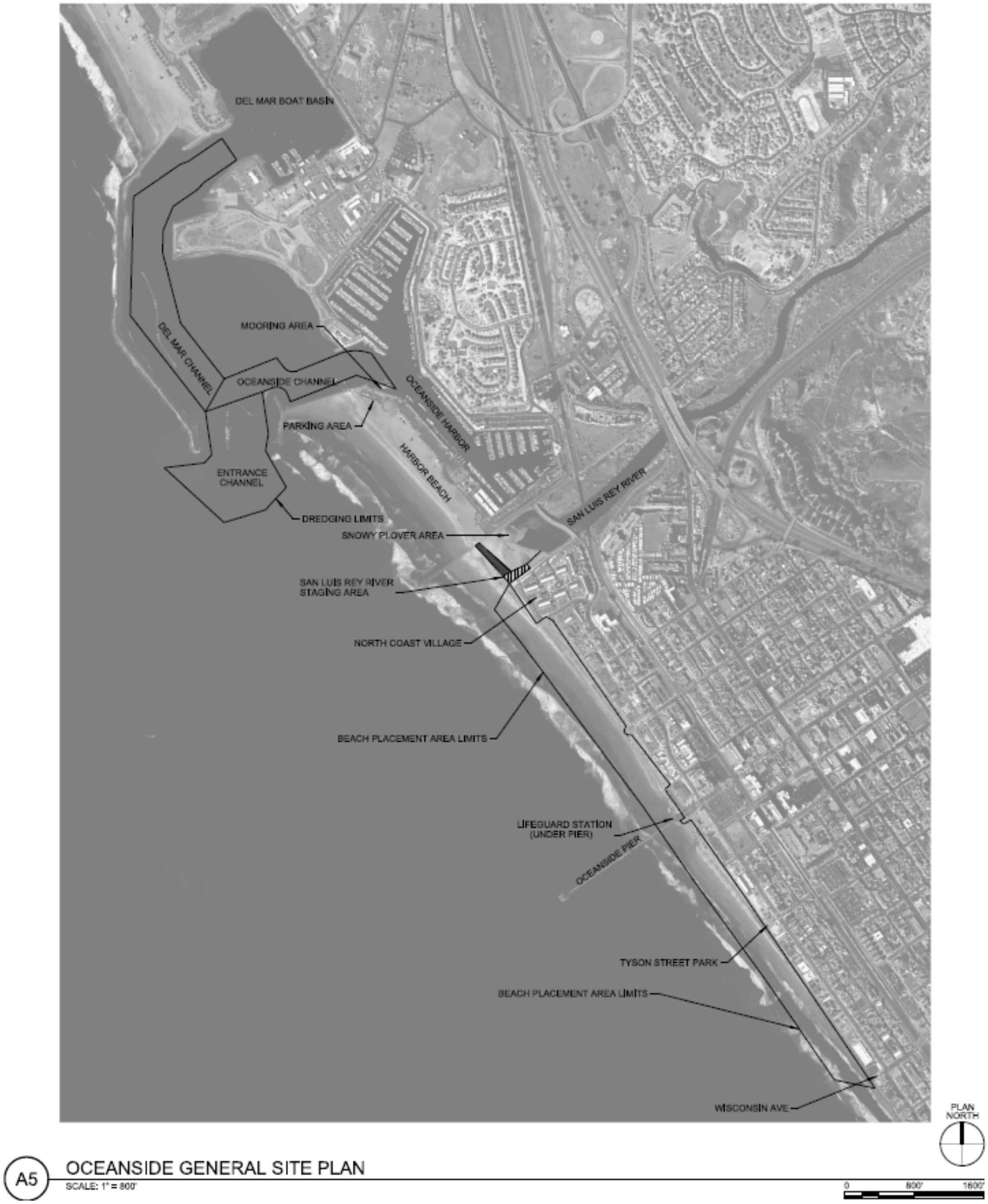


**Figure 3-2. USACE Harbor Dredging Sand Placement Locations (USACE 2020)**

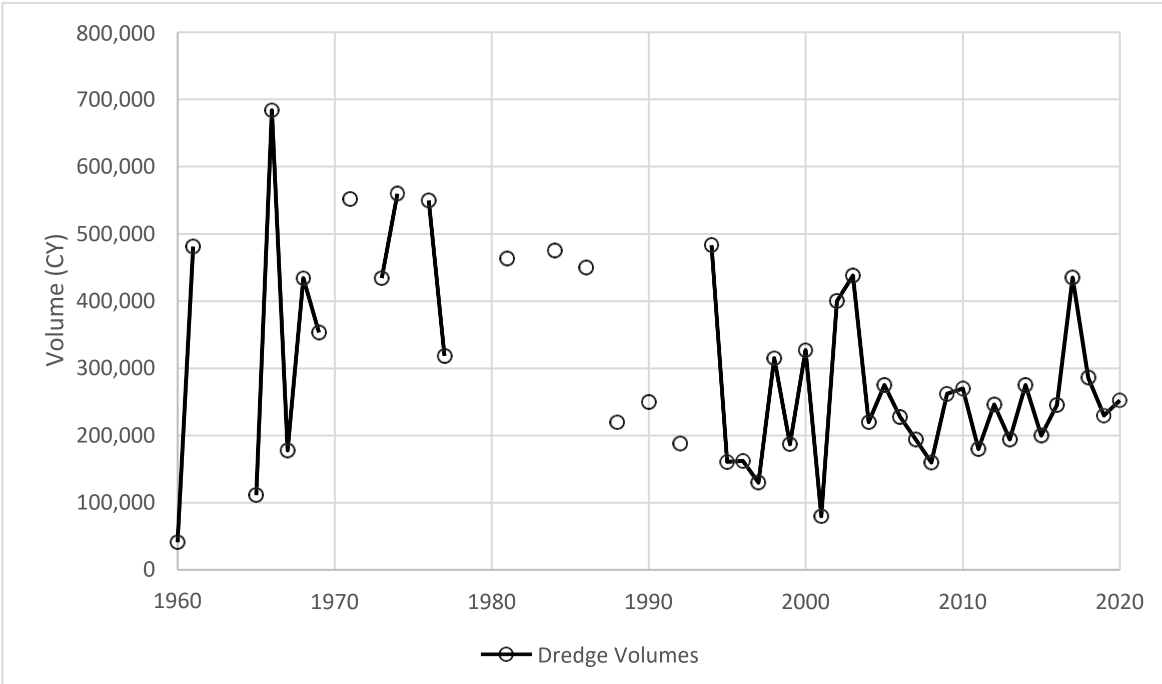


**Figure 3-3. Oceanside Harbor Annual Dredge Volumes from 1942-2020**

## 3.3 Regional Beach Sand Projects

The City has participated in two Regional Beach Sand Projects (RBSP) carried out by the San Diego Association of Governments (SANDAG). In 2001, the RBSP I placed a total of 2 million cy of sand onto 12 beaches within San Diego County. The City received 421,000 cy of sand from this project in the vicinity of Tyson Street. North Carlsbad received 225,000 cy and South Carlsbad received 158,000 cy. Most of the material placed at Oceanside and Carlsbad had a coarser gradation than native sand with a median grain size of 0.62mm (Coastal Frontiers, 2020; Noble Consultants, 2001).

In 2012, the RBSP II placed a total of 1.5 million cy of sand onto eight beaches in San Diego County. Oceanside received 292,000 cy of sand between Buccaneer Beach and Hayes Street. North Carlsbad received 218,000 cubic yards distributed from the Buena Vista Lagoon mouth to Carlsbad Village Drive (SANDAG, 2021). The median grain size of the sand placed in Oceanside was a coarse sand (0.54mm) (Coastal Frontiers, 2020). While these beach fills provided a coarse gradation sand source conducive to dry beach formation, this material moved downcoast rather quickly with only temporary benefits for Oceanside. More analysis and discussion of the performance of these projects are provided in Section 3.4 and 4.3.

## 3.4 Shoreline Changes

Based on review of historical photos from the late 1800s and early 1900s, beaches in the City were observed to be wide and basically stable (USACE, 2016). Beach widths were controlled by the amount of sediment the rivers contributed to the littoral zone and by the longshore transport rate.

Seasonal fluctuations were generally small except near the mouths of San Luis Rey and Santa Margarita Rivers. The San Luis Rey and Santa Margarita Rivers were dammed after the floods of 1916 and 1936/1938, respectively. These dams significantly reduced the amount of sand entering the Oceanside littoral zone (USACE, 2016). The shoreline in the City has changed dramatically over the past century (Figure 3-4). Comparison of the 1934 and 1998 shoreline show the severe erosion downcoast of the harbor during the 64-year period. Conversely, accretion is observed on the updrift side of the harbor at Camp Pendleton.

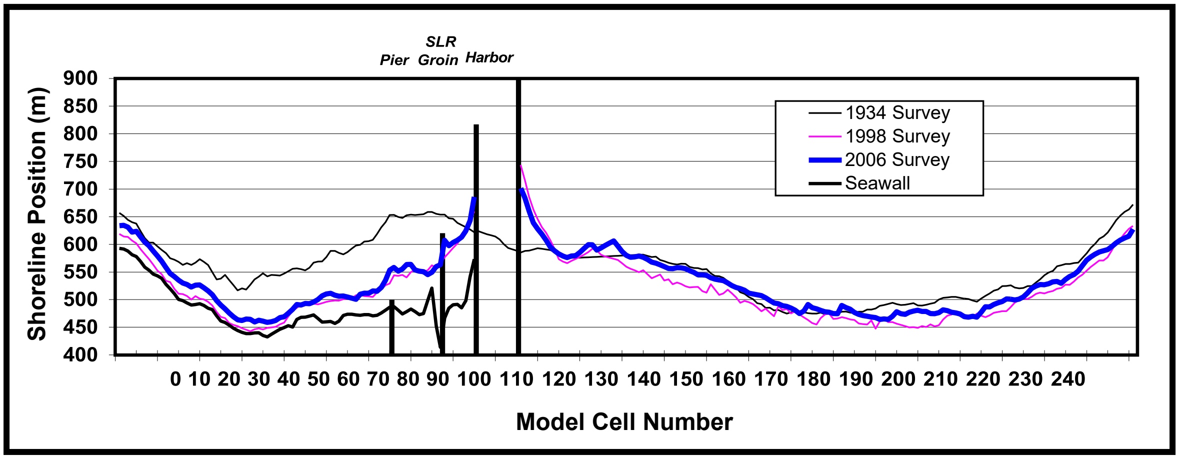


**Figure 3-4. Historical Shoreline Positions in the City (USACE 2015)**

Recent shoreline change was evaluated using beach profile data collected by Coastal Frontiers Corporation (CFC) from 1995 through 2018 and made available to the public on SANDAG's website. This data consists of surveyed beach profiles collected in fall and spring seasons on an annual basis. Ten profiles within the study reach have been surveyed since 1995 providing useful data for evaluating shoreline change over the last several decades. Two South Oceanside beach profiles (OS-947 and OS-915) were established for the RBSP projects and therefore only provide data before and after these nourishment events. The location of these profiles are shown in Figure 3-6. The mean sea level shoreline position data illustrate clear trends of shoreline change that have been organized into three distinct reaches, discussed in this section.

### 3.4.1 North Oceanside

Shoreline change in this reach is characterized by beach profiles OS-1070 (Harbor Beach) through OS-1000 (South Strand, Tyson Street), all of which show a clear trend of shoreline erosion. The rates of shoreline erosion vary from -2.4 ft/yr at Harbor Beach to -3.4 ft/yr at Tyson Street. These rates of shoreline erosion are concerning since beach recreation opportunities are largely confined to this stretch of shoreline due to limited dry beach south of Tyson Street. The highest rate of shoreline erosion was -3.6 ft/yr measured at profile OS-1030, about 1,500 feet north of the Oceanside Pier and shown in Figure 3-6. These results are a clear indication that the annual harbor dredging program is insufficient to maintain beaches of North Oceanside.

### 3.4.2 South Oceanside

This reach of shoreline extends from Tyson Street to the Buena Vista Lagoon and includes beach profiles OS-0930 through OS-0900. This reach of shoreline has historically been a narrow beach almost entirely backed by a rock revetment with only temporary periods of dry beach after RBSP I and II. The profile spacing and survey frequency is of limited use in characterizing shoreline change trends along this reach. Google Earth aerial imagery is a useful tool to understand the shoreline changes along this reach over the last two decades. These images illustrate the progressive loss of sand along this reach, most of which has lacked a dry beach since 2014. Over the last several decades, shoreline change along this reach has been limited by the revetment, another indication of a persistent erosion trend.

Most regional shoreline change assessments prepared for SANDAG use profile OS-0930 to represent this 2-mile reach of shoreline. Unfortunately, this profile is atypical of the south Oceanside shoreline. OS-0930 is measured at Buccaneer Beach, the only location that is not backed by a revetment along the stringline of development. This profile represents shoreline change at a gap in the ~2-mile revetment in which the profile baseline is about 130-150 feet landward of the adjacent revetments. Therefore, beach widths reported at this transect can be quite misleading. For example, if an MSL beach width of 130 feet is reported at profile OS-0930, this means there is essentially no dry beach throughout the 2-mile stretch of shoreline "represented" by this profile. A photograph looking south from Buccaneer Beach in Fall 2017 (Figure 3-5) illustrates the typical beach condition along the South Oceanside reach. Note, an MSL beach width of 58 feet was reported during the Fall 2017 survey at this location. The most notable shoreline changes observed in this reach were a result of the RBSP I and II projects and are discussed in Section 4.3.


**Figure 3-5. Fall 2017 Photograph looking south from Buccaneer Beach**

Profile OS-0900 is located at the south end of Oceanside near Vista Way. This profile reflects a transition zone between an erosional shoreline to an accretional shoreline. From 1995 through 2002 the shoreline position data indicate a trend of accretion. From 2002 through 2018 the shoreline position data indicate a trend of erosion, at a rate of about -1.2 ft/yr.

### 3.4.3 North Carlsbad

This reach of shoreline extends from the Buena Vista Lagoon to the Agua Hedionda Lagoon and includes beach profiles CB-0880 through CB-0830. These five profiles are spread evenly along this reach of shoreline and indicate a dominant trend of accretion, dating back to 1995. Trends of shoreline accretion range from +2.2 ft/yr at CB-0880 to +3.9 ft/yr at CB-0850 with all profiles experiencing a gain of 100 feet or more beach width since the 1990s. Shoreline change at profile CB-0850 is shown in Figure 3-6.

A few factors have likely contributed to the long-term trend of shoreline accretion along the North Carlsbad reach. The north groin at Agua Hedionda has played a major role in retaining sand upcoast in an extended fillet with a dry sand beach which averages 150-200 feet in width. Groins do not work by themselves and require a supply of coarse-grained sand to retain a dry beach area. The RBSP I and II projects provided a large supply of coarse-grained sand to this reach of shoreline. The shoreline position data and aerial images indicate a large amount of the coarse-grained sand placed in RBSP I and II at Oceanside and North Carlsbad remains in the fillet upcoast of this groin. The trend of shoreline accretion at North Carlsbad is a good example of the lasting benefits provided by the combination of a sand retention structure and a supply of coarse-grained sand.

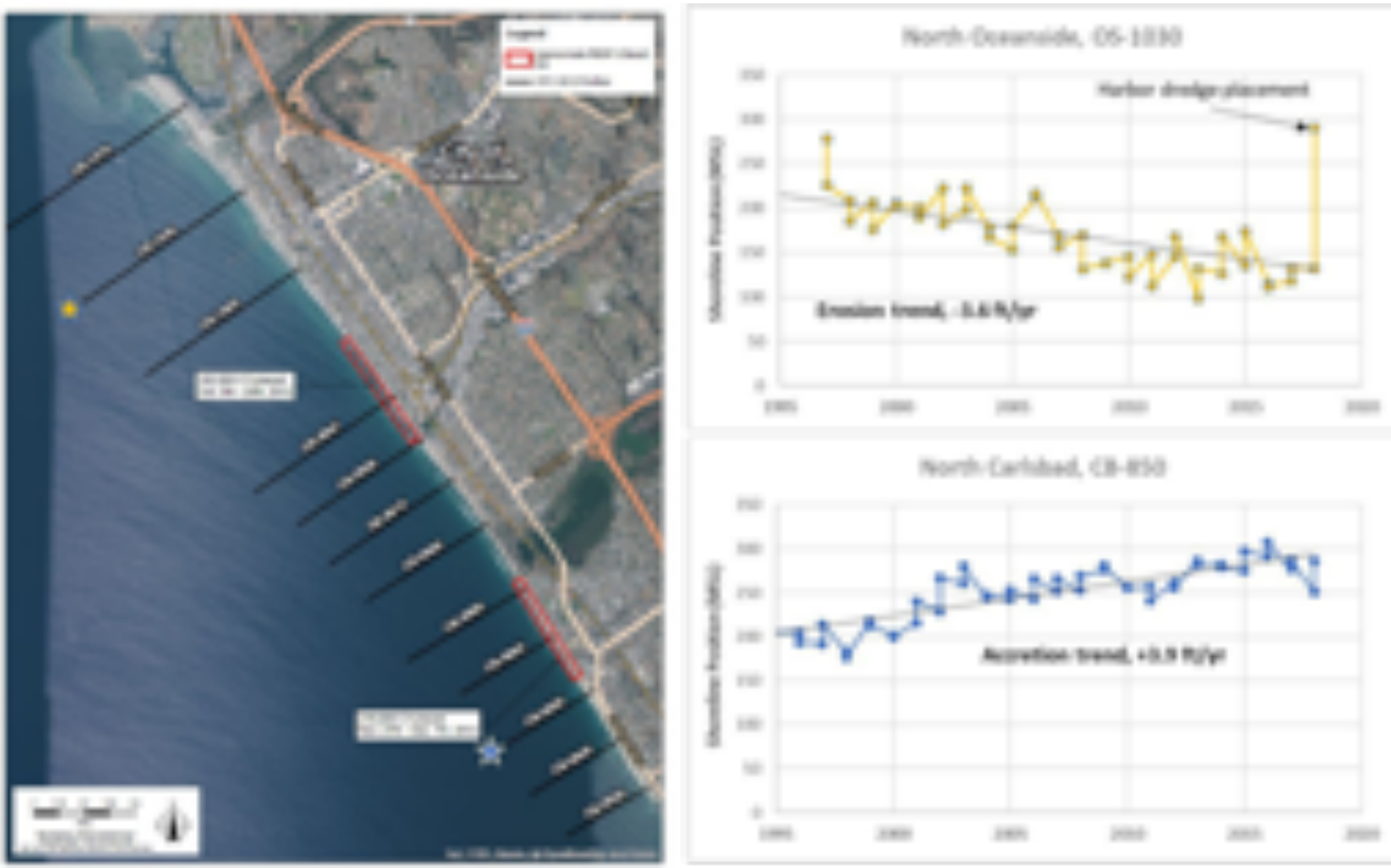


**Figure 3-6. Profile Location Map and Shoreline Change Trends in Study Reach**

# 4. Synthesis of Coastal Challenges

A myriad of coastal challenges exist that have contributed to the erosion of City beaches and have influenced coastal management decisions made over time. A summary of our understanding of the challenges are provided in this section.

## 4.1 Oceanside Harbor Complex & Sediment Gradation

The largest factor contributing to Oceanside's erosion problem results from a limited sediment supply from updrift beaches as a result of the Oceanside Harbor complex. The breakwater acts as a littoral barrier that only allows a portion of fine sediment to be transported around the breakwater into the entrance channel. The coarse-grained fraction of sand in the beach profile is largely retained upcoast of the harbor in a wide beach along MCB Camp Pendleton. Fine-grained sediment which makes its way around the breakwater into the entrance channel is insufficient in quantity and quality to mitigate the long-term trend of shoreline erosion affecting Oceanside's beaches.

Native sediment on City beaches consists of fine sand to silt. Along the beach profile, fine sand with a D50 of 0.2mm exists on the dry beach (i.e. above MLLW). The silty sand below MLLW has a lower D50 of 0.1 to 0.05mm. These subtle changes in values represent a significant difference in beach type and function. The coarser sand are not as easily mobilized by waves and form a dry beach, while the finer sand is easily mobilized and is deposited in deeper waters where lesser currents exist (Figure 4-1).

**Figure 4-1. Comparison of Beach Type and Gradation North and South of Oceanside Harbor**

## 4.2 Limited Beach Gains from USACE Harbor Dredging Program

The current USACE sand placement program is limited in its ability to provide dry sandy beaches in the City for the following reasons:

- **Timing:** Harbor dredging occurs in the Spring of every year, which marks the beginning of a change in the wave climate in the City. The predominate wave energy shifts from the winter's northwest dominant approach angle to one out of the southwest. Waves from the southern quadrant drive longshore currents and sediment to the north. Thus, placed sediment from the harbor in the Spring has a high likelihood of being transported to the north (towards harbor beaches)(Figure 4-2).
- **Sediment Type:** Sediment from the harbor is classified as a fine-grained sand. Fine-grained sand is easily mobilized by waves and transported by longshore currents. Sand with these characteristics form what is referred to as a submerged profile once in equilibrium (Figure 4-3). A submerged profile acts to dissipate wave energy but does not generally form a dry sandy beach. Therefore, placed sand from this program does not achieve the City's goal of having a dry sand beach for recreation and coastal storm damage protection.
- **Placement Location**: In recent times sand has been placed mostly north of the pier due to a combination of reasons described previously. Sand placement at these locations is believed to mostly benefit northern beaches due to the northerly dominant longshore transport direction during the time of placement.

- **Placement Methods**: Dredged sand is transported from the harbor to City beaches via a sand/water slurry. The current contractor uses a large dredge that transports large volumes of sand quickly. Typical construction methods for beach nourishment projects entail the use of training dikes to slow the velocity of the hydraulic slurry to allow sediment to deposit on the beach. Current practice does not entail the regular use of these training dikes. Sediment is discharged in the intertidal and dozers scrape up deposited material just downdrift of the pipeline (Figure 4-4).

All these factors lessen the ability of this placed sand to benefit and "feed" beaches to the south.


**Figure 4-2. USACE Sand Placement Relative to Seasonal Longshore Transport Schematic**

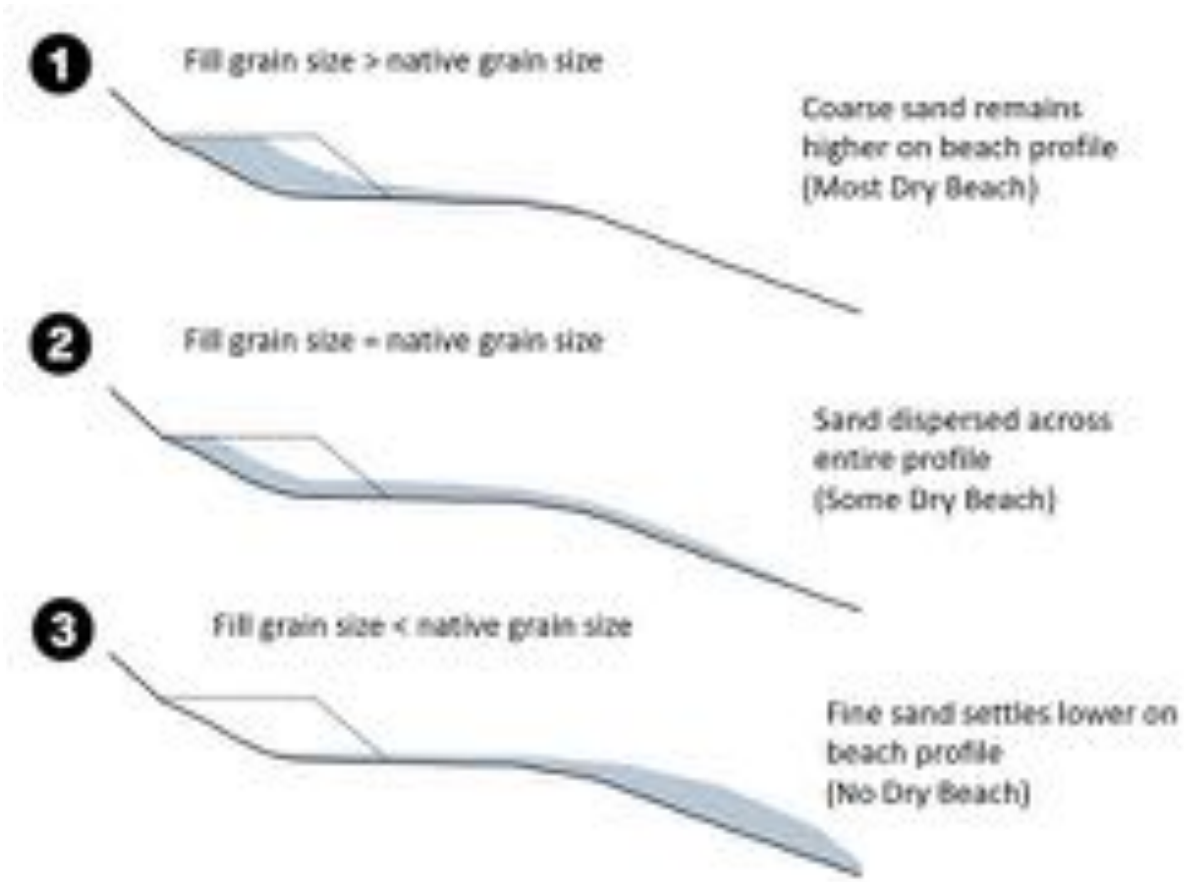


**Figure 4-3. Relationship between Native and Beach Fill Grain Size and Beach Performance (derived from Dean, 1991)**

**Figure 4-4. Current USACE Placement Methods**

### 4.3 Poor Performance of Regional Beach Fills

An analysis of the performance of prior Regional Beach Sand Projects were conducted as part of this study using aerial imagery and monitoring data available from SANDAG. While these projects produced regional benefits by adding sand to a sediment starved coastline, the benefits along Oceanside beaches were short-lived, with most of the material moving downcoast within a few years after placement.

Mean high water (MHW) shoreline positions were traced from aerial imagery from 2006 to 2019 to understand shoreline change before and after the RBSP II project. A total of 11 shorelines were recorded within this timeframe for a study area that spanned from Oceanside Harbor to the Agua Hedionda North Jetty. The shorelines were analyzed via Digital Shoreline Analysis System (DSAS) from which annual trends in shoreline movement were determined. The placement locations can be seen in

Figure 4-5 and clearly illustrate the evolution of these beach fills and accumulation of sand along North Carlsbad. By May 2015, about 2.5 years post-fill, the shoreline position at the placement site had retreated to pre-RBSP II conditions.

The RBSP II beach profile monitoring data provide another source of information to evaluate the local performance of this project. Profile OS-0947 was established just prior to RBSP II and is the only profile within the sand placement area. Beach profiles and mean sea level (MSL) shoreline position are plotted in Figure 4-6 at this transect. The beach profiles indicate some accumulation of sand lower in the beach profile at depths of -2 to -10 feet, mean lower low water (MLLW) which is typical as wave action disperses the initial fill in both cross-shore and longshore directions. The upper profile shows a steady loss of dry beach width which appears to have largely moved in the alongshore direction to the south.

Profiles OS-0930, OS-0915 and OS-0900 are located downdrift of the initial fill but did not perform any better than OS-0947. Profile OS-0930 showed a similar response to OS-0947 (i.e. only temporary dry beach area) and profiles OS-0915 and OS-0900 showed only incremental gains in beach width from RBSP II that were also short-lived. Analysis of profiles updrift of the Oceanside fill showed no evidence of beach width increases from the RBSP II project.

Based on this analysis, a nourishment program on the scale and frequency of RBSP I and II would not be a viable solution for North and South Oceanside without some type of sand retention system. RBSP I and II projects provided long lasting benefits to North Carlsbad due largely to the sand retention provided by the north groin at Agua Hedionda lagoon.

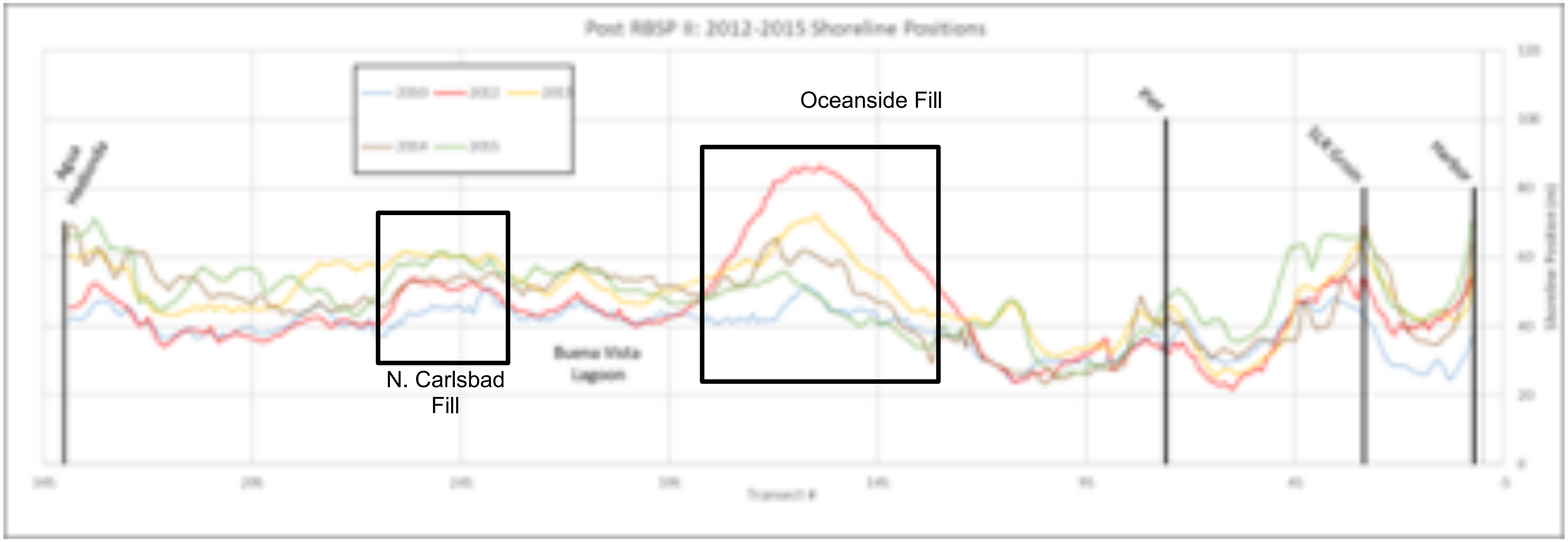


**Figure 4-5. Post RBSP II Shoreline Positions**

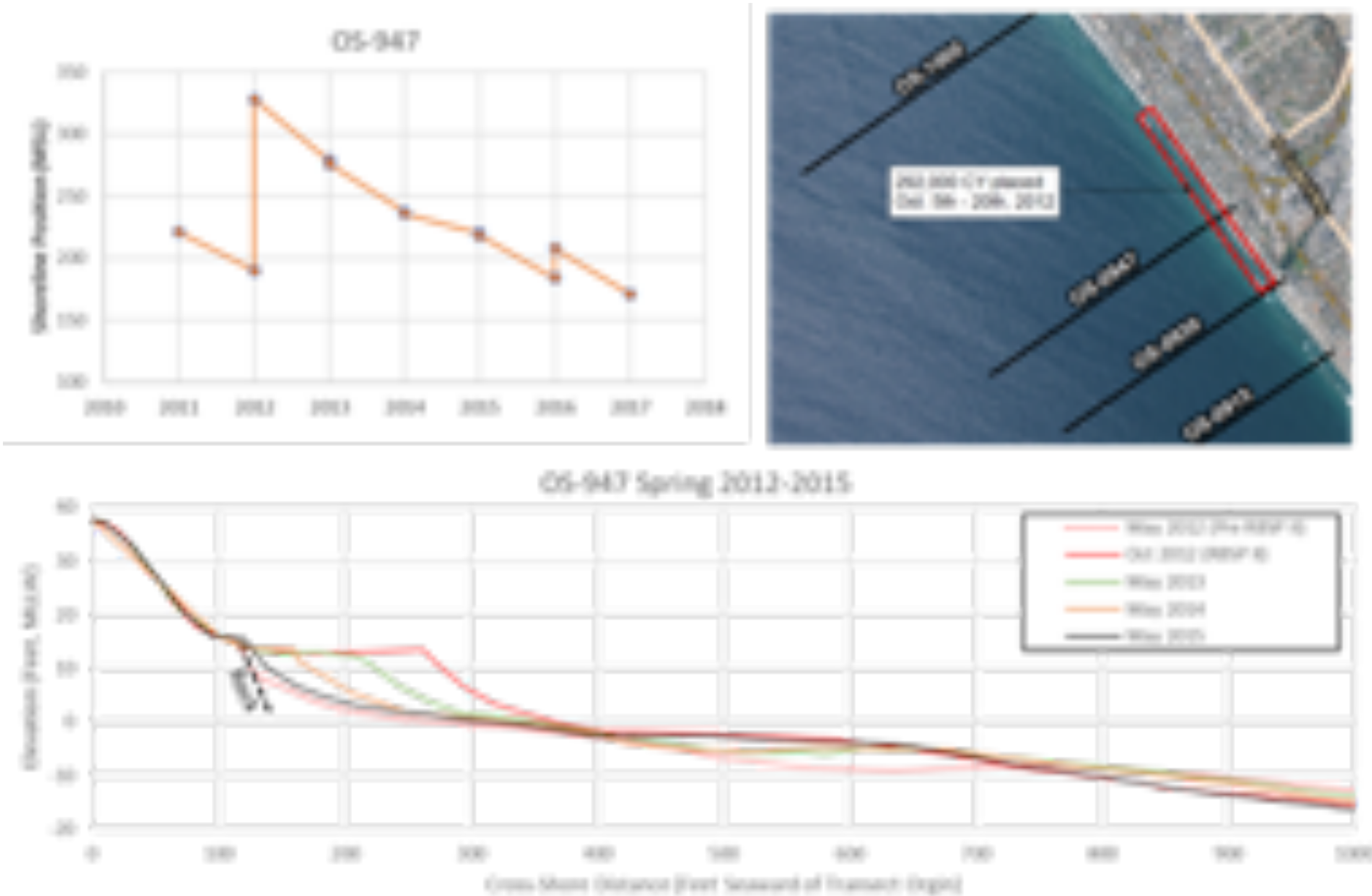


**Figure 4-6. RBSP II Performance at South Oceanside**

## 4.1 Difficulty Reaching Social, Political & Regulatory Consensus

Coastal management decisions are challenging to reach consensus on. Potential downdrift impacts, costs, environmental and recreational impacts and concerns about establishment of precedent being some of the biggest concerns typically voiced when a proposal is being considered. The various stakeholder groups, agencies and community user groups have varying missions and viewpoints on how beaches should be managed. All user groups are sensitive to potential changes.

The difficulty in reaching consensus was exemplified in Saving California's Coast (O'Hara & Graves, 1991), which documented how a similar study to this one was carried out in Oceanside in the 1980's. The study found a series of shore-perpendicular rock groins to be preferrable from a technical and cost perspective to restore eroding beaches in the City. However, the option was rejected by the community and elected officials fueled by local criticism of the Project starting a "chain reaction" of similar structures down the coastline. The USACE then put forward the next highest scoring option, the breakwater option. This option was met with intense opposition from local surfing groups due to the detrimental effects the structures could have on surfing resources in the City. The Experimental Sand Bypass option was born as a compromise that most groups could support but ultimately failed for a number of reasons. Most notable of these reasons from a consensus building perspective included MCB Camp Pendleton's stipulation that the Project did not encroach on their property and consistent funding from the USACE.

Today the City is grappling with the same issue of a persistent eroding shoreline; however, the condition of the shoreline or "the problem" has gotten worse. Consensus-building will again be a challenge in moving any of the alternatives discussed in this report forward. Key agencies and entities that will need to be engaged with and the issues to resolve are outlined below:

- **MCB Camp Pendleton**: Sand from the northern breakwater fillet represents the highest quality, sustainable source of sand to the City. The construction of the harbor and subsequent accumulation of sand at this location has had a clearly documented impact on City beaches.
- **Surfrider Foundation**: Measures to ensure preservation of existing surfing resources.
- **California Coastal Commission:** Issues surrounding Coastal Act resource preservation, including beach access, recreation, and coastal habitats.
- **Adjacent property owners and the City of Carlsbad**: Concerns surrounding downdrift impacts and mitigation.

Many of these agencies have already been engaged as part of this feasibility study. Numerous public, stakeholder and resource agency outreach events were conducted during the period of study. Meetings were held with the following entities to date:

- Resource agencies:
    - California Coastal Commission (CCC)
    - Regional Water Quality Control Board (RWQCB)
    - U.S. Army Corps of Engineers (LA District)

- Stakeholders:
    - Save Our Sand (SOS)
    - Surfrider Foundation
    - Resilient Cities Catalyst
    - San Diego Regional Climate Collaborative
    - SANDAG Shoreline Preservation Workgroup
- City Public Outreach Event (2)
- City planning, public works and engineering

# 5. Data Review and Assimilation

## 5.1 Coastal Studies

As a result of the harbor development and the onset of erosion of downdrift beaches, the City's shoreline has been extensively studied over the last 80 years. This study included a review of available coastal studies to understand coastal conditions but also options considered or carried out in the past. Of the studies reviewed, the following were found to be key to this study:

- **USACE Special Shoreline Study (2016 - ongoing)**: Evaluation of a number of nourishment and sand retention options. Groins and beach nourishment were determined to the favored alternatives. Due to a lack of funding, the study is unfinished.
- **Oceanside Harbor and Beach, California Design of Structures for Harbor Improvement and Beach Erosion Control (1980)**: Examined 88 different options of harbor improvements and 16 beach sand retention concepts that would mitigate the loss of sand along the beaches and sand shoaling within the harbor. These improvements were tested in scaled physical model. The study recommended six to ten, 800' long groins, spaced 1,000 feet apart and tapering to the south or a 4,900-foot long breakwater, 800 feet offshore with groins on either side. The preferred groin option is shown in Figure 5-1.
- **Saving California's Coast, (O'Hara & Graves, 1991)**: A history of the social and political pressures leading to the selection of a preferred alternative from the USACE's 1980 study. The preferred alternative shifted from the groin plan (initially) to the breakwater plan (secondarily) and then to the sand bypass pilot as a fallback, non-structural option.

For a complete list of literature reviewed and summaries of key findings, please see Data Gathering Memorandum (Appendix A).

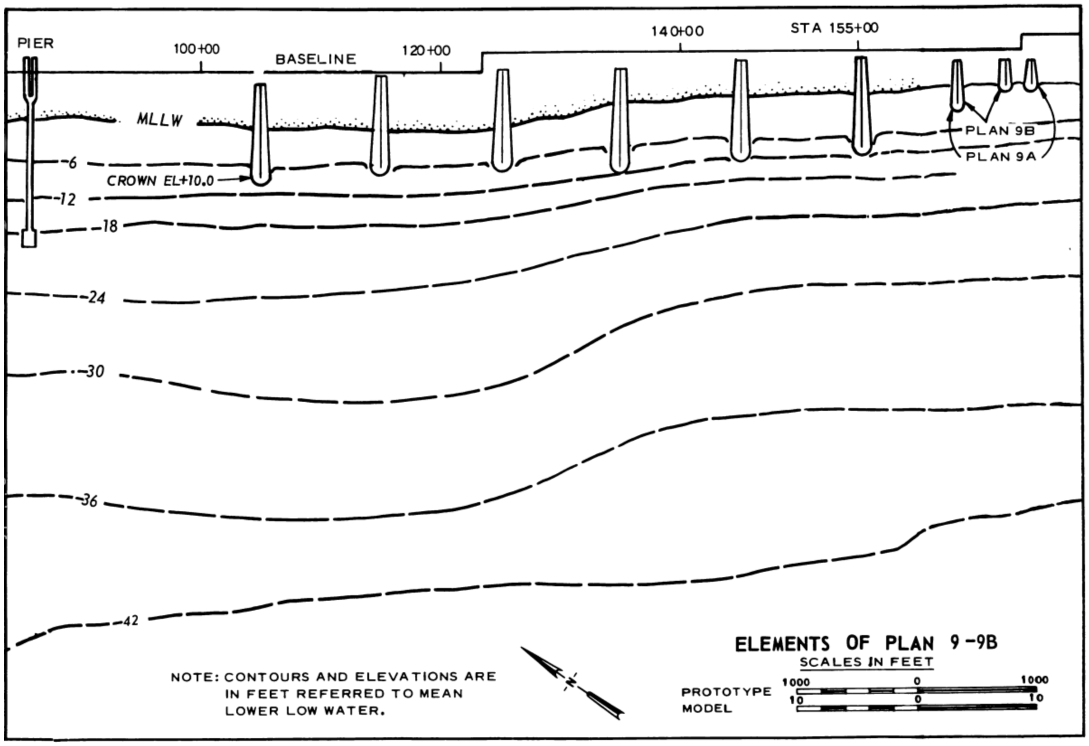


**Figure 5-1. Recommended Groin Concept (USACE, 1980)**

## 5.2 Sand Bypassing Project Examples

Several sand bypassing systems were reviewed for their applicability and utility in resolving the erosion issues in the City. These systems were reviewed after gaining a fundamental understanding of the challenges faced with the Experimental Sand Bypassing Project in Oceanside, of which many references were reviewed. The locations and systems reviewed are summarized below:

- **Tweed River Bypass System (Queensland, Australia):** Large, fixed trestle sand bypass system that transports 650,000 CY per year to downdrift beaches.
- **Noosa Sandshifter System (Sunshine Coast, Australia):** Small, semi-fixed sand bypass system that backpasses 80,000 CY per year to updrift locations to protect coastal development. A buried intake and fluidizer in the foreshore mobilizes sediment.
- **Peninsula Beach Long Beach Bypass System (Long Beach, California):** Small dredge system to backpass sand along Peninsula Beach. Concept is being piloted in lieu of existing trucked backpass system.
- **Indian River Inlet System (Bethany Beach, Delaware):** Small semi-fixed system that bypasses about 100,000 CY per year of sand around an inlet to downdrift beaches. System utilizes a crane manipulated cutter head, pump house and fixed sand pipeline distribution system. The system was constructed and is operated by the USACE.

- **Santa Barbara Sand Distribution System (Santa Barbara, California)**: Harbor dredging program that utilizes a buried pipeline distribution system. Dredging system moves 200,000 CY per year from the harbor channels to downdrift beaches.

## 5.3 Sand Retention Project Examples

The following sand retention projects were reviewed for reference for their applicability to resolving the erosion issues in the City. The retention projects reviewed are summarized below:

- **Upham Beach Groins, Pinellas County, FL:** Geotextile, T-head groins were piloted and studied by a local university for a five-year period. The geotextile groins were replaced with rock at the end of the five-year period. Project approach was mirrored for this study.
- **Palm Beach Surfing Reef, Queensland, Australia:** Submerged multi-purpose artificial reef for beach stabilization and surfing. Constructed in September 2019.
- **Chevron Groin & Pratt's Reef, Dockweiler Beach, CA**: Construction of an 800-foot long groin and subsequent construction of Pratt's Reef, an artificial surfing reef. The reef was constructed to offset surfing impacts from the Chevron groin and was comprised of geotextile bags. The project was deemed unsuccessful at creating surfing waves and was later removed.
- **Agua Hedionda Lagoon Jetties, Carlsbad, CA**: Two series of about 400-foot long jetties at Tamarack Beach and warm water jetties just downdrift of Oceanside beach. Dredged sand from the lagoon is placed various locations within the jetty compartments contingent on beach conditions at the time of dredging.
- **Newport Beach Groins, City of Newport Beach, CA**: Eight, about 500-foot long rock groins spaced about 900 feet apart in southern Newport Beach.
- **Imperial Beach Groins, City of Imperial Beach, CA**: Two, 300 to 500-foot long rock groins spaced about 1,300 feet apart in northern Imperial Beach.

# 6. Alternatives

Based on our understanding of the coastal setting and challenges in the City, four action alternatives were conceived that meet the City's design guidelines of protecting City beaches from long-term shoreline erosion. Furthermore, the alternatives must be environmental sensitive, financially feasible and have a reasonable chance of being approved. These alternatives were compared against a no action "No Project" scenario for context over an assumed design life of 20 years. Note that the proposed alternatives have varying levels of performance (i.e. retention of a dry sandy beach) and is a key difference, as discussed further in this report. The proposed alternatives are depicted on a representative segment of the City's shoreline to demonstrate the scale of the features proposed. The location of the pilot is undetermined at this point.

## 6.1 Pilot Approach

In attempt to overcome the significant social, political and regulatory hurdles surrounding the use of sand retention strategies, the proposed Project approach is start with a small-scale pilot in a representative and impacted segment of coastline in the City. The pilot could then be monitored and expanded or adapted contingent on success. Based on feedback received from the community and City staff, the pilot location may be best suited in South Oceanside. However, the specific location and configuration is to be determined at a future phase based on additional outreach and analysis.

The approach would be to implement one of the proposed sand retention alternatives and intensively monitor the Project for a period of about five years. During this time, monitoring of potential impacts will take place with a focus on changes (positive or negative, from an established baseline condition) to downdrift beaches, coastal resources and surfing. Should impacts be realized, the pilot will be modified in attempt to lessen or mitigate them in close coordination with the City, stakeholders and resource agencies. Potential modifications could range from changes to the amount and location of placed sand to physical changes to the retention structures (removal or addition of rock). Should impacts not be able to be mitigated over a period of adequate time for scientific analysis, complete removal of structures would be considered. Project funding and permits will be crafted such that these modifications could occur in a timely manner.

## 6.2 No Project

The No Project alternative is continuation of the status quo and is being considered for comparative purposes against action alternatives. In this alternative the Corps Harbor Maintenance Program continues unaltered in terms of volumes (i.e. average of 250k CY/yr) and location of placement (sand generally placed from the pier north). The City continues to participate in regional beach nourishment projects, similar to SANDAG's RBSP which occur on an ad-hoc basis. The beach nourishment projects deliver about 300,000 CY of sand on a frequency of about every 10 years.

## 6.3 Alternative 1: Beach Nourishment

The Beach Nourishment Alternative assumes a more aggressive beach nourishment program is carried out by the City or region. The program would deliver 300,000 CY of sand to City beaches at a consistent frequency of every five years; approximately doubling the frequency of the existing placement. The program would identify and utilize coarse gradation sand (i.e. d50 greater than 0.3 mm) such that the placed sediment would benefit the subaerial beach (i.e. dry beach). By delivering more sand at a higher frequency, the beach nourishment alternative would seek to improve beach widths within the pilot reach.

Sand placement would be identical to RBSP II for environmental and regulatory efficiency (Figure 6-1). Specially, details regarding the beach nourishment alternative are below:

- Sand placed just south of Seagaze Drive to Oceanside Boulevard (approximately 4,700 feet in length)
- Build beach berm at an elevation of +13’ MLLW
- Beach berm will be 90 to 200 feet in width

## 6.4 Alternative 2: Groins

The Groins alternative assumes four, 600-foot long, rubble mound groins spaced 1,000 feet apart (Figure 6-2). The proposed groins are shore-perpendicular and would connect to the seawall/rock revetment on the landward side to prevent loss of sand around the structure. The groin structures will be comprised of 4-to-10-ton rock placed with a consistent crest elevation of 10’ MLLW.

The groins would trap sand moving in the longshore direction, creating sediment fillets against the structures on the downdrift side of the predominate longshore sediment transport. The salient formation within the groin compartment will fluctuate seasonally as wave energy shifts between northern and southern approach directions.

Beach nourishment is proposed within this alternative, both as prefill (to fill groin compartments) and at a renourishment interval to maintain beach widths. An initial placement volume of 300,000 CY is proposed, identical to Alternative 1. The beach nourishment placement footprint is also varies from Alternative 1 in that it carries a consistent width of 100 feet. Renourishment is proposed at 5-year frequency; however, placement volumes for renourishment would be reduced over time since more sand would be retained within the groin field. Renourishment volumes would be reduced to 150,000 CY based on the results of the numerical modeling of this option (Section 8).

## 6.5 Alternative 3: San Luis Rey Groin Extension

Alternative 3 proposes to extend the existing San Luis Rey Groin 350’ seaward (Figure 6-3). This alternative would place large rock armor stone (approx. 10 ton) to build out the groin. Beach nourishment is proposed within this alternative, identical in terms of initial and renourishment placement volumes to the Alternative 1.

The groin extension would seek to capture sand moving northerly before being deposited in the Oceanside Harbor. Growth of the existing sediment fillet along the southern end of the groin is anticipated. This could either benefit beaches downdrift of this structure or this alternative could be combined with a sand transfer option to “trap” sand in this location. Trapped sand would then be transported to southern beaches in need.

## 6.6 Alternative 4: Multi-Purpose Artificial Reef

The Multi-purpose Artificial Reef alternative assumes two, 1,000-foot long, rubble mound reefs spaced 1,200 feet apart (Figure 6-4). The reefs would have emergent and submergent crest sections along their lengths to both reflect and focus wave energy, respectively. Beach nourishment is proposed within this alternative, both as prefill and at a renourishment rate. An initial placement volume of 300,000 CY is proposed initially, identical to the other alternatives. However, the renourishment volume would be 150,000 CY at a 5-year interval, which is the lowest of the alternatives. This is based on the effectiveness of the structures at sand retention based on the numerical modeling results (Section 8).

The multi-purpose reefs would effectively function as a detached breakwater, which provides significant reductions in wave energy and longshore transport in their lee. Sand would deposit behind these structures in the form of a salient or tombolo based on design specific parameters to be refined during the next phase. The edges of the structure are proposed to be submerged reefs where waves could shoal and be ideally surfed. The prediction of surfing improvements (or impacts) is both subjective and an emerging science; thus, is difficult to quantify. Typical wave approach directions, typical surfzone and nearshore slopes and peel angles for desirable waves were consulted to generate the conceptual design of the reef edges (Figure 6-5).

**Figure 6-1. Beach Nourishment Concept**

**Figure 6-2. Groin Field Concept**

**Figure 6-3. San Luis Rey Groin Extension Concept**

**Figure 6-4. Multi-Purpose Artificial Reefs Concept**

**Figure 6-5. Multi-Purpose Artificial Reefs Concept - Reef Detail**

# 7. Other Alternatives Considered

A number of other alternatives were considered in this study. A summary of other types of solutions reviewed are below:

- **Detached Breakwaters & T-head groins:** Shore parallel, emergent crest breakwaters and T-head groins were considered within this study. These structures can be effective methods of shoreline stabilization; especially along beach where cross-shore sediment transport is significant. The wave reflection from these shore-parallel structures are known to negatively impact surfing resources. Given the importance of surfing resources to the City and stakeholders, detached breakwaters and T-head groins were not further considered.
- **Geotextile Sand Retention Structures**: Temporary geotextile groins or reefs were considered, modeled after the Upham Beach Groin Project in Florida, given their lower cost to deploy and temporary/reversible nature. Given the water depth and wave climate of the City, the stability of geotextile sand retention structures would likely be compromised quickly. The use of geotextiles were rejected for this reason.
- **Sand Engine**: The sand engine, implemented along the Delfand Coast in the Netherlands, placed over 20M CY of sand on a feeder beach, which allowed natural littoral dynamics to transport sand slowly to downdrift areas of need. Sediment transport along the Delfand Coast is mostly unidirectional, which differs from Oceanside's bidirectional transport regime. Placement of a similar project in the City would result in a significant amount of sand being deposited in the harbor, likley prompting more dredging of the navigational channels.
- **Oceanside Harbor Breakwater Modifications**: Concepts to modify the Oceanside jetties, such as creating a spur to the northern breakwater to act as a sand trap was considered. This feature would need to be combined with a sand bypass system; similar to the one that was constructed in the 1980's. Given the historical precedent of the system at this location, this concept was not carried forward.
- **Nature-based Design Solutions & Living Shorelines**: These solutions consist of use of native materials or living systems or habitats for shoreline protection. These solutions are favored by state agencies and stakeholders as "no-regret", multi-benefit solutions to shoreline protection and SLR adaptation in areas where they are appropriate. Appropriate nature-based design or living shoreline solutions along the southern California open coast consist of use of cobble, dunes and artificial reefs. Given the absence of a stable beach in the City, use of cobble or dunes were not determined to be viable at this time. Should the beach stabilize as a result of implementation of one of the alternatives presented in this study or for another reason, use of these features should be re-considered. Reef features could be incorporated into the design of the groin or artificial reef concepts. The highest potential for reef success would be the artificial reef because of the larger submerged footprint.

# 8. Numerical Modeling of Alternatives

Numerical model was performed to aide in the evaluation of beach nourishment and sand retention alternatives. A primary objective of the modeling effort was to evaluate the ability of sand retention structures to retain and prolong the performance of beach fills. The 2012 Regional Sand Beach Project II (RSBP II) nourishments that occurred in Oceanside and Carlsbad were used to validate the model and evaluate effectiveness of sand retention structures. Using site-specific data, the integrated hydrodynamic, wave and sediment transport model was set up to encompass the entire Project Area and nearshore environment. Using the coupled model, multiple configurations of groins and artificial reefs were simulated.

Numerical modeling of shoreline morphology is inherently imprecise because of the difficultly in mathematically describing the complicated dynamics of coastal processes and inability to forecast future metocean conditions and their effect on nearshore littoral processes. Despite these limitations, numerical modeling remains one of the few tools that can be applied to evaluate the feasibility of sand retention structures and thus approximations are made for nearshore sediment dynamics based on broad and consequential assumptions like the 1-contour line model used here. The model results presented in this section are only one of several criteria to consider in evaluating each alternative.

## 8.1 Model Description

The numerical model chosen to evaluate the effectiveness of each alternative was the Littoral Processes and Coastline Kinetics (LITPACK), part of the MIKE suite of modeling applications developed by Delft Hydraulic Institute (DHI). LITPACK is designed to model long term shoreline evolution for the purpose of optimizing and evaluating the design and development of coastal works. The model couples hydrodynamic and sediment transport models to calculate littoral drift rates and the coastline position across the model domain over the simulation period.

The model domain stretches from the southern side of the Oceanside Harbor to the Agua Hedionda Lagoon north jetty (Figure 8-1). Wave data from CDIP Station 045 was transformed using internally in the LITPACK model to the project shoreline. Water levels from NOAA tidal station #9410230 in La Jolla were used. A high resolution topobathy digital elevation model (DEM) created by the Coastal Conservancy was used for the initial model bathymetry conditions. Cross shore profiles and the initial shoreline position were extracted from the DEM. Local sediment properties reflected sampling analyses completed in the project area by the USACE (2018) and M&N (2016).


**Figure 8-1. Numerical Modeling Domain**

## 8.2 Calibration and Validation

Model calibration and validation are important to evaluate the model's ability to simulate observed shoreline changes. Littoral sediment transport rates were calibrated to fall within the range of values estimated by previous studies. Previous studies agree the net direction of sediment transport is south, but the estimated net transport rate varies in each study within a range of 100,000 to 250,000 cy/year. Most of these studies are evaluating transport at a regional scale and therefore do not attempt to distinguish sediment transport patterns within the study area. The large range and uncertainty associated with measured and estimated littoral sediment transport rates necessitated an iterative approach to calibrating the model.

The LITPACK model was validated against the observed shoreline changes after the 2012 Regional Sand Beach Project II (RSBP II) in which 293,000 cy were placed at Oceanside and 218,000 cy placed at North Carlsbad. The model predicted dispersion of the beach fills throughout Oceanside to North Carlsbad reach with increased beach widths of 50 feet on average three years after the initial placement. In comparison to the observed shoreline changes, the model overpredicted the beach width gained from the RBSP II project along south Oceanside (i.e. beach fill eroded faster than anticipated) and under predicted the accretion that was observed throughout Carlsbad.

A description of the uncertainties and model limitations is described in Appendix B. Some of the key factors influencing the ability of the model to reproduce measured shoreline changes are the uncertainties in local littoral transport rates and the inability to resolve the complicated dynamics of the harbor structures and their effect on littoral transport rates.

The LITPACK model was able to reproduce general trends of shoreline change in the vicinity of the RBSP II placement areas but was unable to accurately reproduce measured shoreline changes at specific locations. Therefore, this model can be useful for estimating the general shoreline change trends from a variety of sand retention configurations but cannot be relied upon to predict shoreline change at a specific time and location.

## 8.3 LITPACK Sand Retention Device Modeling

Multiple configurations of a groin field and series of artificial reefs were evaluated for comparison to a "Nourishment Only Scenario" (NOS). The NOS functions as an assessment of the efficacy of a sand replenishment project similar to what was placed for the RSBP II project. The sand retention alternatives were evaluated at "full-scale" and "pilot-scale" as described below. The full-scale model results were used for direct comparison of sand retention performance to NOS for the entire project reach. The pilot-scale results are intended for use in evaluating the performance of a smaller sand retention project recognizing the need to monitor and measure performance at a smaller scale before implementing a full-scale solution.

### 8.3.1 Full-scale Model Results

The full-scale retention configurations included structures from Tyson Street at the north end to Buena Vista lagoon at the south end. The modeled sand retention devices were simulated using the same input data and parameters as the NOS. The sand retention devices were modeled with the same volume of sand as RBSP II, but the placement locations were adjusted to distribute fill throughout the retention structures and downdrift areas. Some of the key features of the layout of these structures includes:

- Groin field layout (length and spacing) was informed by the extensive physical modeling performed as part of the 1980 U.S. Army Corp of Engineers (USACE) study, Design of Structures for Harbor Improvement and Beach Erosion Control which evaluated ten different groin field layouts. The groin field layout assumes 600-foot long groins spaced at 1,000 feet alongshore. The two southernmost groins were tapered to 400 feet and 300 feet long respectively to reduce downdrift impacts based on findings from the USACE's physical modeling study (1980).

- The artificial reefs are modeled as emergent breakwaters in the LITPACK model. Thespacing and configuration of these reefs were based on guidance from the Coastal Engineering Manual (CEM) as well as some of the results from the USACE's physical modeling study (1980). For modeling purposes the artificial reefs were assumed to have 600-foot-long crests, spaced at 1,200 feet alongshore and placed 1,000 feet offshore.

The model predicted retention of sand throughout the groin field with accretion of sand in fillets on both sides of each groin. Although spread over a larger area, the nourishment prefill stayed in the system and was well retained by the groins. When compared to the accumulated volume of the NOS, the full groin layout retained 175% more sand within the fill placement area based on the 2015 predicted shoreline position. Model results of the artificial reef configuration showed the formation of salient in the lee of the artificial breakwaters, with slight erosional effects between the structures. The artificial reefs performed similar to groins, retaining 185% more sand than the NOS within the fill placement area. A comparison of the model results from the 2015 simulation year are provided in Figure 8-2, illustrating the different shoreline planforms predicted for each alternative.

Figure 8-2. Full-scale model results (simulated 2015 shoreline position)

### 8.3.2 Pilot-scale Results - Groin Field

The full groin and artificial reef layouts stretching from Tyson Street to Buena Vista Lagoon were narrowed down to pilot projects and modeled separately. The groin field pilot was laid out with the goal of demonstrating an effective sand retention project that could be expanded over time.

A series of four groins were modeled to capture the effects in three compartments. The length and spacing of the groins were the same as the full groin layout, since the structures would remain, if successful, and could be expanded to the full groin field layout discussed above. The pilot groins and downdrift area were prefilled with the same 293,000 cy placement volume as the Oceanside fill in RSBP II. The prefill was distributed evenly from Tyson Street at the northernmost groin to Forster Street just downdrift of the southernmost groin. Of the total prefill amount, the 3,000-foot-long groin prefill area received 235,000 cy of prefill and the 750 feet of downdrift area received 58,000 cy of prefill within the model. The results are shown below in Figure 8-3.

Like the modeling of the full groin layout, the model predicts uniform retention of sediment throughout the groin field. The initial fill volume was largely retained within the pilot groin system with accretion of sand in fillets upcoast of each groin. Downdrift erosion was predicted to extend roughly a half mile south of the groin field indicating the importance of a monitoring and management plan to mitigate these potential impacts.

The model results indicate the pilot configuration would retain a much larger beach area within the initial placement zone in comparison to a Nourishment Only Scenario (i.e. RBSP II). The beach width gained from RBSP II in the original placement area was about 50 feet when averaged over the three-year period following initial placement. The model results suggest 100-150 feet of beach width gains when averaged over the model simulation.

While the model results for sand retention are promising, the model limitations must be acknowledged including the inability to simulate the Oceanside Harbor structures and their influence on sediment supply to the study reach. The groins are also simulated as impervious structures which may result in more retention than would occur if these are semi-pervious structures comprised of large armor stone. These model limitations likely result in an overestimate of the beach width retained within the pilot system. Additional analysis of the groin field pilot would involve sensitivity analyses on the placement of initial fill and subsequent fill in the vicinity of the groin field along with variations in groin length and spacing.

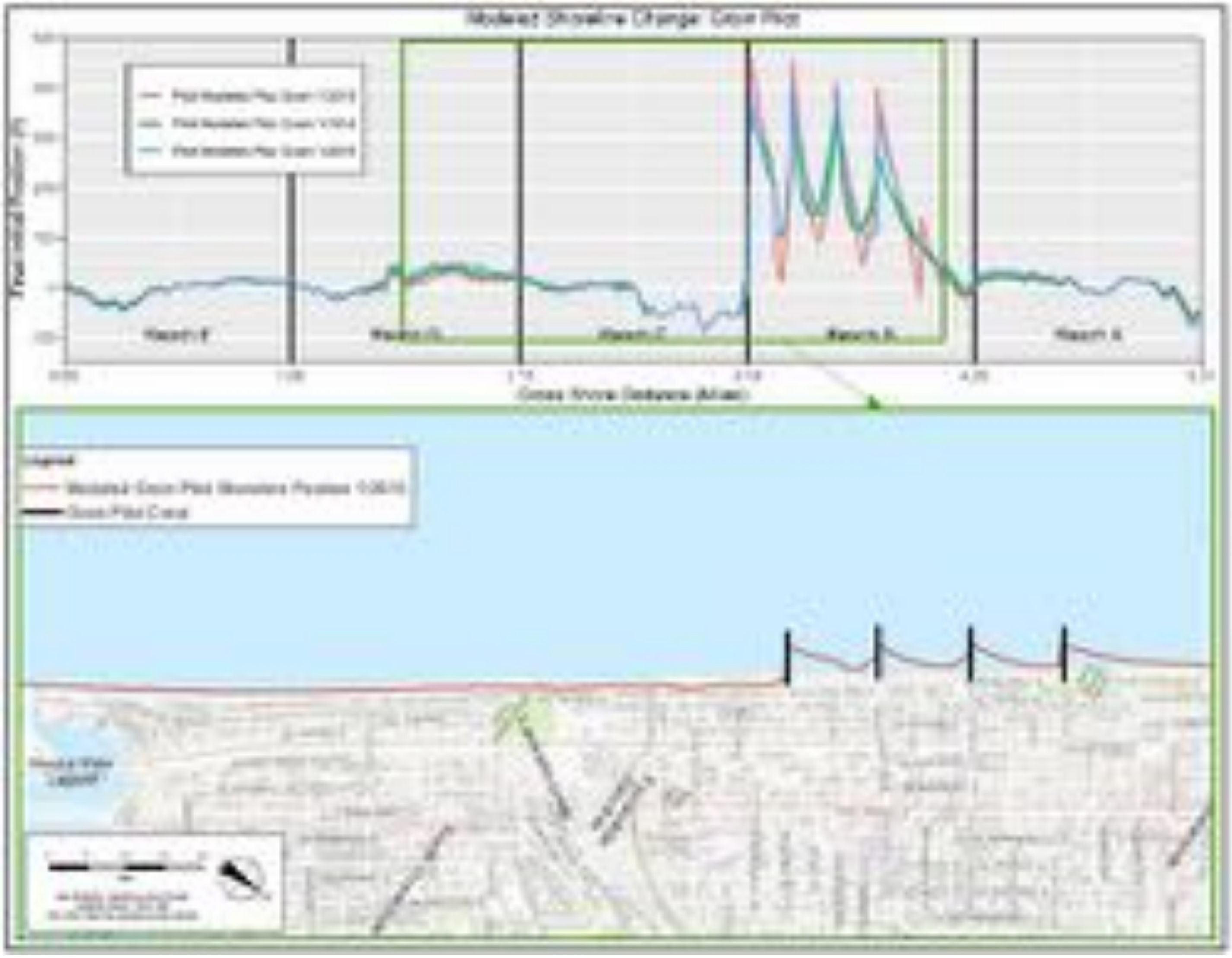

**Figure 8-3. Modeled Shoreline Change for Groin Pilot**

### 8.3.3 Pilot-scale Results - Artificial Reef

The artificial reef pilot project consisted of the northern two artificial reefs, spaced and sized the same as the full layout. A downdrift/prefill of the same amount and placement as the groin pilot was included in the LITPACK model (i.e. 293,000 cy placed from Tyson Street to Forster St. at the beginning of the model simulation). Of the total prefill amount, the 3,000-foot-long groin prefill area received 235,000 cy of prefill and the 750 feet of downdrift area received 58,000 cy of prefill within the model. The results are shown below in Figure 8-4.

The model predicted large salient formation in the lee of each reef structure, with retention benefits extending upcoast well beyond the influence of the offshore structures. More downdrift erosion was predicted for the pilot-scale configuration than the full-scale configuration, extending about a half mile downdrift of the structures. The amount of beach area retained throughout the model simulation was comparable to the Groin Field Pilot results, except the planform distribution of sand would be different. Although the model predicted beach widths are quite large, these are subject to similar model limitations which may be contributing to an overestimate of the potential retention benefits.

Since these offshore reef structures have not been widely implemented in the Southern California region there are limited real world observations of how this system would function. Additional analysis of the Artificial Reef Pilot may involve two-dimensional modeling to simulate the complicated hydrodynamics that may result from these structures. This would provide another tool for estimating their ability to retain a sandy beach and the interaction between two or more artificial reef structures placed in series along the pilot study area.

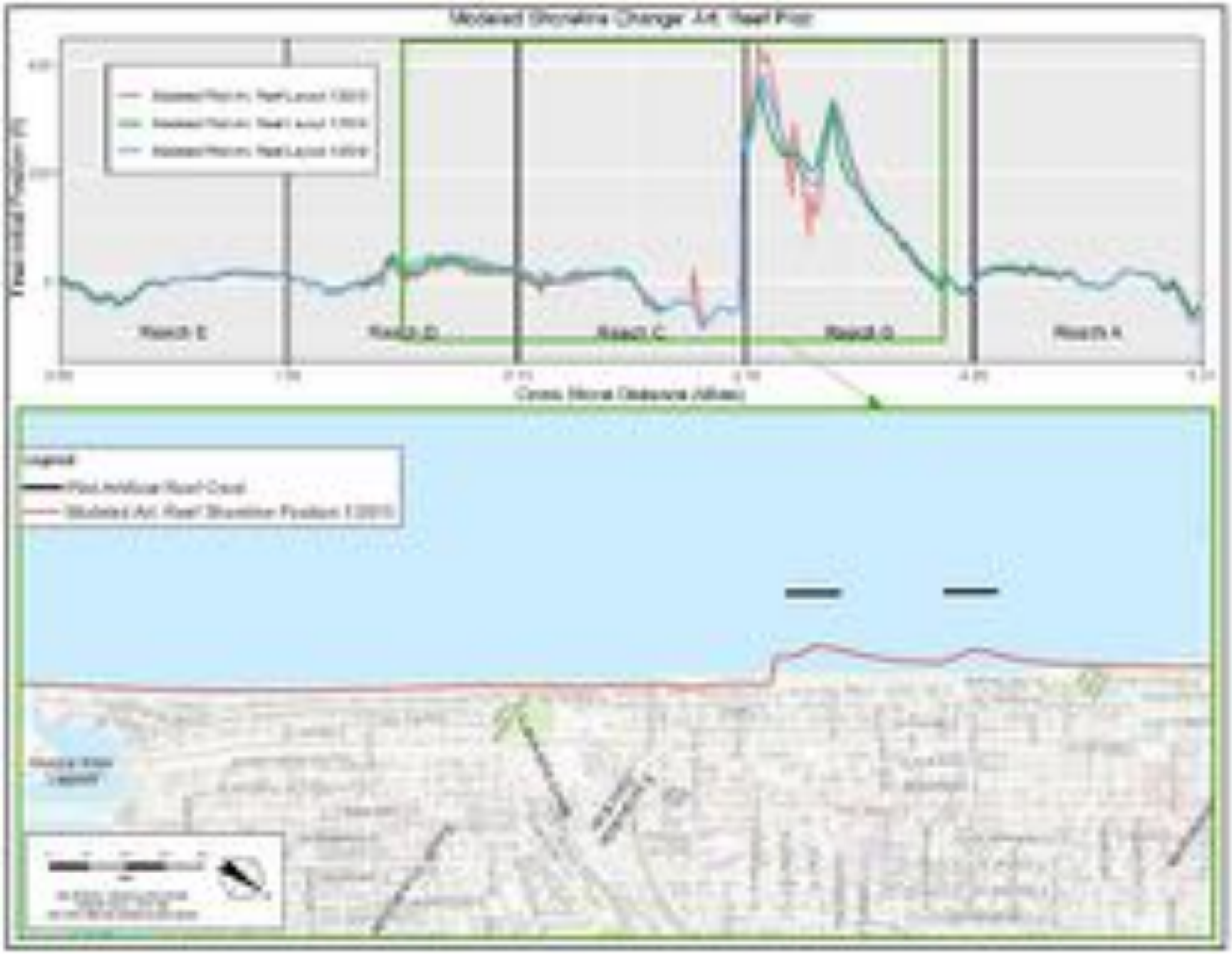

**Figure 8-4. Modeled Shoreline Change for Reef Pilot**

# 9. Multi-Criteria Analysis

A multi-criteria analysis (MCA) was performed to compare alternatives based on a wide range of criteria that reflects the diversity of opinions and input received from the public engagement activities. Rather than rely solely on economics, or a benefit-cost ratio (largely influenced by economics), the multi-criteria analysis is based on customized criteria developed to align with project objectives and public feedback.

## 9.1 Alternative Analysis Criteria

The Oceanside Preliminary Engineering Evaluation and Feasibility Study aims to develop a multi-benefit project that is environmentally sensitive, technically and financially feasible, with a reasonable chance of securing permits. To meet these objectives, the final design of any of the alternatives will start with a pilot project that is adaptable and reversible, and informed by a scientific monitoring program that is led by Scripps Institution of Oceanography.

Public and stakeholder feedback was essential to the development and weighting of the alternative analysis criteria. Results from the polling conducted during a public outreach meeting on September 15$^{th}$, 2021 indicated that downdrift erosion, sea level rise resiliency, and surfing related impacts were of the highest concern. These results were reflected in the poll question results shown in Table 9-1.

**Table 9-1 Public Outreach – Poll Question Result**

| Poll Question 6 | Impacts of concern | Voting Results |
|---|---|---|
| What project impacts are you most concerned about? (Select up to three) | Downdrift erosion | 48% (31/65) |
| | Sea Level Rise Resilience | 46% (30/65) |
| | Surfing related impacts | 29% (19/65) |

The criteria developed for this analysis have been organized into three categories of Technical Performance, Financial and Environmental. These categories reflect the general project objectives and public feedback gathered in the public workshops and stakeholder meetings. The specific criteria within each category are discussed in the following sections along with the basis for evaluating each criterion.

### 9.1.1 Technical Performance

South of the Oceanside Pier, beaches have been limited in width to non-existent in recent years severely limiting safe public access and recreation along this stretch of shoreline. Technical performance criteria relate to the ability of each alternative to restore and retain a sandy beach with a focus on public safety, sediment transport effects on down drift beaches, and resilience to sea level rise. Coastal resilience and the vulnerability of resources and development along the City due to the loss of beach area was a common public concern expressed during the public workshop and stakeholder meetings. The specific criteria for this category are listed in Table 9-2 along with a description about how alternatives will be evaluated for each criterion.

**Table 9-2 Technical Performance Criteria**

| Criteria | Basis of Evaluation |
|---|---|
| Creation/Restoration of Beach | Overall performance of the system, pertaining to the long-term creation/restoration of a dry sand beach. |
| Down-Drift Impacts | Ability to maintain longshore sediment transport to downdrift beaches. |
| Public Safety | Ability to preserve safety of beach and ocean recreation through improved lifeguard access. |
| Sea Level Rise Adaptability | Ability to adapt to future SLR scenarios of up to 2 feet while continuing to meet project objectives. How difficult would it be to augment or modify each alternative to accommodate a 2-foot SLR scenario? |

### 9.1.2 Financial

The financial category includes criteria that account for the approximate lifecycle costs of each design alternative along with a qualitative assessment of the in-direct economic benefits from the alternatives. The lifecycle costs are opinions of costs based on conceptual design drawings and are only intended to provide a rough order-of-magnitude estimate of potential Project costs for the sole purpose of comparing alternatives to one another. These opinions of cost do not reflect the actual cost of the Project and will be subject to refinement upon selection and optimization of a preferred alternative. Lifecycle costs include estimated costs associated with initial costs, operations & maintenance, and adaptation at the end of the pilot phase. Financial criteria and their basis of evaluation are listed in Table 9-3.

**Table 9-3 Financial Criteria**

| Criteria | Basis of Evaluation |
|---|---|
| **Lifecycle Costs:** | |
| Initial Costs | Estimated capital cost of the initial Project including soft costs associated with permitting, engineering design and construction management |
| Operation & Maintenance | Estimated costs of operational and maintenance efforts over the 50-year design life (e.g. beach re-nourishment, or maintenance & repair of retention structures). |
| Adaptation | Estimated costs associated with adapting retention structures to improve performance at the end of the pilot project phase. |
| **Economic Benefits:** | |
| In-direct economic benefits | Based on a qualitative assessment of increased economic activity generated by a stable and sustainable dry beach area available for beach and ocean recreation. |

### 9.1.3 Environmental

Environmental criteria were developed to evaluate the project’s ability to preserve or enhance coastal resources in the project vicinity. The criteria include considerations for marine biological resources, surfing resources, aesthetics, beach recreation and coastal access. The preservation and enhancement of these resources is an objective of the project and will be key focus areas during the environmental analysis, regulatory review and permitting process. The specific criteria and their basis of evaluation are listed in Table 9-4.

**Table 9-4. Environmental Criteria**

| Criteria | Basis of Evaluation |
|---|---|
| Biological Resources | Ability to preserve and/or enhance marine biological resources in inter-tidal and nearshore waters. Alternatives which provide a stable beach will offer more sustainable inter-tidal habitat. Sand retention structures are assumed to have a temporary impact on sand bottom habitat, but also creation of new rocky inter-tidal habitat. |
| Surfing Resources | Ability to preserve or enhance existing surfing resources. |
| Aesthetics | Ability to preserve coastal aesthetics throughout Oceanside. Aesthetics are subjective but the analysis assumes a positive aesthetic is associated with the presence of a sandy beach. |
| Beach Recreation | Ability to preserve and/or enhance beach recreation area (i.e. towel space), particularly in areas most accessible like the Pier and South Strand reaches. |
| Coastal Access | Ability to enhance lateral beach access through the creation of stable, dry beach areas. |

## 9.2 Weighting and Scoring System

The MCA scoring and weighting presented in this report reflects input from the multi-disciplinary Project team including thoughts and opinions from a diverse group of team members with technical, financial and environmental expertise in effort to reduce individual bias and subjectivity from influencing the results.

The maximum potential score for each alternative is a function of how well the alternative satisfies the criteria within three general categories of Technical Performance, Financial and Environmental. The results presented in this report are based on a weighting of 40/20/40 (Technical/Financial/Environmental) breakdown among these categories as shown in Table 9-5. In other words, the Technical Performance and Environmental categories have a maximum score of 40%, and Financial criteria account for up to 20% of the total score. Technical Performance and Environmental categories were weighted slightly higher because the criteria in this category closely align with the primary objectives and feedback received from the public workshop and stakeholder meetings. The sensitivity of these weightings on the results were evaluated and discussed in Section 9.4.

**Table 9-5. MCA Category Weighing**

| Category | Weight |
|---|---|
| Technical | 40% |
| Financial | 20% |
| Environmental | 40% |
| **Total** | **100%** |

The individual criterion within each category were also assigned a weighting to determine what percentage of the available score should be allocated to each. The criteria weightings are shown in the left column of Table 9-6 and make up 100% of the available score within each category. In most cases the criteria were equally weighted within the Technical Performance and Environmental categories, which reflected the feedback from the Project team that no single criterion was significantly more important than others.

The Financial criteria was weighted 70% for lifecycle costs and 30% for in-direct economic benefits resulting from a restored dry beach in the most accessible coastal areas of Oceanside (Pier and South Strand). Lifecycle cost is the estimated actual monetary cost of the project including costs for initial capital investment, operations & maintenance and adaptation/structure modification at the end of the pilot phase, which were calculated for each alternative (i.e. quantitative). The Lifecycle cost score was calculated by applying a graduated scoring system in which the difference between highest and lowest cost alternatives was divided into five equal increments. The highest possible score (5) was assigned to alternatives with a lifecycle cost within the lowest increment. The lowest possible score was assigned to alternatives with a lifecycle cost within the highest increment.

Scoring of individual criteria was based on a scale of 1 to 5 for each alternative. A high score indicates an alternative has a good chance of satisfying the objectives of each criterion. A low score indicates an alternative has a poor chance of satisfying the objectives of each criterion. For some criteria (e.g. beach restoration, lifecycle costs) numerical modeling results and calculations were available to support the scoring of each alternative. For other criteria, where metrics were unavailable to facilitate comparison, the scoring was based on the outcome of discussion and debate among project team members.

Individual scores were multiplied by the criterion weighting and category weighting to arrive at a weighted score for each alternative and criterion. For example, if an alternative received a high score (e.g. 4 out of 5), it would be multiplied by the criteria weighting (e.g. 20%) and the category weighing (e.g. 40%) for a weighted score of 6.4% (i.e. 4/5 x 0.20 x 0.40 = 0.064). The weighted scores were then summed for each alternative and category to form a total score. Note, the weighted and total scores have been rounded to the nearest whole percentage in the results table.

## 9.3 Results

The results of the MCA indicated the highest ranked alternative was Groins, followed by Multi-purpose Reefs. These top two alternatives were separated by 8% from one another in total score which was meaningful when considering the sensitivity of the scoring and weighting system (discussed in Section 9.4). Beach Nourishment ranked third, about 17% lower than the Groins and 9% lower than Multi-purpose Reefs. The No Project alternative ranked last with very low scores in the Technical Performance and Environmental categories. A detailed summary of the MCA is provided in Table 9-6. A summary of the rationale used to assign scores and differentiate among alternatives is provided in the following sections. Please refer to Appendix C for the detailed scoring matrix which includes the numeric score, weighted score, and comments for each criterion.

### Table 9-6. Multi Criteria Decision Matrix

| Weight | Criteria | No Project | Alternative 1<br>Beach Nourishment Program | Alternative 2<br>Groins | Alternative 3<br>San Luis Rey Groin Extension & Beach Nour. | Alternative 4<br>Multi-Purpose Artificial Reefs |
|---|---|---|---|---|---|---|
| | | Weighted Score | Weighted Score | Weighted Score | Weighted Score | Weighted Score |
| **40%** | **TECHNICAL PERFORMANCE** | | | | | |
| 25% | Creation/Restoration of Beach | 2% | 4% | 10% | 4% | 8% |
| 25% | Down Drift Impacts | 2% | 10% | 6% | 10% | 6% |
| 25% | Public Safety | 2% | 6% | 6% | 6% | 6% |
| 25% | Sea Level Rise Adaptability | 2% | 4% | 8% | 4% | 10% |
| | *SUBTOTAL out of 40%* | *8%* | *24%* | *30%* | *24%* | *30%* |
| **20%** | **FINANCIAL** | | | | | |
| 70% | Life-cycle Costs | 14% | 14% | 11% | 11% | 3% |
| 30% | In-direct economic benefits | 1% | 2% | 6% | 2% | 5% |
| | *SUBTOTAL out of 20%* | *15%* | *16%* | *17%* | *14%* | *8%* |
| **40%** | **ENVIRONMENTAL** | | | | | |
| 20% | Biological Resources | 2% | 5% | 6% | 5% | 8% |
| 20% | Surfing Resources | 2% | 5% | 6% | 5% | 6% |
| 20% | Aesthetics | 3% | 5% | 6% | 5% | 6% |
| 20% | Beach Recreation | 2% | 5% | 6% | 5% | 6% |
| 20% | Coastal Access | 2% | 5% | 8% | 5% | 8% |
| | *SUBTOTAL out of 40%* | *10%* | *24%* | *34%* | *24%* | *35%* |
| | Total Score (out of 100%) | 33% | 64% | 81% | 62% | 73% |
| | **Ranking** | **5** | **3** | **1** | **2** | **4** |

1. Lifecycle costs include estimated costs associated with capital, operation & maintenance and estimated adaptation cost at the end of the pilot phase.

### 9.3.1 Analysis of Technical Performance Criteria

Each alternative, except for No Project, involves placement of a significant amount of sand over the design life of the pilot phase. Technical performance was largely based on the ability of each alternative to restore and retain a beach along the project area. Numerical modeling results indicate Groins would be most successful in maintaining dry beach area in Oceanside. Multi-purpose Reefs would also provide a significant improvement over Beach Nourishment. Creation/restoration of a beach was a key differentiator among the alternatives with the sand retention alternatives (Groins and Reefs) receiving higher scores due to longer lasting benefits in comparison to Beach Nourishment alone.

Beach Nourishment is most likely to avoid impacts to down drift sediment supply and received the highest score for this criterion. Groins and Reefs include a significant amount of beach nourishment to pre-fill the retention systems and supply down drift beaches with a supply of coarse-grained sand. Neither of these systems will block longshore sediment transport but there may be an adjustment period where localized downdrift impacts occur as the beach profiles adjust to the sand retention system. With some sediment management measures in place during the pilot phase, any potential down drift impacts could be mitigated. Due to uncertainties over these down drift impacts the Groins and Reefs received a lower score for this criterion. No Project received the lowest score because this option provides no reliable supply of coarse sand, so ongoing erosion trends will continue.

Accessibility for safe public access and lifeguard services will be important design elements of each alternative. Beach Nourishment will improve public safety temporarily after each nourishment event but will leave long stretches of shoreline inaccessible between nourishment cycles. Groins and Reefs are more likely to create and retain sandy beach areas to facilitate safe access for the public and lifeguard services. However, the sand retention structures introduce new risks for ocean recreation with the potential for rip currents to form in the vicinity of these structures. Due to the various pros and cons associated with each alternative, they were all assigned mid-range scores since public safety is not considered a major differentiator between the alternatives.

Adaptability to SLR included consideration for how each alternative could be adapted to perform under future SLR scenarios up to 2 feet. Restoration of a stable dry beach will help mitigate increased erosion and storm damage associated with SLR. All alternatives would likely require greater volumes of sand placement to maintain performance under these future scenarios. Beach Nourishment alone may be an effective regional solution to SLR but will not be a reliable adaptation strategy for Oceanside without retention structures. Groins and Reefs would help retain a sandy beach at specific locations providing a more reliable buffer to SLR and associated storm-related damages. Multi-purpose reefs were scored highest in terms of adaptability because they also provide increased wave energy dissipation in the alongshore direction.

### 9.3.2 Analysis of Financial Criteria

Groins and Beach Nourishment were the highest scoring alternatives in the Financial category. The Financial score was heavily weighted toward a quantitative estimate of lifecycle costs which include initial capital investment, beach renourishment and adaptation/structure modification at the end of the pilot phase, which was assumed to be about 15 years. Estimated lifecycle costs are provided in Table 9-7.

Renourishment is assumed to occur at 5-year intervals for cost estimating purposes but actual timing would depend on monitoring results. Adaptation costs for the retention alternatives are based on a percentage of the initial cost of the structures assuming some adjustments or maintenance of these structures would occur at the end of the pilot phase. No Project costs assume the City contributes to additional harbor dredging or other opportunistic efforts once every five years. Details of the lifecycle costs and assumptions made for each alternative are provided in Appendix C.

Beach Nourishment has a lower lifecycle cost than the Groins due to the initial cost of building the groin structures. The Groins alternative has lower maintenance costs since less volume of nourishment is required over the project duration. Multi-purpose Reefs received the lowest score since this alternative was estimated to have the highest lifecycle cost due to the significant volume of material required to build the artificial reef structures.

A restored sandy beach along the most accessible reaches of the Oceanside shoreline will generate in-direct economic benefits resulting from increased tourism and recreation visits. Since the sand retention alternatives are expected to prolong the benefits of a restored sandy beach, these alternatives were scored higher in this criterion than other alternatives.

**Table 9-7. Alternative Lifecycle Cost Estimates**

| ALTERNATIVE | NO PROJECT | 1<br>BEACH NOURISHMENT | 2<br>GROINS | 3<br>SLRR GROIN MODS | 4<br>MULTI-PURPOSE REEFS |
|---|---|---|---|---|---|
| Initial Cost | $ 1,000,000 | $ 10,000,000 | $ 32,000,000 | $ 16,000,000 | $ 95,000,000 |
| Beach Renourishment | $ 2,000,000 | $ 18,000,000 | $ 14,000,000 | $ 18,000,000 | $ 14,000,000 |
| Adaptation | - | - | $ 5,000,000 | $ 2,000,000 | $ 39,000,000 |
| **Total** | **$ 3,000,000** | **$ 28,000,000** | **$ 51,000,000** | **$ 36,000,000** | **$ 148,000,000** |

Notes:

1. The values provided in this table are considered pre-planning level estimates and should not be used for any purpose other than intended, which is for comparing alternatives for the Project feasibility analysis. Accuracy +50% - 30%.
2. All values shown in this table are 2021 costs.
3. Please refer to the appendix for breakdown of estimated costs and assumptions for each alternative.
4. A 15-30% contingency amount is included in the estimates to cover unknown detail and costs considering the feasibility level of the design.

### 9.3.3 Analysis of Environmental Criteria

Groins and Multi-purpose Reefs scored significantly higher than other alternatives in the Environmental category. Although some temporary marine biological resource impacts would be expected for each nourishment event, over longer durations the sand retention alternatives improve the viability of sandy inter-tidal beach habitat within the project area. The sand retention structures will occupy sand bottom habitat but will also create rocky intertidal/subtidal habitat over the long-term. The trade-offs associated with these resource impacts will be a focus of environmental analyses conducted in subsequent project phases. The retention alternatives (Groins and Reefs) also score slightly higher than Beach Nourishment in aesthetic, recreation and coastal access due to the pro-longed benefits associated with sandy beach areas retained.

Surfing resources are an important consideration for each of the alternatives developed. Oceanside offers a long stretch of beachbreak with a wide exposure to incoming swell from multiple directions. In recent years, the surfing resources have been adversely impacted by the loss of a sandy beach and continued erosion of the beach profile in front of the revetment. These conditions render long reaches of shoreline unrideable during medium-high tides because of the deep nearshore profile and backwash (i.e. waves rebounding off the revetment into the surfzone).

Alternatives which restore a stable sandy beach along the City are expected to preserve and enhance existing surfing resources. For this reason, Groins and Reefs were scored slightly higher than Beach Nourishment because of their improved ability to retain a sandy beach. Groins are a common feature of surf breaks throughout Southern California and globally with the San Luis Rey River Groin (commonly referred to as south jetty) one of the most popular surfing resources in the area. Groins are not expected to significantly alter the surfing resources along Oceanside and there is a potential they enhance surfing resources due to the occurrence of sandbars which often form in the vicinity of these structures.

Multi-purpose Reefs are an intriguing alternative for enhancing surfing resources while retaining a beach but remain expensive and unproven in their ability to provide a consistent and rideable break in an open ocean environment like Oceanside. This alternative would likely require some adjustments in the field to mitigate adverse impacts on surfing resources.

## 9.4 Sensitivity

### 9.4.1 Criteria Scoring Sensitivity

The MCA scoring matrix generated questions from the Project team regarding sensitivity of the analysis. The key question being "How would these results change if one or two scores were revised up or down for each alternative?" There were only a few criteria in which the Project team had more difficulty arriving at a consensus score for a given alternative. One example was the scoring for aesthetics, which is somewhat subjective and dependent on a person's perspective and interests. In this case, changing a single score by one increment would result in only a 2% change in the total score. For each alternative there were only one or two criteria in which scoring was debatable and, therefore, the overall scoring sensitivity was estimated to be 2-4% when considering the total score. Through this sensitivity analysis it was determined that changes to multiple individual criteria scores would not change the overall alternative rankings since the top three alternatives have an 8-9% separation in total score. The results indicate a robust consensus among the Project team that Groins are the highest scoring alternative in comparison to Multi-purpose Reefs, Beach Nourishment, San Luis Rey Groin Modification and No Project alternatives.

### 9.4.2 Category Weighting Sensitivity

Sensitivity of Category Weightings was another area of interest to understand how the breakdown between Technical Performance, Financial and Environmental influences overall results. The results presented in Section 9.3 are based on a breakdown of 40% for Technical Performance (TP), 20% for Financial (FIN) and 40% for Environmental (ENV). The consensus of the Project team was that Technical Performance and Environmental warranted a higher emphasis because their criteria closely match the Project objectives, feedback from public engagement, and provide the best indicator for Project success.

Figure 9-1 illustrates the total scores for each alternative for several different Category Weightings. When these weightings are adjusted a clear pattern emerges in which Groins (Alternative 2) is consistently scored highest and No Project is consistently scored lowest. If these Category Weightings are adjusted to place equal emphasis on each category (TP=33.3 / FIN=33.3 / ENV=33.3), the scores and rankings do not significantly change. If a major emphasis is placed on any single category (60% weighting), Groins is still the top ranked alternative.

The findings of this sensitivity analysis give the Project team high confidence that Groins have the best chance to satisfy the Project objectives. Although the Multi-purpose Reefs also scored high in the Technical Performance and Environmental categories, the low Financial score is an indication this alternative may be very challenging to fund.

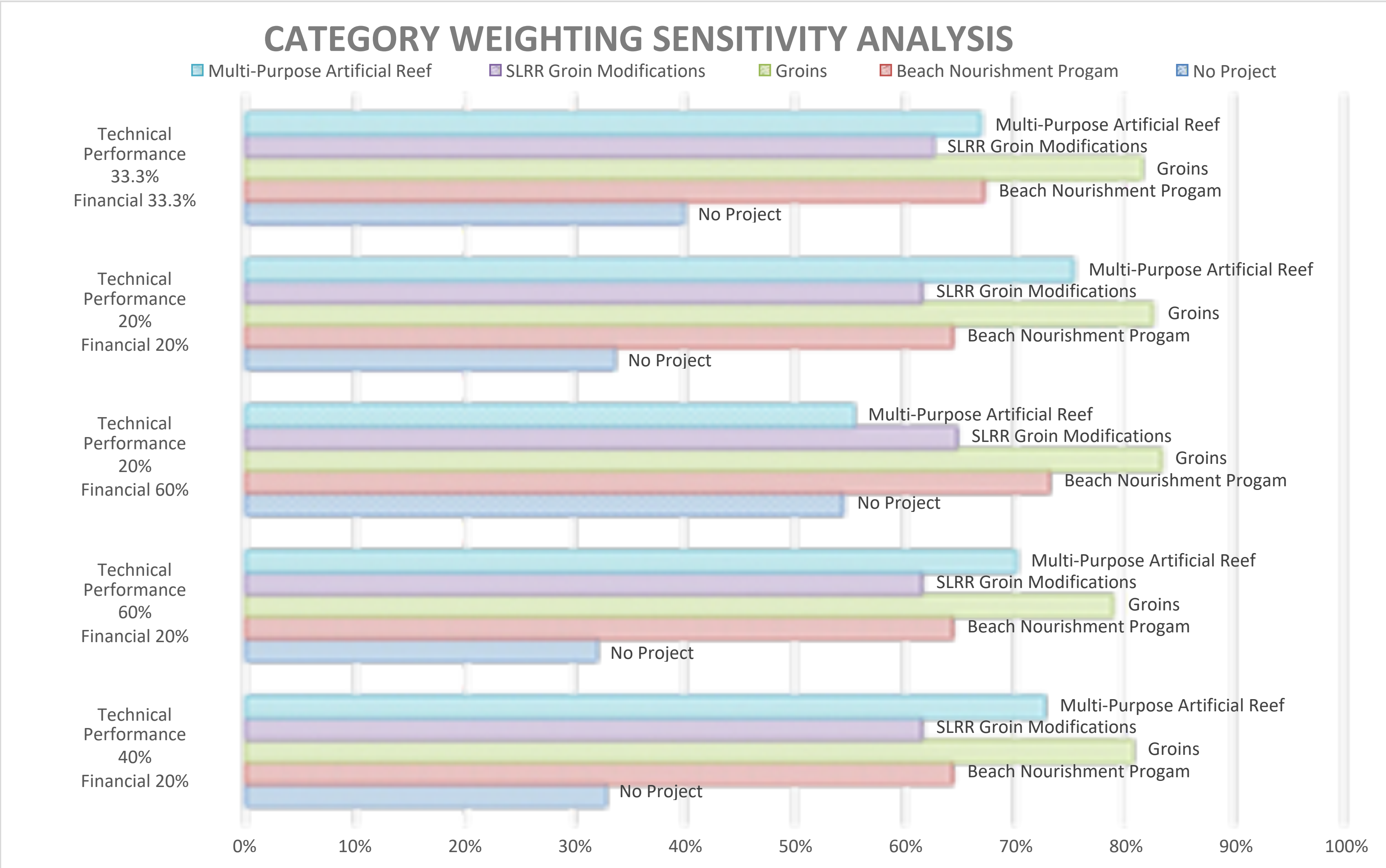


**Figure 9-1 Sensitivity to Category Weighting**

# 10. Value Comparison, Beach Nourishment vs Sand Retention

Beach width is an important parameter in evaluating the feasibility of beach nourishment with sand retention structures. Most of the data presented in this study refers to mean sea level (MSL) beach width since that is the most common metric reported in the SANDAG RBSP monitoring data. MSL beach width refers to the distance between the back beach (revetment in most cases) to the MSL shoreline. This can be a useful metric for documenting shoreline change trends over long time periods or large areas (i.e. RBSP I and II), but MSL beach width can be a misleading measurement of dry beach area available for recreation (i.e. towel space).

Figure 10-1 provides a few example profiles of varying beach width to illustrate the difference between MSL beach width and dry beach width. The May 2012 profile is typical of South Oceanside in which a submerged beach forms in front of the revetment but there is little or no dry beach to support typical beach recreation activities. Since the foreshore (beach face) slope is relatively flat in Oceanside, a 50-foot MSL beach width is submerged half the time, or more depending on wave conditions. In other words, a 50-foot MSL beach width does not provide enough dry beach for coastal access and recreation except for some low tide activities.

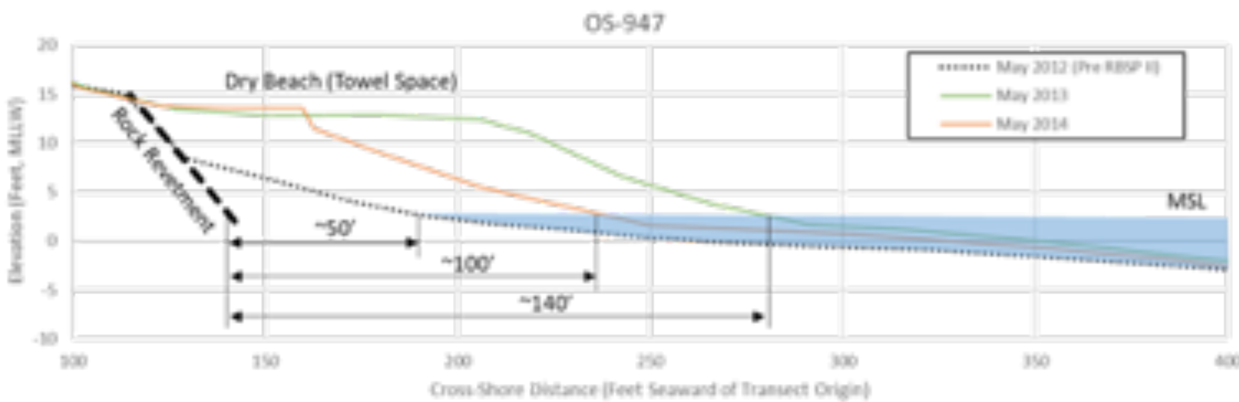


**Figure 10-1. Illustration of MSL Beach Width vs. Dry Beach Width**

In order to provide opportunity for coastal access and recreation, the sand retention alternative should target an MSL beach width of 100 feet or more to provide a sufficient dry beach area to support these activities. The post RBSP II profiles of May 2013 and 2014 (Figure 4-5) are examples of the dry beach area available for MSL beach widths of 100-140 feet. Unfortunately, in the case of RBSP II, these beach widths were short-lived conditions and demonstrate the need for a sand retention system to prolong these benefits.

The beach area generated over the lifecycle of each alternative provides a useful metric for comparing the value of each alternative. Modeling results of the pilot-scale sand retention alternatives indicate they could potentially retain up to 18 acres of beach area, over three times larger than the beach area generated within the initial placement area after RBSP II. The MSL beach widths in each of the groin fillets or reef salients would be wide enough and stable enough to support coastal access and recreation on a year-round basis with average beach widths of 100-150 feet. The lifecycle cost of each alternative was divided by the beach area generated to compare the value (cost/acre of beach area) of each alternative in Figure 10-2. The alternatives considered all require a large investment, but this comparison indicates groins would provide the best value in terms of the beach area generated for the lifecycle cost. While Beach Nourishment has a significantly lower lifecycle cost, the area of beach generated is also significantly lower. Groins, while requiring a significant capital expense, offer the highest return on the investment with the best chance of success in providing a stable dry beach along the pilot reach.

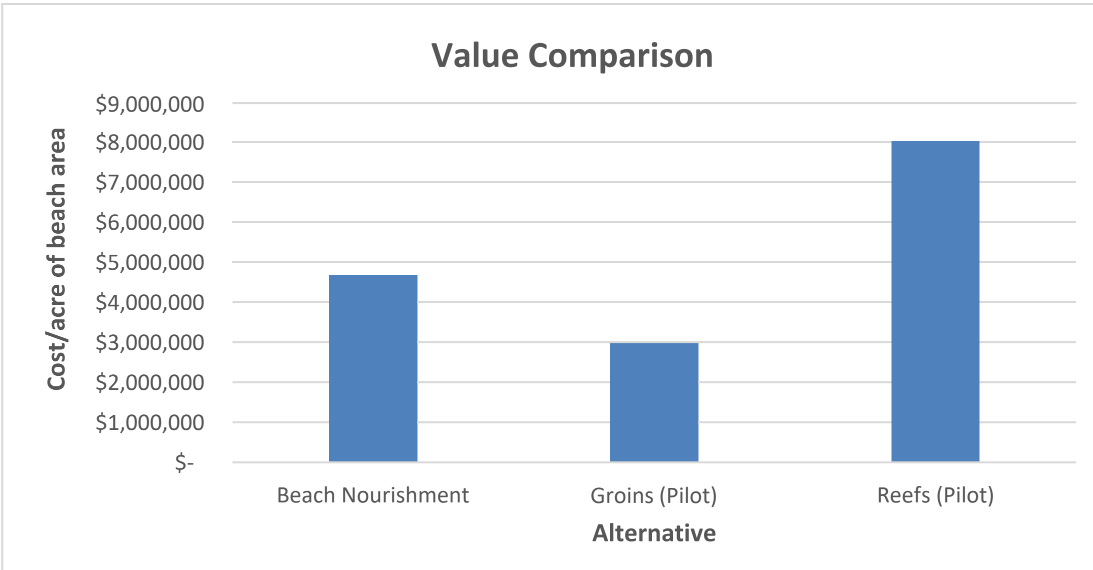


**Figure 10-2. Value Comparison for Each Alternative**

# 11. Sand Management Systems Evaluation

Each of the proposed action alternatives require frequent nourishment of City beaches with coarse gradation sediment. As opposed to developing options of idealized beach nourishment templates and placement locations, this study focused on identifying sustainable, high quality sand sources and then developing the mechanisms that could be deployed to transport sand more efficiently to City beaches that need it most. These options draw upon lessons learned from the City/USACE's prior Experimental Sand Bypassing Pilot in the 1980s and more recent successful global project examples.

A critical first step to sediment management in the City is identifying a sustainable source of high-quality sand. This study identified several sand sources to consider as part of a long-term nourishment strategy. Each of these sand sources have positive and negative attributes that need to be considered, as well as potentially significant obstacles to overcome. The sand sources considered in this study are as follows:

- **Camp Pendleton** – Unlike most open coast harbors in California, Oceanside Harbor does not have an established sand bypassing program. As a result, millions of cubic yards of coarse gradation sand has built up against the northern harbor breakwater (USACE, 2016). This

Unacceptable

source of sand is the most logical and economical source to restore a supply of sediment to Oceanside beaches. The Marine Corps have declined to discuss the feasibility of bypassing this sand around the harbor to maintain a supply of sand to downdrift beaches. Unfortunately, this is consistent with past coordination with the Marine Corps about dredging this deposit (i.e. Sand Bypass Project). Political and jurisdictional challenges remain the most significant barriers to this sand source.

- **San Luis Rey River**: A significant deposit of coarse gradation sand exists at the mouth of the San Luis Rey River. The recharge of this area, once sand is dredged, is unknown but would likely not be a sustainable long-term source of significant quantities of sediment. While not sufficient to mitigate the sediment supply deficit, this source of sand is worth consideration as an opportunistic source to supplement with other efforts. Previous USACE studies have also evaluated dredging of sediment further upstream to increase conveyance capacity of the river. The San Luis Rey River mouth area is critical habitat for the Western Snowy Plover and the tidewater goby. Any dredging activity would include a thorough environmental review of the potential impacts on ecological functions within the river.
- **City of Oceanside Harbor Beach**: A fillet of sand exists along the north jetty. This area could be dredged to form a sediment capture area for sand before entering the harbor. The recharge of this area, once sand is dredged, is unknown but would likely not be a sustainable long-term source of significant quantities of sediment.
- **Offshore Sediment Deposits**: Offshore sediment deposits, like the ones used in RBSP I and II, are a proven source of sand high in both quantity and quality. These could be dredged more frequently for local projects but require specialized marine contractors and equipment to dredge, transport and place material. The high mobilization costs for this type of project make the economics challenging at the local scale. Since this source requires a different set of means and methods, it was not included in evaluation of the following sand management systems.

Once a source of sediment is identified, the next step is to determine how to efficiently move sand from the source location to the receiving beach. Sediment bypassing is most effective when the sand source location/borrow area is fixed and the area recharges quickly once dredged. The ability for the borrow area to recharge was a key limitation of the Experimental Sand Bypassing Pilot, which was evaluated closely prior to proposing new bypassing options. Other limitations of the bypassing pilot were pipeline clogging issues and inconsistent federal funding leading to a scaled down pilot project and deferred maintenance of the system. Options for bypassing sediment in the City are presented in this section.

## 11.1 Fixed Trestle Sand Bypass

Similar to the Tweed River Project, this option would construct a fixed trestle updrift of Oceanside Harbor on Camp Pendleton (Figure 11-1). The trestle would extend into the surfzone/nearshore with a series of pumps to capture sand moving in the longshore direction. Sand pickup locations would be optimized based on beach conditions and observed recovery time of the depressions where sand had been removed.

The system would transport pumped sand to City beaches via a network of shallow and deep underground pipelines. The size and pipeline composition (HDPE or steel) would be determined at a later phase once sand bypass volumes are finalized. It is proposed that pipelines be constructed underground (via horizontal directional drilling) under the Oceanside Harbor and the community of North Coast Village. Four junction boxes are proposed to allow for booster pumps to be added or for sand to be discharged at these locations. This system would be designed to work with the USACE's harbor dredging program. The installation of a fixed distribution system would reduce costs associated with above-ground pipeline placement, improve public safety and reduce the disruption to public access and beach uses during each dredging event.

Initially, the system would bypass over 200,000 CY of sand per year to City beaches to make up for the long-term sediment deficit. Over time, this bypass rate would be reduced to keep pace with longshore sediment transport rates and maintain a sufficient dry beach area updrift of the harbor. While requiring a major capital investment, this option avoids the need for mobilization of equipment and pipeline placement on an annual basis reducing the disruption to beach users at Camp Pendleton and Oceanside.

**Figure 11-1. Fixed Trestle Sand Bypass Option**

## 11.2 Semi-fixed Sand Bypass

This option would entail construction of a bypass system that could be moved relatively easily to accommodate changes in the sand source location. Similar to the fixed system (Figure 11-1), this option would entail construction of sand distribution pipelines and junction boxes to transport sand within the City. Unlike the fixed system, this system could source sand from the Camp Pendleton fillet, Harbor Beach or the SLRR mouth with some manipulation.

This system is envisioned to transport approximately 100,000 CY per year; similar to other comparable systems. Due to the decreased capacity of the system, nourishment would need to be carried out frequently; assumed annually for a period of 4-6 months.

The sediment intake at the source location could be similar to the Tweed River Sandshifter that is in a semi-fixed location within the foreshore (Figure 11-2). Once the system is turned on, the sand above it is fluidized and pumped into the pipelines forming a depression that is filled by active littoral transport. Another option for the sediment intake would be to construct something similar to the Indian River Inlet system. This system entails a fixed pipeline distribution system and pump house but allows for some flexibility with the intake through manipulating the cutter head dredge with a crane (Figure 11-3).

The semi-fixed sand bypass system avoids the high capital cost of a fixed trestle system. As a result, the operational and maintenance requirements for this system will be greater and likely require the mobilization of materials and equipment for each dredging event, depending on the location and volume to be dredged.

The variable location and quantity is a benefit of this system with the flexibility to access multiple local sand sources. However, this flexibility poses a challenge when paired with a distribution system that has a fixed pipeline diameter. It may not be possible to design a one-size fits all distribution system since the pipe diameter may not be perfectly suited to all dredge equipment and production rates. For example, if the fixed distribution pipeline is under-sized for a specific dredging event, production rates will suffer, increasing the duration and costs of each dredging event. On the other hand, if the fixed system is oversized for a small-scale dredging event, booster pumps may be required to deliver the sand to the designated downcoast receiver site.

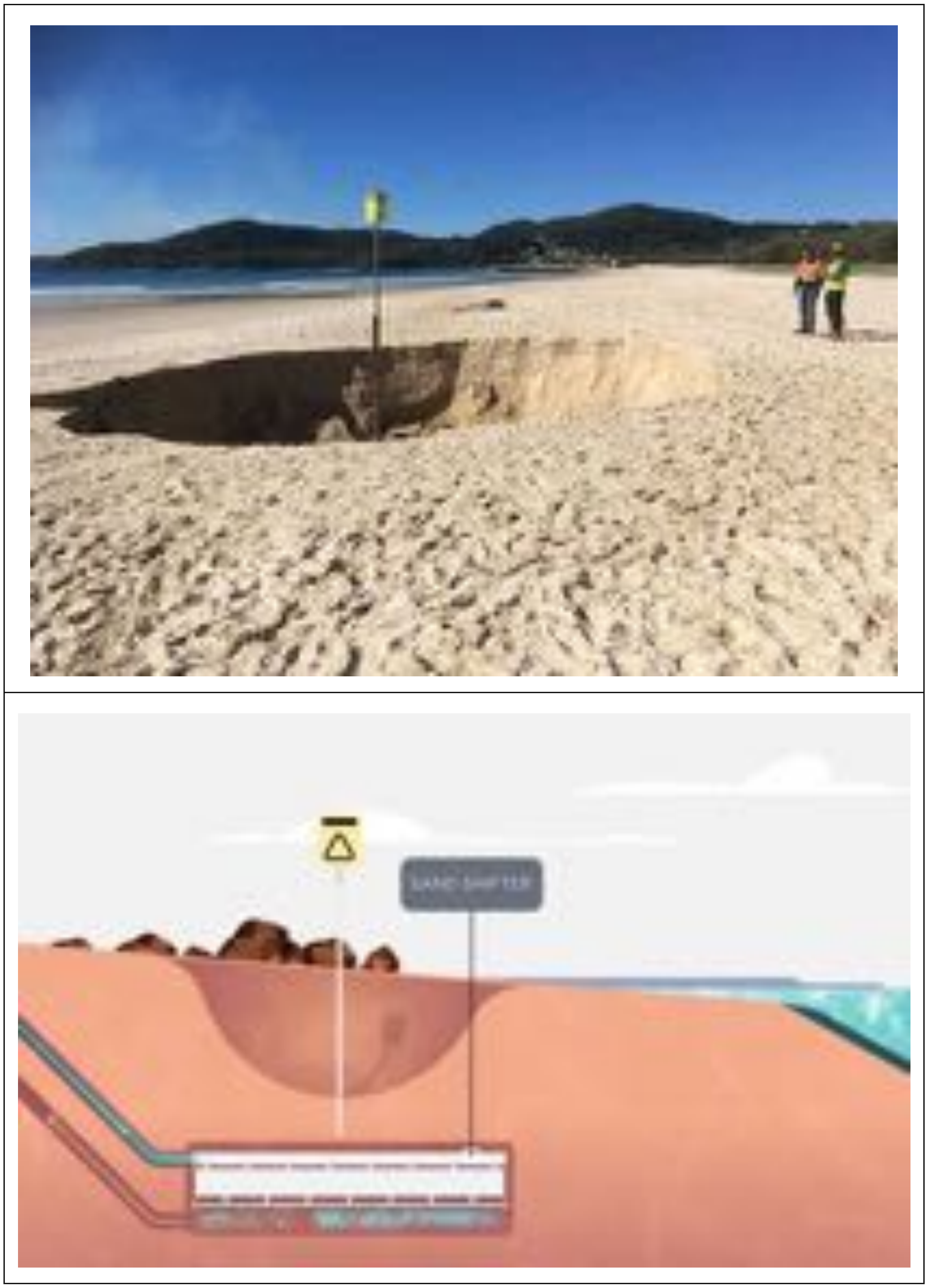


**Figure 11-2. Mobile Sand Bypass Option – Sandshifter Detail (Swash, 2021)**

**Figure 11-3. Mobile Sand Bypass Option – Indian River Inlet, Delaware (USACE, 2021)**

## 11.3 Piggyback on USACE Harbor Dredging Program

This option would install the proposed series of underground pipelines described in the above options without purchasing mechanical dredge equipment. This option assumes the City would “piggyback” on the USACE’s annual harbor dredging program to bypass sand from the MCB Camp Pendleton fillet using the sand distribution system shown in Figure 11-4. Piggybacking on other dredging operations is a common practice to save on contractor mobilization/demobilization costs. Logistics surrounding how to access and dredge the fillet or other high-quality sand source would require further coordination with the USACE dredge contractor and the MCB Camp Pendleton.

The series of sand distribution pipelines would be designed to allow for the efficient distribution of sand from the navigation channel and fillet to southern portions of the City past known constriction points (i.e. North Coast Village and Pier). This system would be similar to underground pipelines used for the Santa Barbara Harbor dredging and the Channel Islands Harbor bypassing programs. Having fixed underground pipelines would benefit the USACE’s program in that it would lower mobilization costs. They could also reduce the amount of heavy equipment on the beach during construction, which would benefit public safety.

This option may also be viable with the use of the fabricated, above grade dredge pipelines used by the USACE’s dredge contractor annually. The City could piggyback on the USACE’s program to move additional high-quality sand (i.e. from a source other than the harbor navigation channel) through the established pipelines at the end of the harbor dredging cycle. This would take advantage of the lain pipe offering a significant reduction in mobilization costs. However, this option may not allow sand to be placed as far to the south as desired to benefit these heavily impacted beaches.

**Figure 11-4. Piggyback on USACE Program Option – Sand Distribution System**

## 11.4 Comparison of Sand Distribution Systems

Sand bypass systems have the limitation of being expensive to construct and sometimes difficult to maintain. However, bypassing works well in situations where large quantities of sediment needs to be moved around impediments, like the Oceanside harbor. In these scenarios, the comparative costs of constructing a sand distribution system can be cheaper and less disruptive than conducting one-off dredging episodes on an annual basis or even more frequently.

The sand distribution systems presented in this section are compared in Table 11-1. Without having secured a significant source of high-quality sand for the City, there is limited benefit to further design and analysis. The ideal sand source for a sand bypass system is the MCB Camp Pendleton fillet despite the significant political and jurisdictional obstacles that exist. Should that sand source become available, a semi-fixed sand distribution system should be evaluated in more detail and designed to work with the USACE's annual harbor dredging program. A pilot, or proof-of-concept could be carried out at harbor beach with the system to raise the level of comfort with the MCB, if deemed necessary and appropriate.

## Table 11-1. Comparison of Sand Management Systems

| System | Approx. Capital Costs (USD, Million) | Approx. Annual Operation & Maintenance Costs (USD, Million) | Assumed Annual Bypass Yield (thousand, CY) | Pros | Cons |
|---|---|---|---|---|---|
| **Fixed Trestle Sand Bypass** | $36 | $5.2 | 100 - 300 | • Can bypass large quantities of high-quality sand to facilitate beach accretion in Oceanside.<br>• Bypassed sand volumes could be scaled up or down based on need.<br>• Multiple pump intakes allow for flexibility in sourcing sand from surfzone/inter-tidal.<br>• Improved public safety & beach access (no pipe) | • Expensive to construct and operate.<br>• Dependent on recharge of surfzone/inter-tidal sand depressions.<br>• Requires MCB Camp Pendleton cooperation. |
| **Semi-fixed Sand Bypass** | $11M | $0.2 | 50 - 100 | • Lower capital cost to construct<br>• Bypassed sand volume could be scaled up or down based on need.<br>• Mobility of intakes allow for some flexibility in sand sourcing.<br>• Improved public safety & beach access (no pipe) | • Difficulty in designing a one-size fits all pipeline distribution system.<br>• Higher costs to operate & maintain for each event.<br>• More uncertainty in annual bypass volumes<br>• Requires MCB Camp Pendleton cooperation. |
| **Piggyback on USACE Harbor Dredging Program** | $9M | $0.2 | 50 - 100 | • Reduce mob/demob costs for sand bypassing<br>• Same equipment performs harbor dredging and bypassing<br>• Fixed pipeline benefits USACE program<br>• Improved public safety & beach access (no pipe) | • Dependent on contractor/equipment used for harbor dredging<br>• Requires MCB Camp Pendleton cooperation. |

# 12. Conclusions

Since construction of the Oceanside Harbor complex 80 years ago, the City of Oceanside and USACE have struggled to offset the erosional impacts to downdrift beaches. The current condition of South Oceanside beaches are dismal for beach recreation, with many areas having little to no dry beach during the majority of the tidal cycle. Wave events are impacting coastal infrastructure with greater frequency and severity, resulting in the need for repairs and improvements to shoreline protection systems. Projected sea level rise threatens to make these conditions worse. The primary coastal challenges are as follows:

- **Oceanside Harbor Complex blocks littoral drift.** The natural supply of coarse-gradation sand is impounded in the upcoast fillet which has formed a 400-500 foot wide dry beach along Camp Pendleton's Del Mar Beach Resort. Only a small fraction of the net longshore sediment transport volume reaches the harbor and only consists of fine-grained sediment.
- **Limited beach gains from USACE Harbor Dredging.** The timing, sediment type and placement locations are insufficient to mitigate the sediment supply deficit. The fine-grained sediment disperses low on the beach profile, providing limited dry beach.
- **Poor performance of Regional Beach Fills.** While these projects added coarse sand to a sediment starved coastline, the benefits along Oceanside beaches were short-lived. Oceanside sand moved downcoast soon after placement, accumulating in the fillet upcoast of the north groin at Agua Hedionda Lagoon.
- **Difficulty Reaching Social, Political & Regulatory Consensus**. Potential downdrift impacts, costs, environmental and recreational impacts are valid concerns that need to be addressed. Unfortunately, social, political and regulatory interests don't always align in how to address these concerns. These have been key issues in the long history of addressing coastal challenges in Oceanside.

Of the four alternatives developed and evaluated in this study, Groins scored the highest based on a multi-criteria analysis based on Technical Performance, Financial and Environmental considerations.

Groins require a larger capital expense than Beach Nourishment alone but offer the highest return on the investment with the best chance of success in providing a stable dry beach along a pilot reach of shoreline. Estimated cost per acre of beach area was \$2.8M/acre for Groins, compared to \$4.6M/acre for Beach Nourishment.

GHD recommends the Groins pilot-scale concept be advanced for further analysis, additional public/agency outreach and preliminary design to prepare for the environmental review and permitting process. Additional analysis of the groin field pilot would involve sensitivity analyses on groin length and spacing, the pre-fill volumes and sand management systems required to mitigate potential impacts.

Without having secured a significant source of high-quality sand for the City, there is limited benefit to further design and analysis of a sand bypass system. The ideal sand source for a sand bypass system is the MCB Camp Pendleton fillet despite the significant political and jurisdictional obstacles that exist.

Should that sand source become available, the Semi-fixed Sand Bypass or USACE Piggyback option should be evaluated more closely to determine the most cost-effective solution.

# 13. Next Steps

Recommended next steps are as follows:

- **Agency and Stakeholder Coordination & Engagement:**
  - Overcoming the social, political and regulatory challenges surrounding the use of sand retention structures is going to require continued coordination with key agencies and stakeholders to address concerns surrounding downdrift impacts, recreational impacts and precedent-setting type concerns. Key agencies to continue to engage include the CA Coastal Commission, Surfrider Foundation and other non-government agencies that have expressed concern.
  - Access to the sand source along the northern fillet is also a critical element in making any sand bypassing option viable. Engagement with the MCB Camp Pendleton at the appropriate level is also a key next step to securing a sustainable, high-quality source of sand and progressing sand bypassing options.
- **Further Refine Groin Design:**
  - Further engineering analysis and design of the groin concept is needed to refine the length, spacing, location, and structural details of these structures. The volume and distribution of the initial nourishment will also depend on this additional analysis and design effort.
  - Development adaptive management plan to address public, agency and stakeholder concerns about potential impacts. The plan will identify triggers where action would be taken to remedy an impact, if realized. The plan would be informed by the scientific monitoring program.
- **Enhance Beach Data Monitoring Efforts**: Beach width data is important to understand changes and base management decisions on. Establishing a baseline of data will also be useful should a sand retention pilot be constructed. The following monitoring actions are recommended:
  - Continue to support tracking of subaerial beach widths (dry beach) with the citizen science program conducted by SOS and others in coordination with SIO.
  - Annual to bi-annual, high resolution beach and nearshore SIO “Jumbo Surveys” are recommended to track the spatial and temporal changes in sand in the City. These surveys supplement the subaerial surveys and provide a greater level of detail than the existing regional transect monitoring program.
- **Develop Project Financing Strategy**: Any of the alternatives considered will require a significant amount of capital and operational expenditure. Financing strategies should be considered in concert with seeking state and federal grant funds for the Project.
- **Stay Actively Engaged in Local and Regional Sediment Management Activities:** The City should remain actively engaged in ongoing management activities and seek new sources of sand, as they become available. This recommendation works in concert with the sediment retention

project as local sediment management activities alone will lack the magnitude or quality to sustain beaches in the city.

- Continue to engage with the USACE on annual harbor dredging program activities. The timing, placement methods and locations should be discussed to see if they can be modified to increase local benefits.
- Continue to seek opportunistic sources of sand (i.e. San Luis Rey River, Buena Vista Lagoon Restoration, etc.) for beach nourishment. Maintain City's permits for the Opportunistic Beach Fill Program to streamline approval of these sand sources as they become available.
- Continue to participate in future SANDAG regional beach sand projects with consideration for different placement locations, quantities or timing within the City to increase local benefits.

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# APPENDIX A

**Data Gathering Memorandum**

## APPENDIX A

## Data Gathering Memorandum

This appendix presents a summary of the data, literature, and relevant projects that were reviewed for the City of Oceanside (City) as part of the Sand Replenishment and Retention Device feasibility study.

# 1. Local Data Review

A thorough understanding of the environmental conditions and coastal processes along the City shoreline and adjacent beaches is necessary to develop and evaluate viable solutions for shoreline erosion. The review including downloading and analyzing measured data sets for the following parameters:

- Water levels
- Winds
- Waves
- Bathymetry and topography
- Seabed surface and sub-surface conditions
- Sediment grain size.

These data are summarized in this section.

## 1.1 Hydrodynamic Data

### 1.1.1 Water Levels

The National Oceanic and Atmospheric Administration (NOAA) Center for Operational Oceanographic Products and Services (CO-OPS) maintains tide stations throughout the United States. The stations provide water level, current, and meteorological data depending upon the type of sensors installed. The nearest buoy to the project site is in La Jolla, about 24 miles south-southeast of Oceanside. Table 1-1 provides the tidal datums relative to both mean lower low water (MLLW) and North American Vertical Datum 1988 (NAVD88). This station has a significant historical data record, having been established in August 1924.

**Table 1-1. Water Levels for La Jolla (Station 9410230)**

| Datum | MLLW (ft) | NAVD88 (ft) |
|---|---|---|
| Highest Observed (11/25/2015)* | 7.81 | 7.62 |
| Highest Astronomical Tide | 7.14 | 6.95 |
| Mean Higher High Water (MHHW) | 5.32 | 5.13 |
| Mean High Water (MHW) | 4.60 | 4.41 |
| Mean Tide Level (MTL) | 2.75 | 2.56 |

| Datum | MLLW (ft) | NAVD88 (ft) |
|---|---|---|
| Mean Sea Level (MSL) | 2.73 | 2.54 |
| NAVD88 | 0.19 | 0.00 |
| Mean Low Water (MLW) | 0.90 | 0.71 |
| Mean Lower Low Water (MLLW) | 0.00 | -0.19 |
| Lowest Astronomical Tide (LAT) | -1.88 | -2.07 |
| Lowest Observed (12/171933)* | -2.87 | -3.06 |

The La Jolla tidal station also provides data on extreme water levels. Table 1-2 presents the extreme water levels for 1, 2, 10 and 100 year return periods.

**Table 1-2. Extreme Water Levels for La Jolla (Station 9410230)**

| Annual Exceedance Probability Levels | Return Period (years) | Elevation (ft, NAVD88) |
|---|---|---|
| 1% | 100 | 7.43 |
| 10% | 10 | 7.20 |
| 50% | 2 | 6.94 |
| 99% | 1 | 6.51 |

### 1.1.2 Wind

The La Jolla station identified previously has also been measuring wind continuously since April 2009. A review of this 11-year data record has revealed the predominant wind direction to be northwest with wind speeds of 3 to 10 mph (Figure 1-2). Wind speeds greater than 10mph are most frequently out of the WSW to the NW.

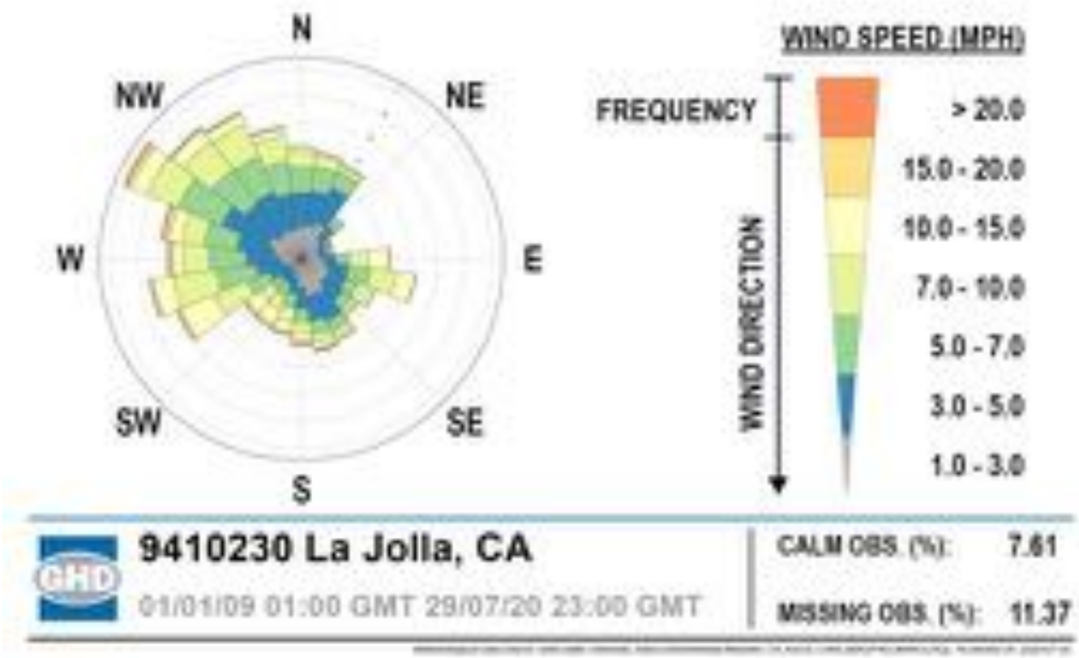


**Figure 1-1. Wind Rose for Station 9410230, La Jolla. (NOAA CO-OPS, 2020)**

### 1.1.3 Waves

Oblique waves are the primary mechanism of longshore sediment transport along the Oceanside shoreline. It is important to quantify the wave height, wave period and wave direction relative to the shoreline. Consideration of seasonal variability is also essential. Wave data from two different sources have been analyzed:

1. The USACE provides high quality wave hindcast data along United States coastlines via the Wave Information Studies (WIS) project (USACE, 2020). The wave climate is predicted using observed wind fields and spectral wave models to provide hourly, long-term wind and wave data. Station 83105 is located offshore of the Project Area at a water depth of 824m (2,700ft) and the results are provided based on a 32-year wave hindcast (1980 – 2011). A wave rose is presented in Figure 1-4, and extreme value analysis identifying design wave heights for various return periods in Figure 1-5. Based on this figure, the 100-year design offshore wave height is approximately 22.5ft.

2. The Coastal Data Information Program (CDIP) maintains a wave buoy offshore of Oceanside. Station 045 is located at a water depth of 238m (780ft) and provides a continuous measured dataset from May 1997 through to present day. An extreme value analysis is presented in Figure 1-6, and indicates the 100 year design offshore wave height is in excess of 19ft. A wave rose is also presented in Figure 1-7.

The locations of both data sources is presented in Figure 1-3.

The most notable difference between the two sources is the wave direction. Both wave roses in Figure 1-4 and Figure 1-7 indicate larger wave heights are from the west; however, the direction with highest frequency of occurrence differs. The WIS data suggests westerly waves occur most frequently while the CDIP buoy measured southerly waves most often. It is recommended more value be placed on the CDIP data given this is a real-time measured dataset, as opposed to a hindcast prediction, and is determined at a location closer to the project shoreline.

The effect of seasonality and wave climate has been explored further via the preparation of wave roses for various criteria on the CDIP data from 2000 to 2020. Common trends evident include:

- Large, mid to long period waves occur from the west during winter and early spring
- Small, long period waves occur from the south throughout the year but particularly in fall, summer and spring
- Short period waves occur almost exclusively from the west

Additional information is presented in Section 2.3.3.


**Figure 1-2. Wave Data Locations**


**Figure 1-3. Wave Rose for WIS Station 83105 (1980-2011)**

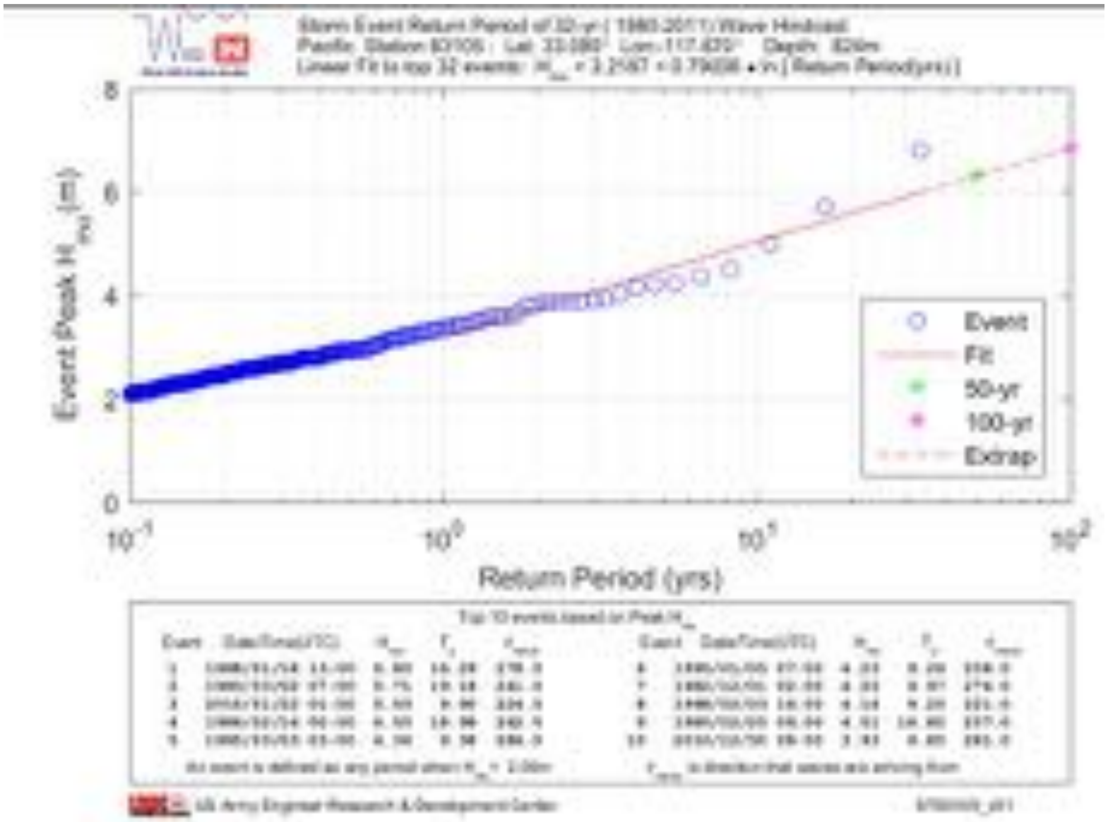


**Figure 1-4. Extreme Wave Analysis 1980-2011 (WIS Station 83105)**

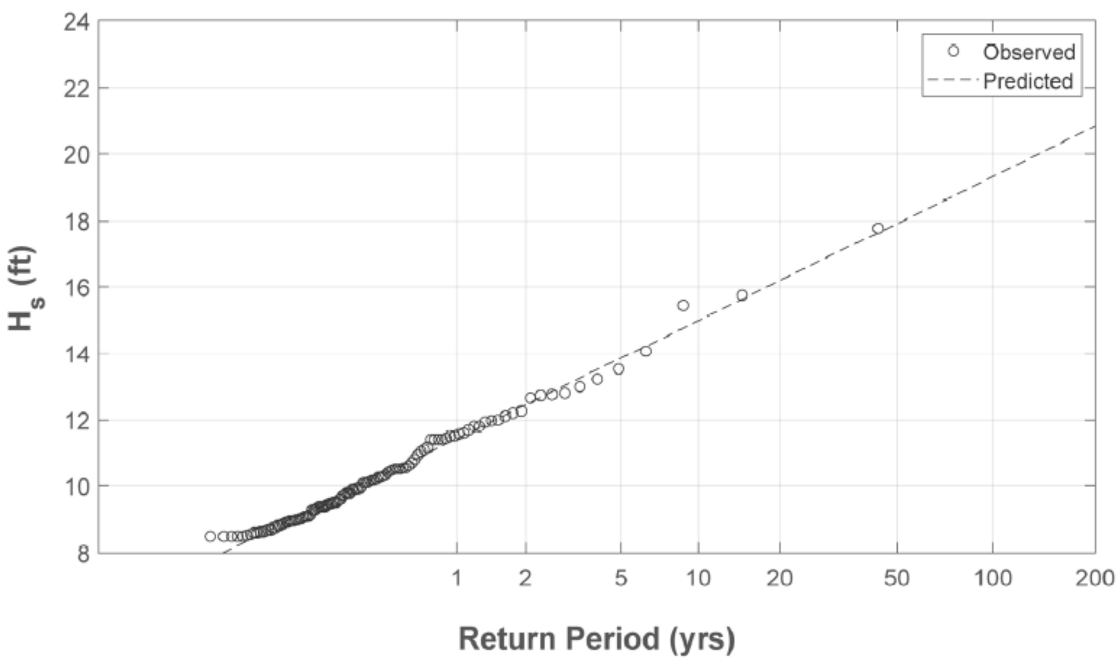


**Figure 1-5. Extreme Wave Analysis 1998-2019 (CDIP Station 045) (CFC, 2019)**

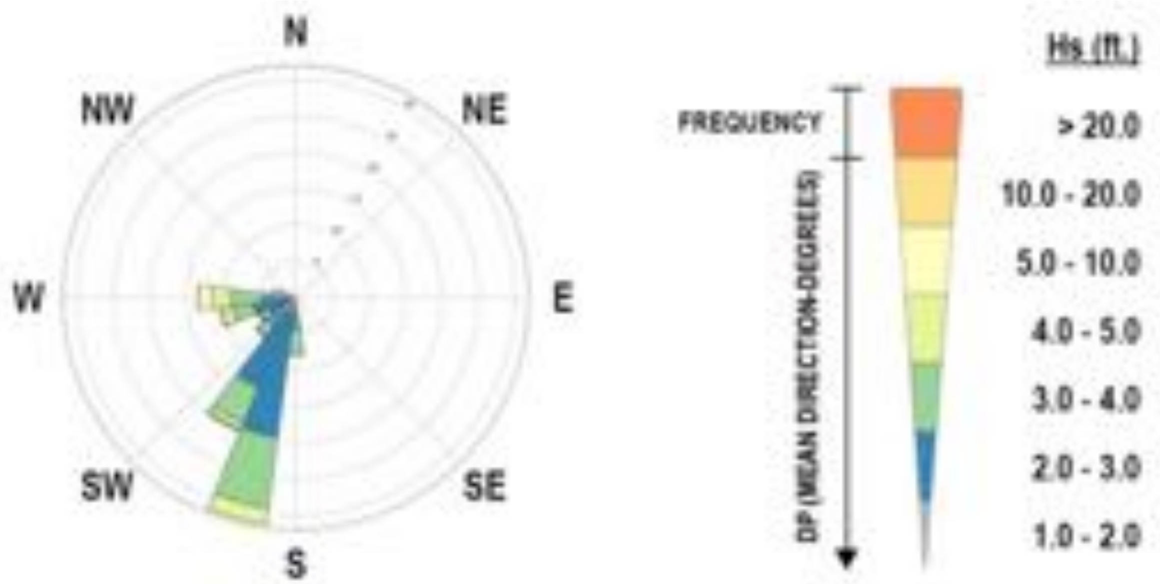


**Figure 1-6. Wave Rose for CDIP Station 045 (2000-2020)**

### 1.1.4 Currents

According to the USACE Hydraulic Model Study (WES, 1980; USACE, 1989), wave-induced current patterns were determined at Oceanside Harbor with the use of dye tracers. It was found that northwest and west swell produced southerly longshore currents along the north breakwater, harbor entrance and past the San Luis Rey river groin (aka South Jetty) (Figure 1-8). Waves approaching from the southwest produced northerly longshore currents along the seaward end of the north breakwater. The mean seasonal offshore current velocities are estimated to range from 5 cm/s to 40 cm/s and variations due to tidal influx are estimated to have peak current velocities of 20 cm/s (USACE, 1994). Note that only moderate wave heights (i.e. 10-foot) with short periods (i.e. < 9 sec) were analyzed in this study.

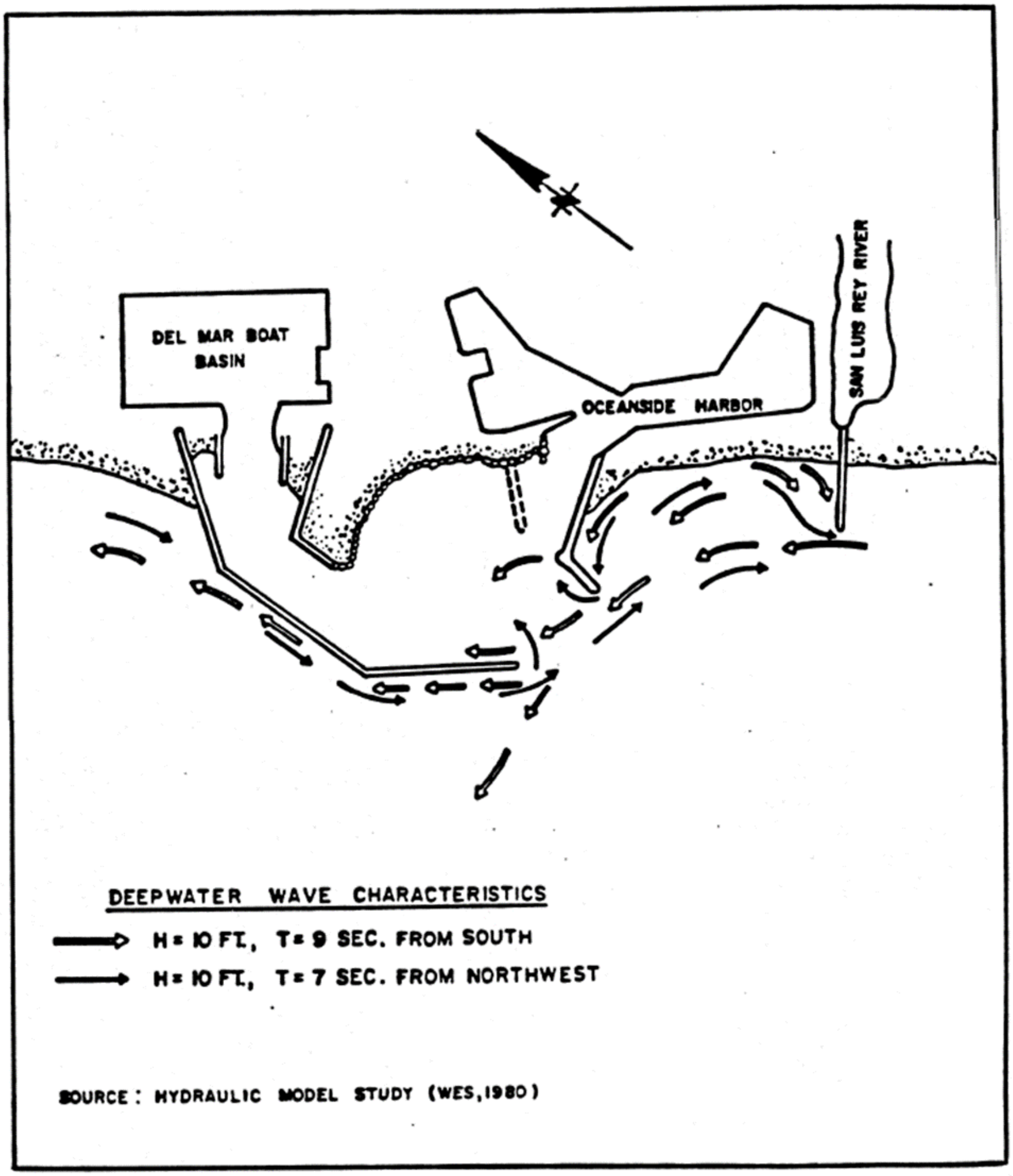


**Figure 1-7. Wave-Induced Current Patterns (WES, 1980; USACE, 1989)**

## 1.2 Elevation Data

### 1.2.1 Bathymetry

A number of publicly available elevation data sets are available for Oceanside and were utilized for this study. The elevation data downloaded is listed in Table 1-3. It should be noted that datasets have spatial coverage limitations and vary in resolution.

**Table 1-3. List of Bathymetric Data Sources**

| No. | Name / Source | Notes (spatial coverage, resolution) | Date of Survey |
|---|---|---|---|
| 1 | 2016 USGS CoNED Topobathymetric Model (1930-2014) | Dataset extends offshore to 2,847 meters<br>1-meter spatial resolution | 03/03/1930 to 12/31/2014 |
| 2 | 2016 USGS Lidar DEM | Coverage extends 400 to 500 ft offshore. | 04/28/2016 to 05/28/2016 |
| 3 | 2014 USACE NCMP Topobathy Lidar | 1-meter grid resolution | 09/08/2014 to 10/05/2014 |
| 4 | 2014 USCAE NCMP Topobathy Lidar DEM | Dataset extends offshore approx. 1000 meters | 09/08/2014 to 10/05/2014 |

### 1.2.2 Topography

The most recent publicly available topographic data for Oceanside is listed in Table 1-4. It should be noted that datasets have spatial coverage limitations and vary in resolution.

**Table 1-4. List of Topographic Data Sources**

| No. | Name / Source | Notes (spatial coverage, resolution) | Date of Survey |
|---|---|---|---|
| 1 | 2016 USGS Lidar | Coverage extends approximately to the high tide line.<br>0.35 meter spatial resolution | 04/28/2016 to 05/28/2016 |
| 2 | 2016 USGS Lidar DEM | Coverage extends 400 to 500 ft offshore. | 04/28/2016 to 05/28/2016 |
| 3 | 2016 USGS CoNED Topobathymetric Model (1930-2014) | -Dataset extends offshore to 2,847 meters<br>-1-meter spatial resolution | 03/03/1930 to 12/31/2014 |
| 4 | 2014 USACE NCMP Topobathy Lidar | 1-meter grid resolution | 09/08/2014 to 10/05/2014 |
| 5 | 2014 USCAE NCMP Topobathy Lidar DEM | Dataset extends offshore approx. 1,000 meters | 09/08/2014 to 10/05/2014 |

## 1.3 Sediment Transport

### 1.3.1 Sediment grain size characteristics

Oceanside's shoreline was characterized in a Sampling Analysis Plan Results Report (SAPR) prepared for the USACE (M&N 2016). The reaches used in this analysis are presented in Figure 1-9 and the results are summarized in Table 1-6. All sediment samples were described as a poorly graded sand and silty sand. The coarsest sediment was found in sub-aerial samples while the finest sediment appear to be located offshore and in close proximity to the harbor entrance.

**Table 1-5. Oceanside Sediment Characteristics (M&N, 2016)**

| | Reach | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sediment Characteristics | A | B | C | D | E | F | G | Santa Margarita |
| $D_{50}$ Range (mm) | 0.1 to 0.5 | 0.1 to 0.4 | 0.1 to 0.3 | 0.1 to 0.3 | 0.1 to 0.2 | 0.1 to 0.2 | 0.1 to 0.2 | 0.1 to 0.2 |
| % Fines | 0.6 to 54.7 | 0.7 to 64.2 | 0.4 to 67.6 | 0.4 to 73.3 | 0.7 to 79.6 | 1.2 to 53.9 | 1.4 to 78.9 | 1.0 to 77.7 |

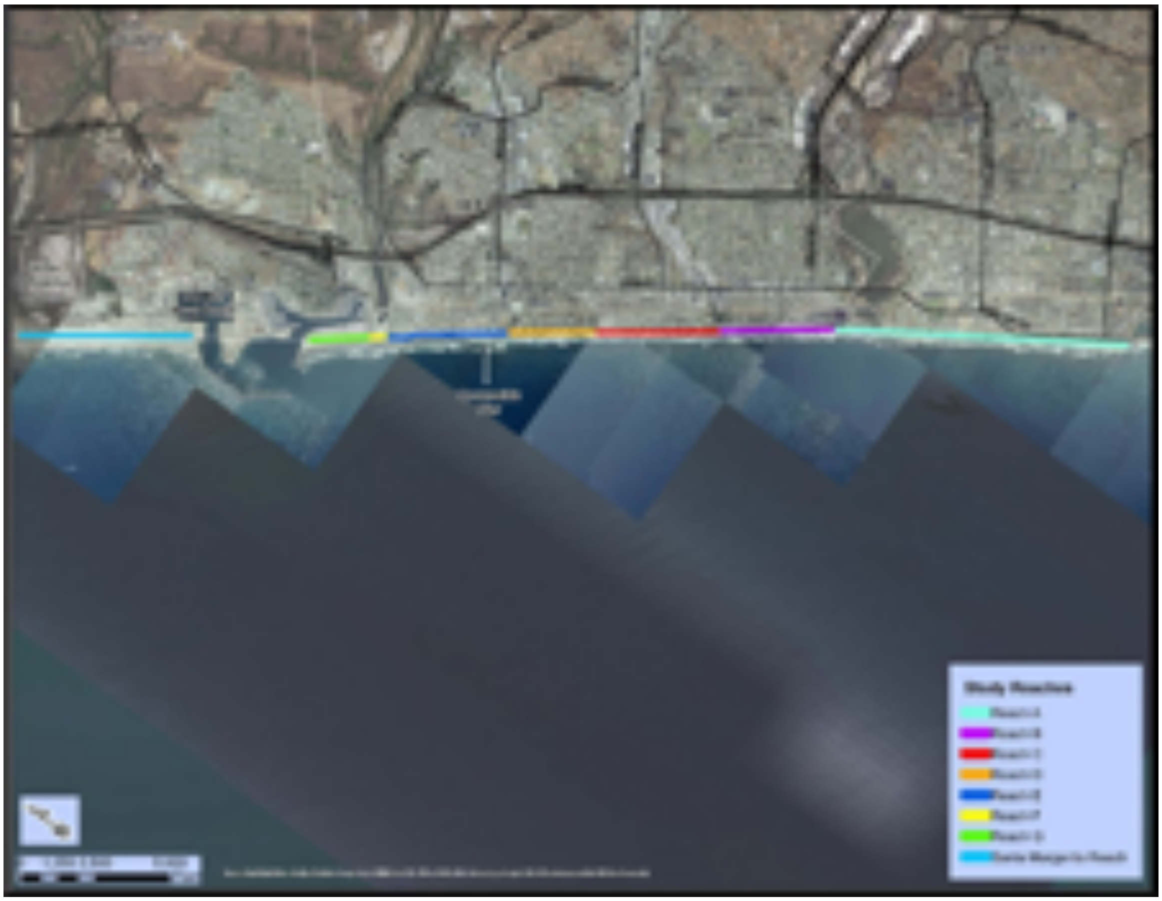

**Figure 1-8. 2016 SAPR Shoreline Reaches (M&N, 2016)**

### 1.3.2 Offshore Sediment Resources

Vibracore samples were collected at locations offshore of Oceanside Harbor in 1999, as presented in Figure 1-10, to determine whether the site was a viable offshore borrow area for a beach nourishment project. The seabed surface and subsurface at offshore borrow site SO9 was found to have a 12" sandy silt layer on the surface, followed by a 3' to 23' fine to medium grained sand layer, and a fine grained silty sand layer below the sand layer. Additionally, a geophysical survey in 1999 revealed eight quarry rock artificial reef habitats within site SO9 (Sea Surveyor, Inc., 1999). A cross section is shown in Figure 1-11.

To the immediate south, offshore borrow site SO8 was found to have a surficial silty fine grained sand layer that ranged from 4’-13’ thick, followed by a fine grained sand that was 6’-25’ thick. Four piles of artificial reef remains were found on the seafloor at this site. A cross section is shown in Figure 1-12.

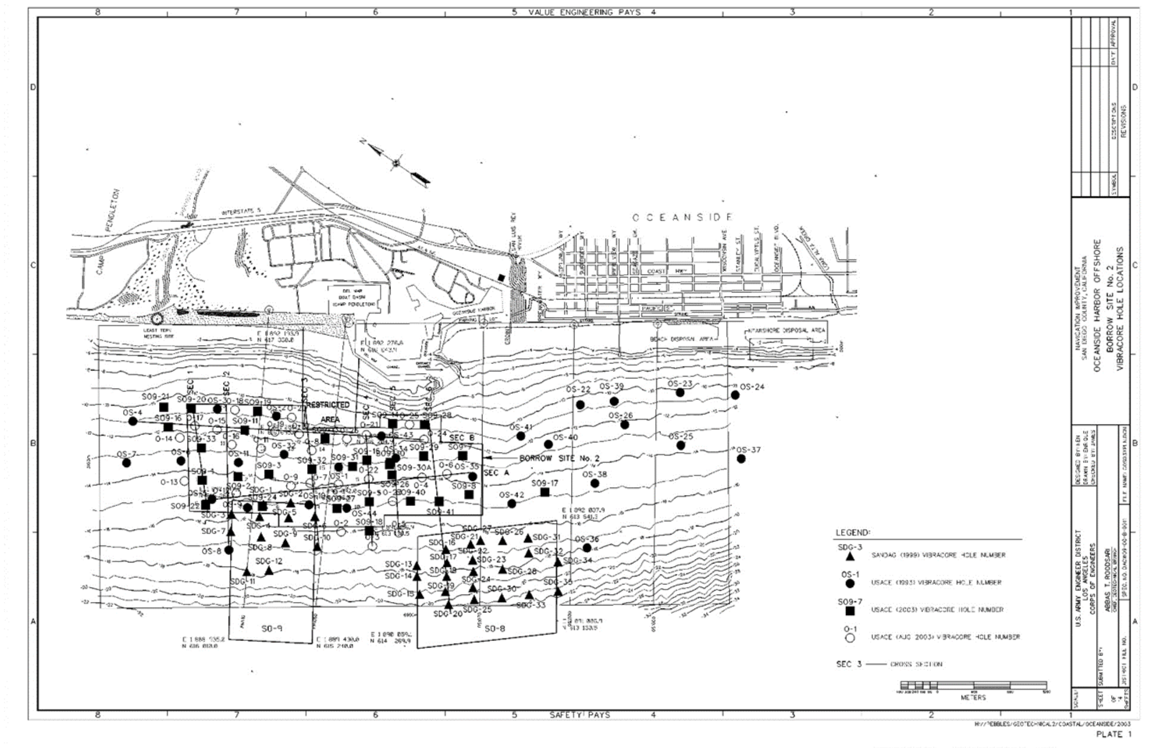


**Figure 1-9. Vibracore Sampling in Oceanside (M&N, 2016; USACE, 2011)**

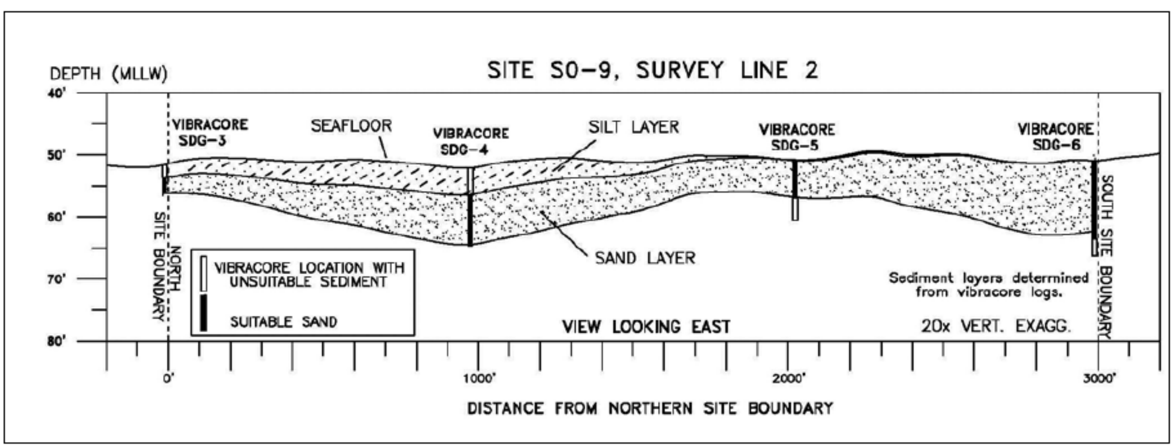


**Figure 1-10. Typical Cross Section at Site SO9 (Sea Surveyor, Inc., 1999)**

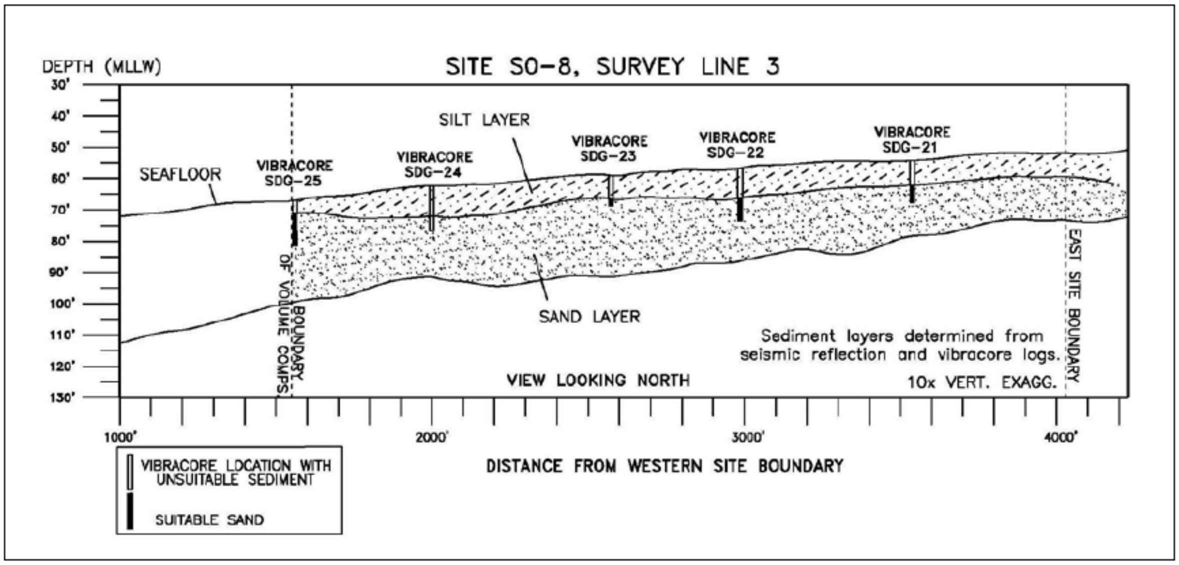


**Figure 1-11. Typical Cross Section at Site SO8 (Sea Surveyor, Inc., 1999)**

### 1.3.3 Longshore Transport

The net longshore currents for Oceanside are understood to be southern, although seasonal variations are common and depend on the swell direction. During the summer, long period swells directed from the south produce a northern current. Northwesterly swells in the winter produce southern currents. The gross southern transport typically exceeds the northern transport on an annual basis. There are numerous estimates of the longshore sediment transport for the City and within the Oceanside littoral cell, as shown in Table 1-7. There is general agreement amongst the sources provided that Oceanside experiences a net sediment transport to the south of 100,000 to 200,000 cubic yards (cy) per year.

**Table 1-6. Longshore Sediment Transport Estimates in the City**

| Location | Estimated Gross Northern Transport Rate (cy/yr) | Estimated Gross Southern Transport Rate (cy/yr) | Estimated Net Southerly Longshore Transport Rate (cy/yr) | Source |
|---|---|---|---|---|
| Oceanside Littoral Cell | 545,000 | 760,000 | 215,000 | Marine Advisors (1961) |
| | NA | NA | 250,000 | Inman (1976) |
| | 550,000 | 740,000 | 194,000 | Hales (1979); Inman & Jenkins (1985); Dolan et al. (1987) |
| Oceanside Harbor Southside | 934,000 | | 106,000 | USACE, (1991); Tekmarine, Inc., (1978) |
| Oceanside | NA | NA | 146,000 | Patsch & Griggs, 2006 |
| Oceanside | 553,000 | 807,000 | 254,000 | Inman & Jenkins (1983) |

| Location | Estimated Gross Northern Transport Rate (cy/yr) | Estimated Gross Southern Transport Rate (cy/yr) | Estimated Net Southerly Longshore Transport Rate (cy/yr) | Source |
|---|---|---|---|---|
| Oceanside | 541,000 | 643,000 | 102,000 | Hales (1978) |
| Oceanside | NA | NA | 175,000 | USACE, 2016 |

### 1.3.4 Cross Shore Transport

Cross-shore sediment transport within the Oceanside littoral cell is estimated to range from 26,000 to 113,000 cy/year (USACE, 1991). These currents predominantly exist during high energy storm events and will most likely be concentrated at creek mouths and around structures USACE (1994).

It is also hypothesized that the Oceanside Harbor structure produces cross shore currents capable of transporting sediment offshore (USACE, 1991). After construction of the harbor, an average of 146,000 cy/year to 440,000 cy/year was found to accumulate in the offshore vicinity of the harbor (Tekmarine, 1987; USACE, 1991).

The closure depth (i.e. depth at which the bathymetry remains unchanged over time) for the Oceanside shoreline provides insight to the range of sediment fluctuation between the nearshore and offshore region. Estimates of closure depth from SANDAG's Regional Beach Monitoring Program data set is presented in Table 1-8 from seven beach profile transects within the City. These beach profile transects are shown in Figure 1-13. The average depth of closure in the City is 22.4 feet below MLLW.

**Table 1-7. Depth of Closure Estimates for Oceanside (Coastal Frontiers, 2019)**

| Beach Profile Transect | Location | Depth of Closure (ft, MLLW) |
|---|---|---|
| OS-0900 | Saint Malo, Oceanside | -24 |
| OS-0915 | Caissdy Street, Oceanside | -22 |
| OS-0930 | Buccaneer Beach, Oceanside | -25 |
| OS-0947 | Crosswaithe | -23 |
| OS-1000 | South Strand, Oceanside | -21 |
| OS-1030 | North Strand, Oceanside | -21 |
| OS-1070 | Oceanside Harbor Beach | -21 |
| **Average** | **-** | **-22.4** |


**Figure 1-12. Regional Beach Monitoring Program Transect Locations**

# 2. Literature Review

## 2.1 Existing Studies

### 2.1.1 USACE Sand Diego Coastal Storm and Tidal Waves Study (1991)

This study defines the oceanographic, geological and economic factors that have affected the beaches within the San Diego region. In regards to the Oceanside sub-reach, this study defines three events that have affected the shoreline during the study period. The first event is the construction of the harbor which began in 1942 and was completed in 1963, in which an erosion rate of 4 ft/year was observed along beaches south of the harbor following construction. The second event covers the nourishment projects from 1960 to 1980, where beaches south of the Oceanside harbor displayed patterns of accretion. The volumes of sand placed were large and regular, often in the order of hundreds of thousands of cy annually, although there was one large event in 1963 where approximately 3.8 million cy were placed on Oceanside. The third event relates to storms between 1978 and 1988. During this time, beaches in Oceanside displayed erosion rates ranging from 4ft/year to 33 ft/year. The shoreline change for all three events is shown in Figure 2-1.

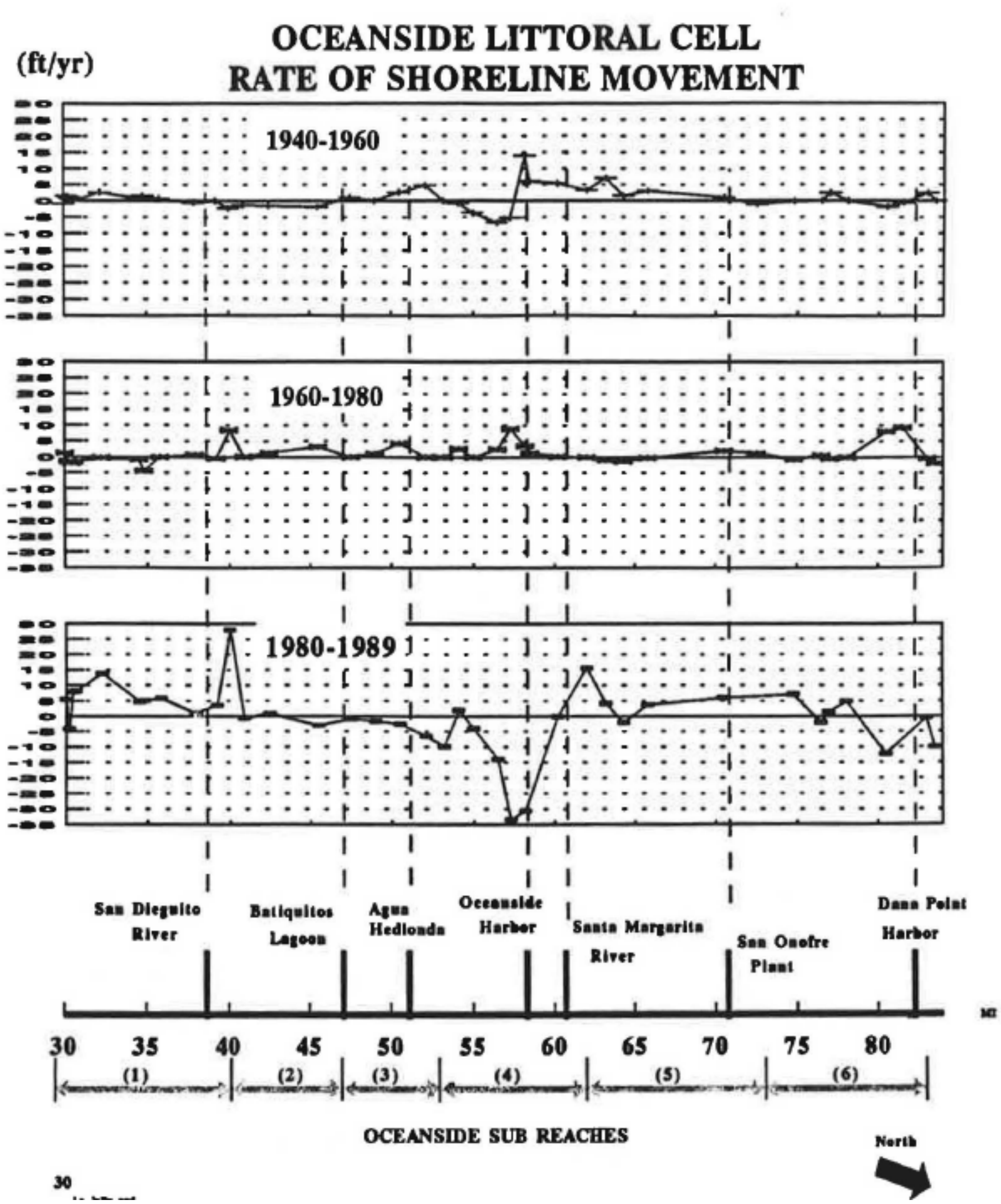


**Figure 2-1. Shoreline Change for the Oceanside Littoral Cell (USACE, 1991)**

### 2.1.2 USACE Oceanside Shoreline Feasibility Study (2016 - ongoing)

Important

The purpose of this study was to evaluate and characterize the coastal processes along Oceanside's beaches while also investigating possible erosion mitigation actions/projects. The study area was divided into eight reaches, from the northern tip of the Oceanside Harbor to the Agua Hedionda Lagoon (Figure 2-2). Shown in Figure 2-3, the beach north of the harbor remains relatively stable and the beaches south of the harbor display high rates of erosion. Accretion is evident adjacent to both the harbor structure and the San Luis Rey groin, giving further evidence to the bimodal nature of longshore erosion at Oceanside.


**Figure 2-2. Study Area (USACE, 2016)**

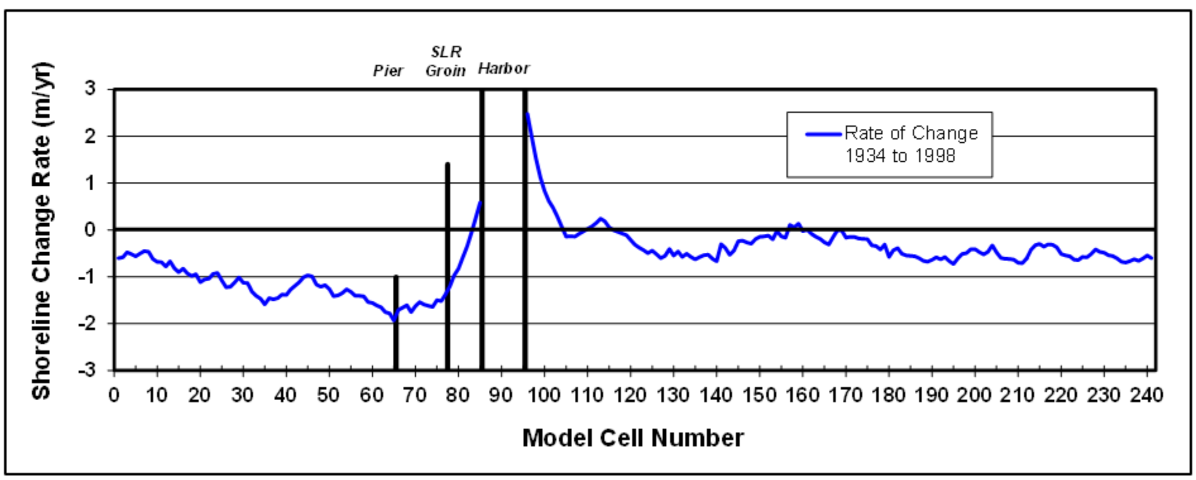


**Figure 2-3. Rate of Beach Change from 1934 to 1998 (USACE, 2016)**

This study evaluated nine action alternatives that included managed retreat, flood proofing, beach nourishment, revetment or seawall, groin field, harbor bypass, and use of O&M dredged material. Some of these options would need to be implemented in conjunction with others to be effective. The action alternatives evaluated in this study are provided in Table 2-1.

**Table 2-1. Action Alternatives Analyzed in USACE 2016**

| Alternative | Description |
|---|---|
| 1 | Beach Nourishment with Harbor Condition |
| 2 | Beach Nourishment with Managed Retreat |
| 3 | Beach Nourishment with Floodproofing |
| 4 | Beach Nourishment with Revetment |
| 5 | Beach Nourishment with Seawall |
| 6 | Beach Nourishment with Groins |
| 7 | Beach Nourishment with Harbor Bypass |
| 8 | Beach Nourishment with O&M Dredged Material |
| 9 | Beach Nourishment without Harbor Condition |

These options were screened based on completeness, effectiveness, efficiency, and acceptability. Completeness refers to the extent that an alternative provides, accounting for investments and actions required to achieve the projects goals. Effectiveness is defined as the extent to which a plan achieves its objectives. Efficiency refers to the provided net benefits and acceptability refers to an alternatives alignment with federal law and policy. It also considers real estate issues, operations, maintenance, monitoring and sponsorship.

The preliminary screening process revealed the best alternative solutions to be Alternative 1: Beach Nourishment with Harbor Condition, Alternative 6: Beach Nourishment with Groins and Alternative 9: Beach Nourishment without Harbor Condition.

The next stages of this study are to further evaluate the final array of alternatives and then to select and recommend a plan. This study is awaiting funding for completion.

### 2.1.3 USACE Oceanside Shoreline Reconnaissance Report (1994)

This study divides the shoreline of Oceanside in five (5) reaches for analysis (Figure 2-4). Reach 1 has shown patterns of accretion and stability in the past (1972 to 1989), possibly as a result of the deposition from the San Luis Rey River Mouth and south groin. Reach 2 has been characterized as erosional, about 3.5 feet per year from 1972 to 1989. Reach 3 displays very similar patterns of erosion to that of reach 2, eroding 3 feet per year from 1972 to 1989. Reaches 4 and 5 displayed an erosion rate of 2.5 and 2 feet per year; respectively.

The projected sediment budget for Oceanside is shown in Figure 3-5. The longshore transport rate is estimated to be 270,000 cy/yr in a southerly direction. About 30 cy/yr is lost in the cross-shore direction while the San Luis Rey River provides around 10,000 cy/yr of sediment to the system. Additionally, 100,000 to 200,000 cy/yr is deposited at the harbor entrance, which is dredged annually and redistributed along the beach.

The predominant sediment sources for Oceanside include the San Luis Rey River, sediment transported from north of the Harbor, and dredging of the harbor entrance. The sediment sinks include sand deposited within the harbor, sand lost to the south, and sand lost offshore. The net sand volume change in the City has been estimated to be a loss of 90,000 cy/yr.

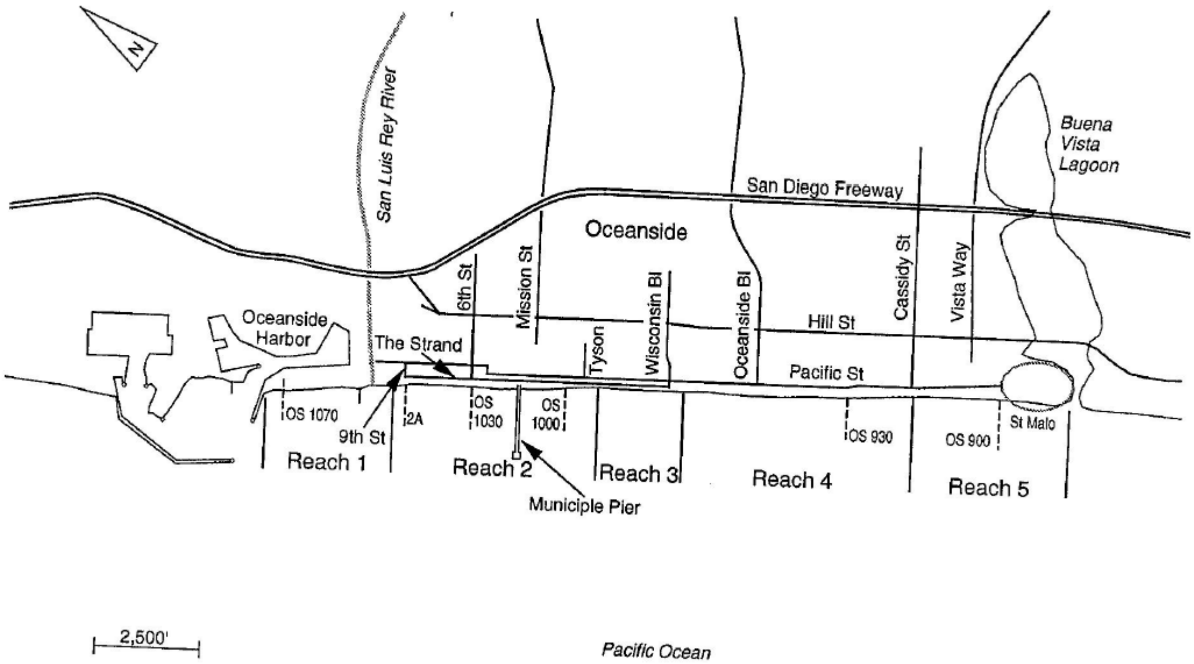


**Figure 2-4. Defined Study Reaches (USACE, 1994)**

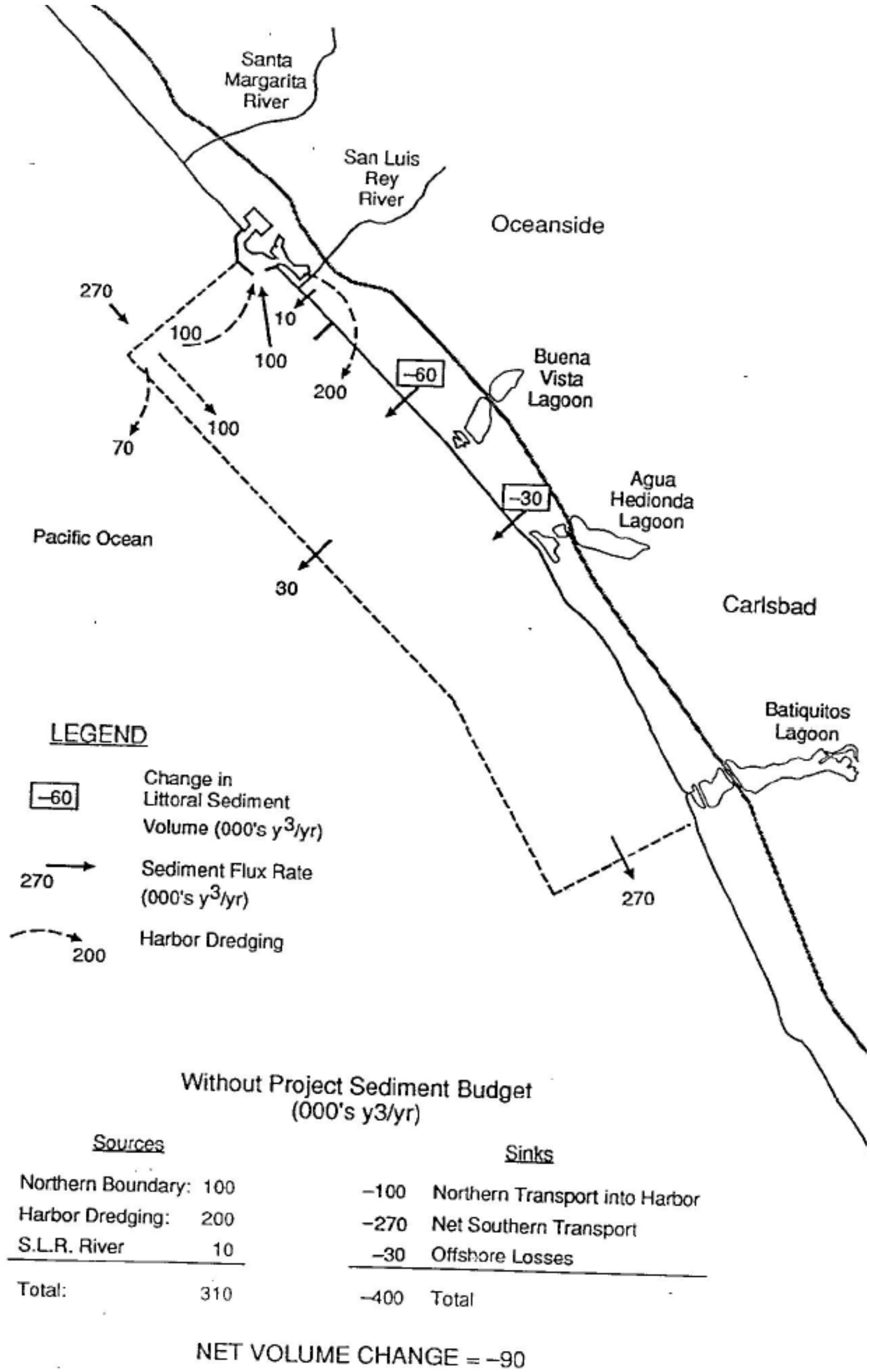


**Figure 2-5. Projected Sediment Budget for Oceanside (USACE, 1994)**

### 2.1.4 City of Oceanside Sea Level Rise Vulnerability Assessment & Adaptation Plan (2018)

The City of Oceanside assessed its coastal assets using four sea level rise (SLR) scenarios:

- 0.8ft by 2025-2045
- 1.6ft by 2040-2070
- 3.3ft by 2070-2100
- 5.7ft by 2100-2140

Five potential hazard zones were mapped, with the following outcomes observed:

(1) Potential ocean water levels with beach erosion – predominantly affecting the low-lying areas adjacent to the San Luis Rey River, Loma Alta Creek, and the Buena Vista Lagoon.

(2) Potential coastal flooding and waves – predicted to impact the infrastructure and coastline nearest to the San Luis Rey River mouth and the Loma Alta Creek river mouth.

(3) Potential coastal and riverine flooding – predominantly affecting the low-lying areas adjacent to the San Luis Rey River, Loma Alta Creek, and the Buena Vista Lagoon.

(4) Potential coastal flooding wave runup – predicted to impact the coastline and infrastructure on the western side of the railroad and north of the Buena Vista Lagoon, as well as the Strand south of the pier and coastline south of Oceanside Harbor. In addition, over-flooding of wetlands could lead to mudflats and the loss of critical species habitats such as the Coastal California Gnatcatcher, Least Bell's Vireo and South-western Willow Flycatcher.

(5) Potential development erosion – The Small Craft Harbor and 15 recreational buildings that are in close proximity to the harbor are expected to experience more regular flooding. The Oceanside harbor, jetties and breakwater, and pier may experience flooding along with increased erosion of the structures. The homes clustered around the Buena Vista Creek and the Oceanside harbor are most at risk to the effects of SLR.

### 2.1.5 San Diego Regional Beach Sand Monitoring Program (CFC, 2019)

SANDAG began the Regional Shoreline Monitoring Program in 1996 to measure the changes in beach width over time and document the sand replenishment projects in San Diego. Beach profile data is collected biannually along the coastline of San Diego County. The monitoring program data was valuable for the design of the RBSP I and II projects (SANDAG, 2019).

As can be seen in Figure 2-6, the 2020 beach width and shorezone volume for Oceanside has dropped below the post-RBSP I and II levels. From 2000 to 2020, the average shorezone volume displays a net loss of sediment for the region.

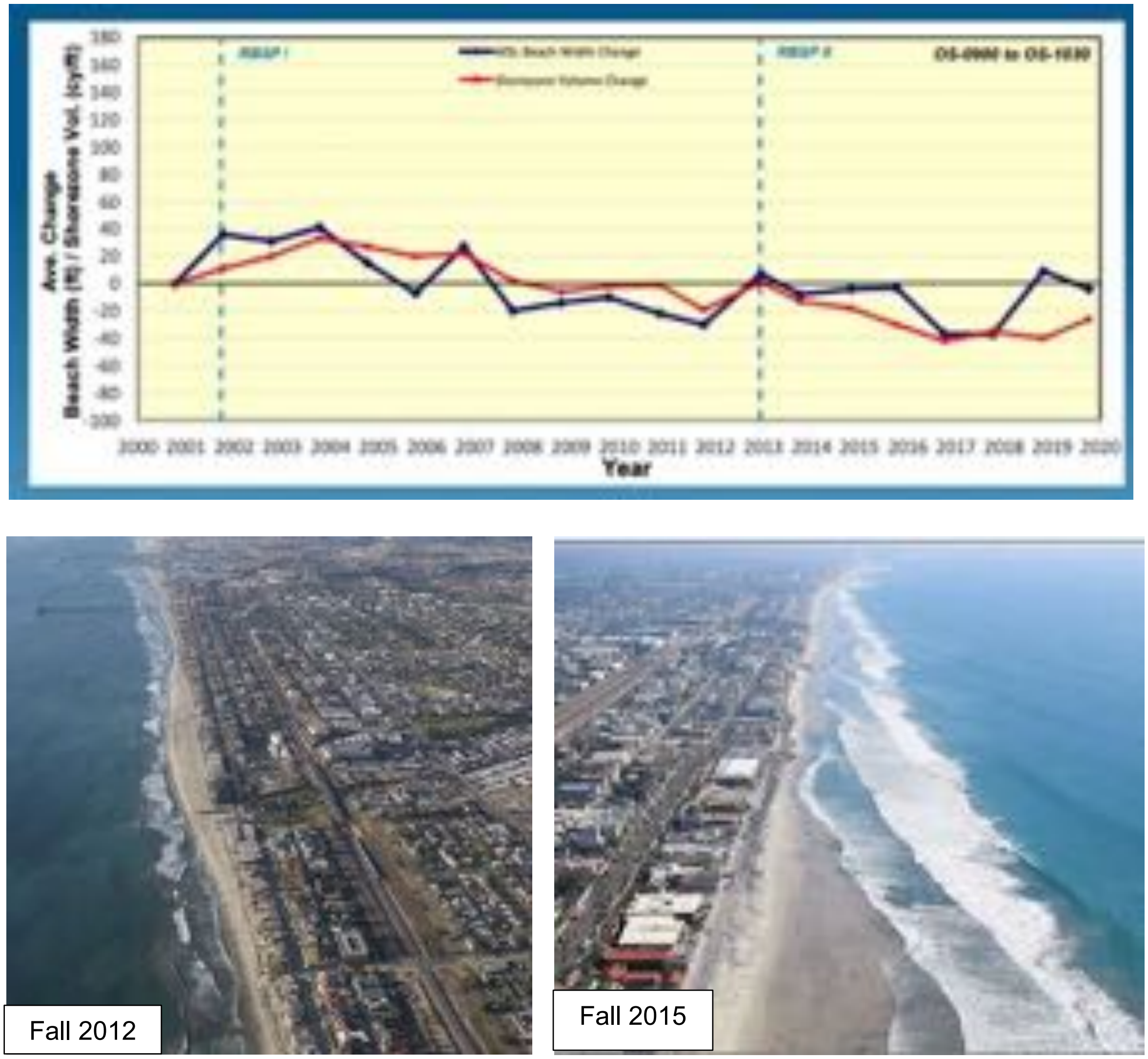


**Figure 2-6. Average Beach Width and Shorezone Volume for Oceanside (CFC, 2020)**

## 2.2 Prior Projects

### 2.2.1 Regional Beach Sand Projects I and II

In 2001, the RBSP I placed a total of 2 million cy of sand onto 12 beaches within San Diego County. The majority of this beach fill sediment was placed among 10 beaches within the Oceanside littoral cell. These 10 beaches received 1.8 million cy and Oceanside Beach alone received 421,000 cy. The median grain size of the material placed in Oceanside was a coarse sand (0.62mm) (Coastal Frontiers, 2019; Noble Consultants, 2001).

In 2012, the RBSP II placed a total of 1.5 million cy of sand onto eight beaches in San Diego County. Approximately 1 million cy was placed in the Oceanside littoral. Oceanside received 292,000 cy of sand between Buccaneer Beach and Hayes Street. The median grain size of the sand placed in Oceanside was a coarse sand (0.54mm) (Coastal Frontiers, 2019; Webb, 2013).

Since the RBSP I and II, the Oceanside shoreline has shown episodic periods of accretion but continue to follow a pattern of erosion. By 2008, the average shoreline position had retreated below the Pre-RBSP I shoreline levels. The RBSP II nourishment in 2012 increased the shoreline width and volume to Pre-RBSP I conditions. However, the net accretion trend has continued and Oceanside currently has a sediment deficit.

### 2.2.2 Buccaneer Beach Ocean Outfall

As part of the La Salina Wastewater ocean outfall pipeline construction, rock was placed shore-perpendicular to protect the shallow pipeline at Buccaneer Beach. An aerial showing the extent of the structure in 1971 is shown in Figure 2-7. In function and in design, the protective rock and pipeline acted similar to a groin and offers site-specific empirical evidence of shoreline response. A small fillet of sand is observed on the south side of the ocean outfall structure during an observed south swell. Although a date of the image could not be confirmed, given the wave conditions, the aerial is presumed to be taken during the south swell season of April-October. The emergent pipeline depicted was replaced relatively quickly with a pipeline that went underground through the beach and surfzone and emerged on the seafloor in the nearshore.

**Figure 2-7. Buccaneer Beach Rock Protected Ocean Outfall in 1971 (Moffatt and Nichol, 2001)**

### 2.2.3 Oceanside Harbor Experimental Sand Bypassing Pilot Project

Constructed in 1985 and operating from 1989 to 1992, the sand bypassing system utilized an array of fixed jet pumps, fluidizers, and a portable jet pump system (Figure 2-8) (Moffatt and Nichol, 1982; Boswood & Murray, 2001). The system was designed to pump 2,000-3,000 cy/day with a net discharge of 350,000 cy annually (Moffatt and Nichol, 1982 USACE, 1996). Accounting for seasonal variations in longshore sediment transport patterns, approximately 200,000 cy of sand was proposed to be pumped from the channel entrance in the summer months and 150,000 cy of sand from the northern fillet in the winter months (USACE, 1995; USACE, 1996).

This project ultimately had a multitude of issues revolving around maintenance of the pumps and inadequate funding. With an estimated total cost of $5 million and an actual cost of $15 million, only the first two phases of the project were completed (Boswood & Murray, 2001). Phase one consisted of basic installations and phase two covered the installation of two crater fill fluidizers and two jet pumps at the main channel entrance (USACE, 1996). The overall performance of the sand bypassing system is summarized in Table 2-2.

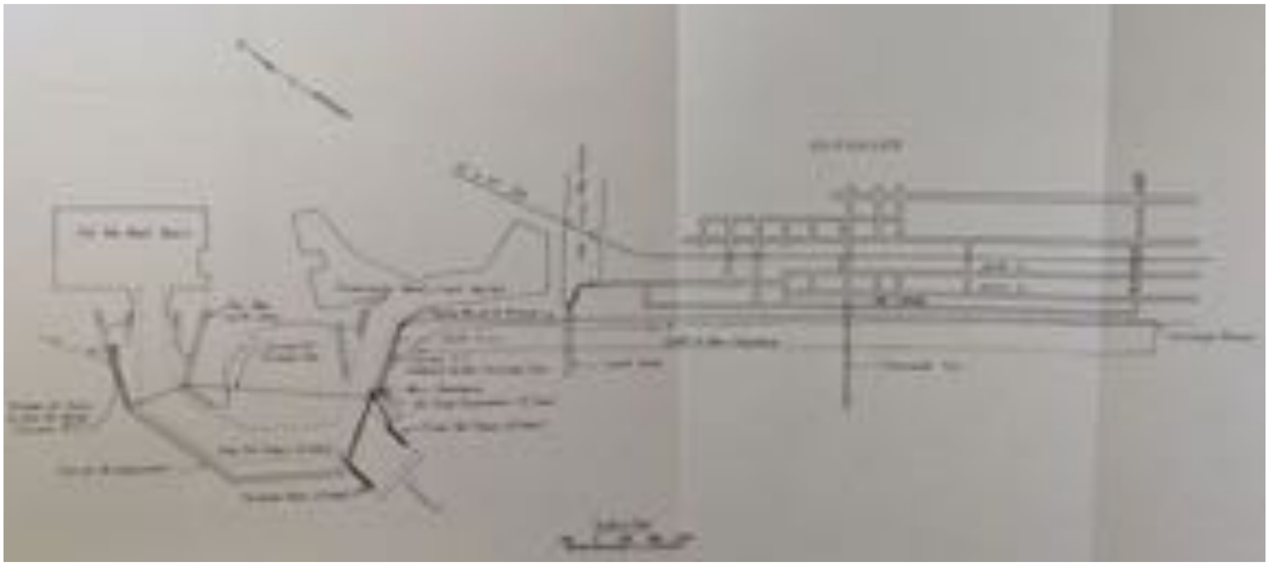

**Figure 2-8. Experimental Bypass System Schematic (Moffatt & Nichol, 1982)**

**Table 2-2. Sand Bypassing Performance (Boswood & Murray, 2001)**

| Phase | Date | Total Operating Hours | System Downtime and Maintenance Hours | Averaged Bypassing Rate | Total Bypassed |
|---|---|---|---|---|---|
| Phase I | June 1989 to August 1990* | 744 | - | 63 cy/hr | ~18,300 cy |
| Phase II | December 1991 to December 1992 | 1,128 | 607 | 95 cy/hr | 106,000 cy |

*Excludes January 1990 to April 1990

## 2.3 Ongoing Projects and Programs

A summary of ongoing coastal management programs and projects were reviewed for potential opportunities to integrate Project needs with ongoing efforts.

### 2.3.1 USACE Harbor Dredging Program

Sand is dredged annually from the Oceanside Harbor entrance channel via a cutterhead suction dredge, transported south in a slurry via a pipe, and placed on City beaches. Dredged sediment is discharged onto intertidal portions of the beach and dozers, located downdrift of the discharge, scrape material up from the intertidal to the foreshore or dry beach (Figure 2-9). The gradation of the sediment dredged from the harbor entrance for six years between 2012 and 2020 is shown in Table 2-3. Samples taken at the placement sites revealed the dredged sediment to be mainly fine sands, with a mean median grain size ($D_{50}$) between 0.11 mm and 0.18 mm. Samples were classified predominantly as poorly graded, silty-sand (Smith-Emery Laboratories, 2020). The specific sand placement locations and volumes vary by year based on a variety of factors. The annual dredged sediment quantities from 1942 to 2021 for the Oceanside Harbor are shown in Table 2-4.


**Figure 2-9. Harbor Channels and Typical Discharge Locations**

**Table 2-3. 2012-2020 Sieve Analysis Data Summary (Smith-Emery Laboratories, 2020)**

| 2012-2020 Harbor Dredging | Year | | | | | |
|---|---|---|---|---|---|---|
| USCS Gradation | 2020 | 2018 | 2017 | 2014 | 2013 | 2012 |
| Mean % Gravel | 0.0 | 0.0 | 0.98 | 0.0 | 0.0 | 0.0 |
| Mean % Sand | 94.5 | 95.1 | 95.7 | 93.6 | 94.2 | 96.3 |
| Mean % Fine | 5.52 | 4.90 | 3.37 | 6.37 | 5.80 | 3.7 |
| Mean $D_{50}$ | 0.13 | 0.12 | 0.18 | 0.11 | 0.14 | 0.13 |

**Table 2-4. Harbor Dredging Quantities for Oceanside Harbor (M&N 1982; USACE, 1991; Coastal Frontiers, 2018)**

| Year | Dredge Quantity (cy) | Year | Dredge Quantity (cy) |
|---|---|---|---|
| **1942-1944** | 1,500,000 | **1997** | 130,000 |
| **1945** | 219,000 | **1998** | 315,000 |
| **1957-1958** | 800,000 | **1999** | 187,000 |
| **1960** | 41,200 | **2000** | 327,000 |
| **1961** | 481,150 | **2001** | 80,000 |
| **1962-1963** | 3,810,700 | **2002** | 400,000 |
| **1965** | 111,400 | **2003** | 438,000 |
| **1966** | 684,000 | **2004** | 220,000 |
| **1967** | 177,900 | **2005** | 275,000 |
| **1968** | 433,900 | **2006** | 228,000 |
| **1969** | 353,000 | **2007** | 194,000 |
| **1971** | 551,900 | **2008** | 160,000 |
| **1973** | 434,100 | **2009** | 262,000 |
| **1974-1975** | 559,750 | **2010** | 270,000 |
| **1976** | 550,000 | **2011** | 180,000 |
| **1977-1978** | 318,550 | **2012** | 246,000 |
| **1981** | 463,000 | **2013** | 194,000 |
| **1984** | 475,000 | **2014** | 275,000 |
| **1986** | 450,000 | **2015** | 200,000 |
| **1988** | 220,000 | **2016** | 245,000 |
| **1990** | 249,818 | **2017** | 435,000 |
| **1992** | 188,345 | **2018** | 286,000 |
| **1994** | 483,000 | **2019** | 230,000 |
| **1995** | 161,000 | **2020** | 252,000 |
| **1996** | 162,000 | **2021** | 350,000 |
| **Average Annual Bypass Rate*** | **292,674 cy/yr** | | |

*Average annual bypass rate from 1945 to 2021, excludes beach nourishment and harbor improvements

### 2.3.2 Buena Vista Lagoon Restoration Project (AECOM, 2020)

The Buena Vista Lagoon, a State Ecological Reserve, provides habitat to a range of species and recreation for the public. The project investigated freshwater, saltwater and hybrid approach-solutions that will benefit the biological and hydrological functions of the lagoon. As dredging is involved in all alternatives, this provides a potential opportunistic sand source for City beaches.

Our understanding is that the preferred alternative is the “Modified Saltwater Alternative”, which combines aspects of the Saltwater and Hybrid A options. According to the 2019 Engineering analysis memorandum, a total of 937,000 CY is proposed to be excavated or dredged as part of the construction of this alternative. The disposal of this material is considered in two approaches:

- Approach 1: Dispose of suitable material on nearby beaches and nearshore, and fine-grained material offshore.
- Approach 2: Dispose of suitable material on nearby beaches and the nearshore. Fine-grained material would be disposed of in an on-site overdredge pit where existing material being replaced is found to be suitable for beneficial reuse within the littoral zone, beach or nearshore.

It is estimated that 798,000 CY of fine-grained material would be disposed of in the dredge pit under Alternative 2. The disposal approaches being considered for the preferred alternative are shown in Table 2-5.

**Table 2-5. Disposal Plan for Buena Vista Lagoon Restoration Project**

| Construction Approach | Volume of Disposal (cy) | |
|---|---|---|
| | Approach 1 | Approach 2 |
| **Beach** | | |
| Oceanside | 119,000 | 245,000 |
| North Carlsbad | 0 | 0 |
| **Nearshore** | | |
| Oceanside | 33,000 | 692,000 |
| **LA-5** | 785,000 | 0 |
| **Total Export** | 937,000 | 937,000 |

#### 2.3.3 Corps San Luis Rey River Maintenance Dredging (City of Oceanside)

The USACE was tasked with dredging approximately 230,000 CY of sediment from the San Luis River in 2016. This sand was to be redistributed for the nourishment along Oceanside's beaches. Due to issues regarding permits, endangered species habitat and the contractor's time frame, the project was delayed and initially rescheduled to the Fall of 2019. Today, this is considered an active, uncompleted project.

Will this still happen if USACE returns area to city?

### 2.4 Previous Sand Retention Concepts

#### 2.4.1 Regional Beach Sand Retention Strategy (M&N, 2001)

The purpose of this report was to evaluate various sand retention strategies based on the needs and opportunities of various beaches throughout San Diego. The City of Oceanside was assessed based on the feasibility of an emergent groin field in the vicinity of Buccaneer Beach (Figure 2-10). The primary objectives of the structures were to minimize down drift impacts while retaining beach width. Groin design considered cross shore length, pre-fill of sand in the groin fillets, and modification of the federal sand bypassing program to extend south of the groin field. The conceptual design included two groins spaced 1,500 feet apart with lengths of 930 feet. A maximum fillet width of 280 feet and minimum beach width of 150 feet between groins was proposed with a total retained beach area of 750,000 square feet. The structure crest would be at an elevation of +14 feet MLLW at the beach berm, which will then slope down to be submerged in the nearshore at an elevation of +3 feet MLLW.

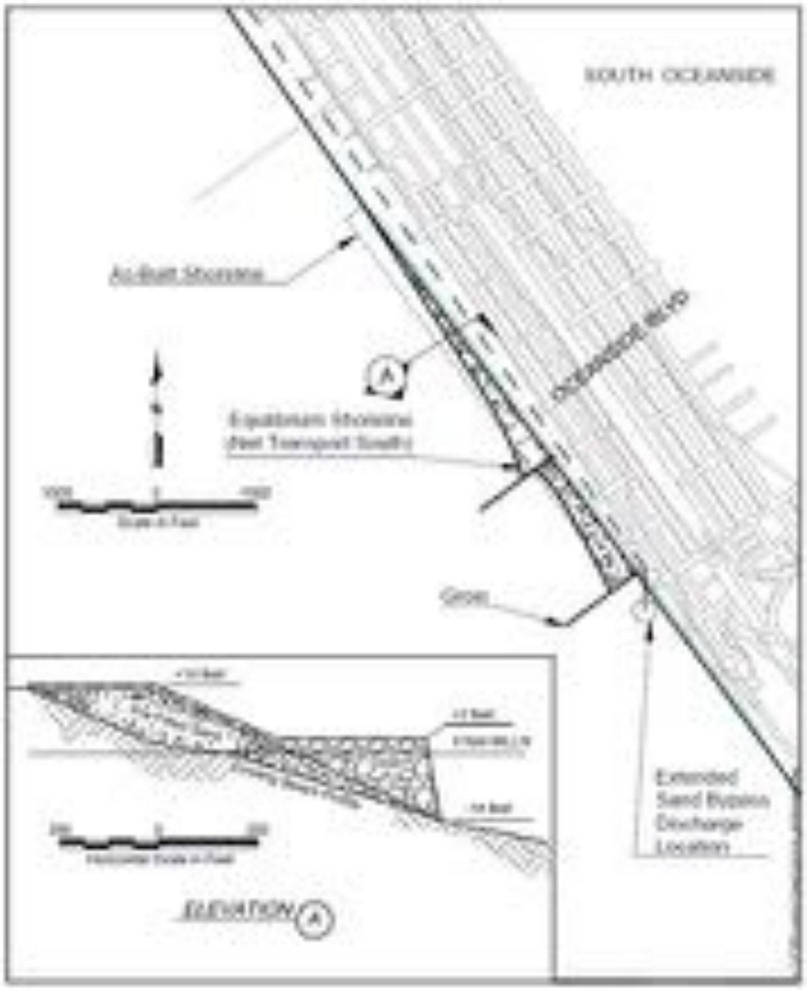


**Figure 2-10. Conceptual Groin Field Design at Buccaneer Beach (M&N, 2001)**

### 2.4.2 Preliminary Engineering Report for Beach Protection Facilities (Noble Consultants, 1983)

Noble Consultants provided four alternative groin field designs (Figure 2-11) and recommended that the groins be adjustable in height and length, be wave absorbent, and be constructed in conjunction with beach nourishment. Additionally, the groins should extent offshore to -10 feet MSL (approximately 500-600 feet length) and be spaced 1,000 feet apart.

- The first alternative design consists of 13 groins spaced 1,000 feet apart between the Oceanside Pier and Buena Vista Lagoon. The cross-shore length would vary, stating 11 groins be 600 feet, one 400 feet, and one 200 feet.
- The second alternative would consist of 12 groins with varying spacing and length. Ten groins would be 500 feet long, one 300 feet, and one 200 feet. Three groins would be spaced at 1,500 feet, one at 1,300 feet, six at 1,000 feet, one at 800 feet and one at 600 feet.
- The third alternative consists of 10 groins with varying spacing and length spread between the Oceanside Pier and Cassidy Street. Eight groins would be 600 feet long, one 400 feet and one 200 feet. Additionally, eight groins would be spaced 1,000 feet apart with one at 800 feet and one at 600 feet.
- The fourth alternative consists of 8 groins with varying spacing and length spread between the Oceanside Pier and the Loma Alta Creek. Six groins would be 650 feet long, one 400 feet long and one 250 feet long. Six of the groins would be spaced at 650 feet apart and the remaining two would be spaced 800 feet apart.

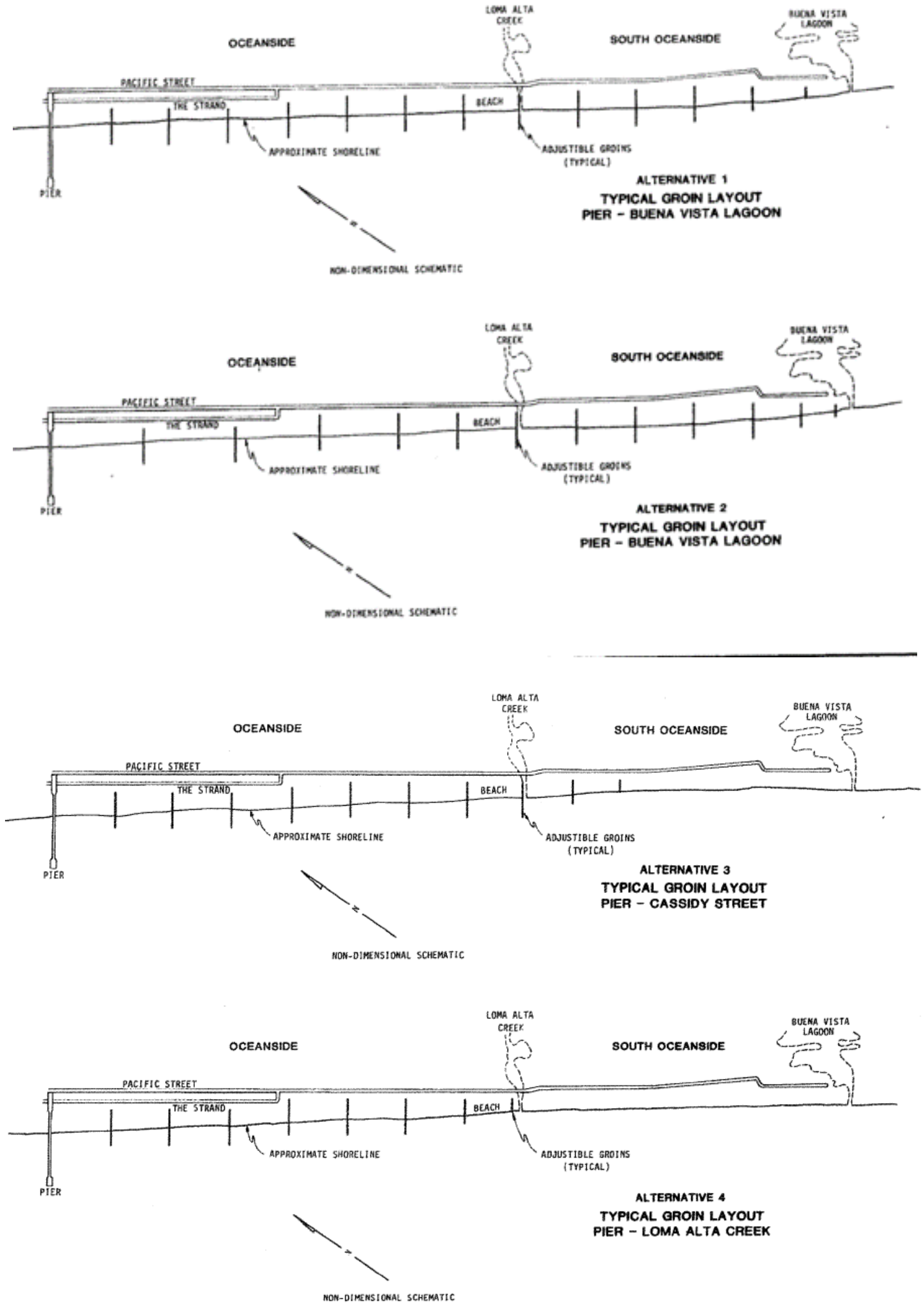


**Figure 2-11. Alternative groin field designs (Noble Consultants, 1983)**

## 2.5 Review Similar Coastal Projects

Relevant project examples throughout the U.S. and internationally were reviewed for design inspiration for Oceanside. Some of the most relevant projects reviewed are summarized in this section.

### 2.5.1 Groin Concepts

#### 2.5.1.1 Upham Beach Shoreline Stabilization Project, Pinellas County, Florida

The goal of this project was to stabilize Upham Beach, which is situated downdrift of the Blind Pass Inlet, with sand retention devices. Given regulatory challenges surrounding potential downdrift and surfing impacts, the County of Pinellas teamed with a local university to study an easily deployable and reversible system. The project installed five temporary geotextile T-head groins in 2005, which are shown in Figure 2-12. The five groins were constructed from 44 geotextile tubes, with three geotubes in the base layer, two in the center and one on top (Elko & Mann, 2006). After a period of about five years, the groins were determined successful in retaining an adequate beach width while minimizing down drift impacts. Given the success, the temporary geotextile groins were replaced with permanent rock groins within minor alterations in configuration in 2018.

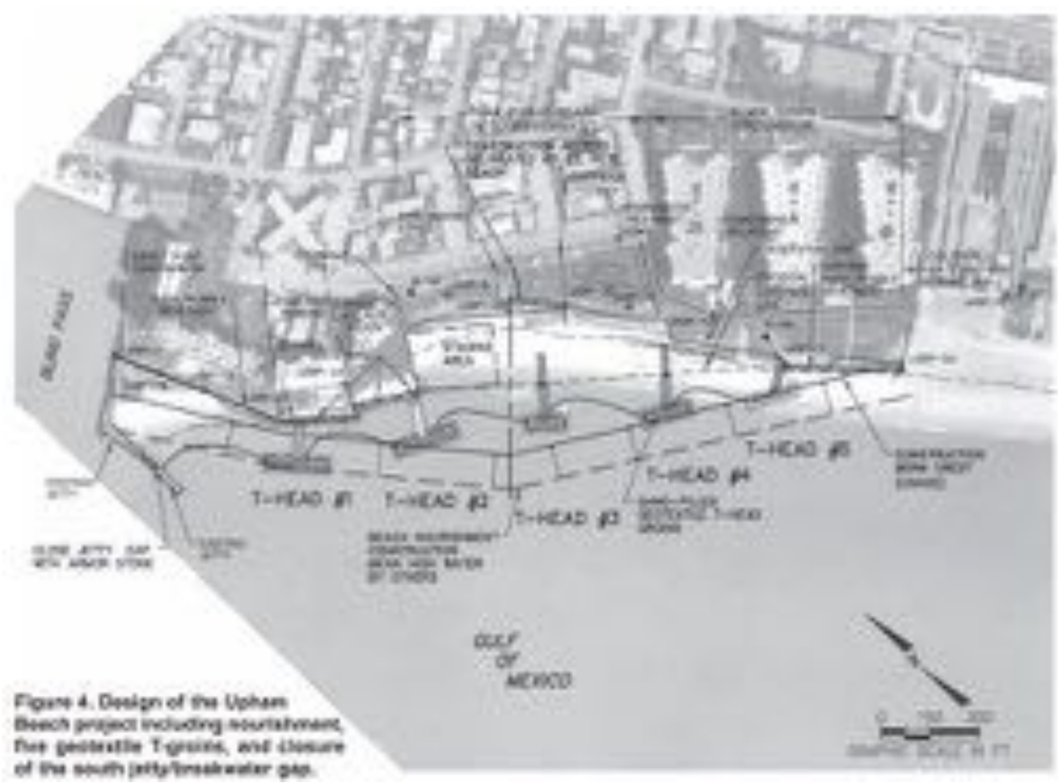


**Figure 2-12. Design layout of Upham Beach groins (Elko & Mann, 2006)**

#### 2.5.1.2 Lower Newport Beach Groin Field, Newport Beach, California

This region of Newport Beach (Figure 2-13) contains eight rubble mound groins constructed by the U.S. Army Corps of Engineers between 1969 and 1973 to slow erosion and increase beach widths along approximately 6,000 linear feet of the City of Newport's shoreline. The groins are spaced 750 feet to 900 feet apart and vary in length from 400 to 650 feet. Relative to pre-construction, surveys by the Corps collected from 1978 to 1995 have shown a higher volume of sand retained and a widening of the beaches (USACE, 1998).

**Figure 2-13. West Newport Beach Groins - South (DBW & SCC, 2002)**

#### 2.5.1.3 Chevron Groin, El Segundo Beach, California

In response to high rates of erosion along the shoreline fronting the Chevron facility in 1982-1983, Chevron proposed a 900 ft long, 65 to 100 ft wide groin with beach fill to protect exposed pipes and its facility. This struck a large debate between Chevron and Surfrider, in that the groin would have adverse effects on the surf conditions at El Segundo Beach and specifically at the updrift groin. Chevron was granted approval for the groin by the CCC so long as surfing monitoring efforts were carried out for a period of five years. Should surfing impacts be realized during this period, Chevron would be responsible to mitigate for those impacts. Following the construction of the Chevron groin and monitoring period, it was concluded that the surf at the updrift groin had been negatively impacted. It was determined that mitigation for these impacts would take the form of a surfing reef, ultimately called Pratt's Reef, and was constructed in 2000. The reef was constructed of geotextile bags that degraded in the marine environment quickly. The reef was also small and placed in shallow water; the scale was a function of the limited Project funding (about $1M). The reef was ultimately deemed unsuccessful in creating surf-able waves and was removed in 2008.

#### 2.5.1.4 Imperial Beach Groins, Imperial Beach, California (Curren, C. & Chatham, C., 1997)

In response to high rates of erosion in the 1950's, the U.S. Army Corps of Engineers constructed two groins between 1959 and 1963. The groins are 400-feet and 740-feet long, spaced approximately 1,325 ft apart (Figure 2-14). The first groin was 400-feet long and was constructed in 1959. It was deemed unsuccessful at retaining adequate beach widths, which led to the construction of the second groin in the early 1960's. The second groin was 300-feet longer than the first and was still deemed ineffective at retaining beach width at that time. From a review of aerial images, these groins appeared effective at retaining the coarse gradation sand from the RBSP II Project in 2012. These structures were a part of an original five groin plan, which was further evaluated in a 1977 hydraulic modeling study.

Why ineffective?


**Figure 2-14. Imperial Beach Groins (Google Earth, 2021)**

#### 2.5.1.5 Agua Hedionda Jetties, Carlsbad, California

The Agua Hedionda jetties were constructed in 1954 to stabilize the lagoon inlet and allow for continuous flow of cool water for the power plant (M&N, 2001). Two twin jetties systems were constructed, one to the north at Tamarack Beach and one to the south fronting the powerplant (Figure 2-15). These structures have an approximate fillet angle of 2.5 degrees and a blocking distance of 150-ft for the northside and 250-ft for the southside (M&N, 2001). The inlet channel between the northern system is approximate 200-ft wide and approximately 70-ft wide for the southern system. These structures were evaluated in regard to sediment retention and blocking.

Figure 2-15. Agua Hedionda Jetties (Google Earth, 2021)

### 2.5.2 Artificial Reefs

#### 2.5.2.1 Palm Beach Artificial Reef, Gold Coast, Australia

The Palm Beach Artificial Reef was constructed from 2017 to 2019 in accordance with the City of Gold Coast Ocean Beach Strategy. It cost $12.5M and is approximately 160 meters (~525 feet) long, 80 meters (262.5 feet) wide and is located 270 meters (~886 feet) offshore (Figure 2-16) (City of Gold Coast, 2019). It consists of 80,000 CY of 5 to 8-ton armor rock and was supplied with 615,000 CY of pre-fill beach nourishment. It was designed to protect the shoreline south of the reef by dissipating incoming waves and surrounding currents, while also providing a surfing resource.

Is it effective?


**Figure 2-16. Palm Beach Artificial Surf Reef (Source: City of Gold Coast, 2019)**

#### 2.5.3 Sand Bypassing

##### 2.5.3.1 Tweed River Sand Bypassing, Gold Coast, Australia

Of the 35 regular sand bypass and transfer systems operating in Australia, the bypass operating at the mouth of the Tweed River is one of the largest, transferring around 500,000m$^3$ each year at an average annual cost of $7.6M AUD. Of the many bypass operations, the Tweed Sand Bypass (TSB) has been selected as a relevant example given its proximity to world class surf breaks and its role in modifying surf conditions. The TSB also demonstrates how bypass systems can work with natural processes to accommodate multiple, and sometimes competing, priorities for coasts and beaches.

The TSB was constructed in 2001 to establish and maintain a navigable entrance to the Tweed River and to restore and maintain coastal sand supply along the southern Gold Coast beaches (refer to Figure 2-17). The project was designed and constructed under a 24-year 'build, own, operate and transfer' contract with the state government partners, a form of Public-Private Partnership (PPP).


**Figure 2-17. Tweed Sand Bypass Overview (TSB, 2020)**

Under the agreement, the Tweed River Entrance Sand Bypassing Company operates a sand bypassing jetty facility comprised of a 450 m (~1,500 ft) long permanent fixed jetty structure that is sited around 250 m (~820 ft) south of the Tweed River entrance and extends offshore to the -5.0m(~16 ft) Indian Spring Low Water (ISLW) contour. The jetty supports ten jet pumps installed in series that are buried beneath the seabed (refer to Figure 2-18). When operational, the jet pumps create cones in the sand that intersect each other to form a trench at right angles to the beach alignment which captures the sand moved by waves and currents along the more active portion of the beach profile.


**Figure 2-18. Tweed Sand Bypass Intake System (GHD, 2011)**

The sand is pumped hydraulically to a sump located at the onshore end of the structure from where it is again pumped via a slurry pump into a 400 mm (~16-inche) diameter discharge pipeline. The discharge pipeline crosses under the Tweed River and directs sand slurry to outlets located at Duranbah beach, Snapper Rocks (East and West) and Kirra Point, as shown in Figure 2-17. Once discharged the sand is reworked northwards by natural coastal processes across and along the beach profile.

Amongst the global surf community, the project is famous for the development of a long continuous surfing bank from Snapper Rocks to Coolangatta known as the 'Superbank'.

It is important to note that due to the large number of different beach users, the project hasn't been considered a success by all. Given the varied preferences of beach users, debates have arisen about which stakeholder's interests should be prioritized.

Excess sand quantities were of particular concern at Kirra, where the offshore reef was significantly impacted by increased sand levels, raising ecological issues and limiting the recreation potential of the reef for SCUBA diving and fishing (Castelle et al., 2006, Lazarow, 2007). In addition, the once world class surf break to the west of Kirra Point groin suffered as the previously well aligned sandbanks were buried by excess sand and as a result became poorly aligned to the predominant swells (Lazarow, 2007).

Another key lesson learned from the TSB project has been the involvement of key stakeholders since the project's inception. The Community Advisory Committee has included representatives of local universities, commercial and recreational fishers, divers, boardriders clubs, surf lifesaving clubs and marine rescue organizations. This has enabled the design, construction and operation of the TSB to be tailored as far as practicable to suit the varied preferences of beach users. Regular communication has also ensured that debates are well informed using the best available data.

#### 2.5.3.2 Mobile Sand Backpassing System, Noosa, Australia

Noosa Main Beach is a prime holiday destination, situated on the Sunshine Coast, approx. 90-minute drive north from Brisbane. Noosa Main Beach has a history of erosion during cyclones and storm events, which has a detrimental effect on the amenity of the beach.

Noosa Main Beach is directly adjacent to the Noosa river mouth which is highly mobile by nature. Southerly movement of the river entrance at the northern end of the main beach is constrained by a rock groin and another groin is located approximately half way along the beach, between the surf club and the river entrance. The littoral drift along the main beach is from south to north, with sand able to be captured against the most northern groin (Figure 2-19).

**Figure 2-19. Sandshifters on Noosa Beach, Queensland**

In 2005, a sand recycling system was piloted to capture sand at the northern end of the beach and recycle or backpass sand 1.5km south to the Surf Club. The system implemented was a diesel powered Sandshifter, which remained in place for approximately three years and was capable of recycling 30,000m3/yr.

Following the success of this trial, approval was given for a permanent electrically powered installation, the installation and commissioning of which was completed in January 2012. The system is semi-automated and is capable of being operated from Slurry Systems office in Gippsland, Victoria. The new system is capable of recycling 60,000m3/yr and had a capital cost of approximately $1.5M.

The Sunshine Coast Regional Council have a 10-year lease on the equipment and pay Slurry Systems $11,000/month for the lease and to maintain the equipment. In addition, Slurry Systems receive payment per cubic meter of sand pumped through the system ($3.50/m3). A densitometer has been installed to measure the amount of sand which passes through the pipeline as a means of calculating payment.

Discussions with Sunshine Coast Regional Council noted that the densitometer caused significant delays in the commissioning of the system due to Customs and approvals processes related to its nuclear components and overseas manufacture (Germany). This is an item with a long lead time and permitting requirements which need to be considered if entering into a construction contract.

As the beach is a highly utilized public facility, the system only operates at night and during off peak periods. From a public safety perspective, care needs to be taken at the outfall to ensure it is clear of people and obstructions prior to pumping commencing.

Outfall flexibility has been allowed for with multiple outlets provided in the pipeline which runs under a boardwalk at the back of the beach.

A pump house has been constructed behind the back dune which houses the pumps and electrical automation equipment. A slurry trap is also included, which screens any debris before the sediment moves through to the slurry transfer pumps. These features are shown in Figure 2-20.

Figure 2-20. Clockwise from top left: Pump Station; Slurry Sump; Electric Motors

#### 2.5.3.3 Indian River Inlet, Delaware

The Indian River Inlet, located in Bethany Beach, Delaware, operates annual sand bypassing from the south side of the inlet to the north side. The inlet is stabilized by a system of two parallel jetties which were constructed in 1938-1939 (Gerbert et al., 1992). Since the construction of these jetties, the beach on the north side of the inlet began to retreat. The littoral drift pattern for this portion of the coastline reflects 110,000 CY of sediment moving to the north annually (Gerbert et al., 1992).

A sand bypassing system was designed to bypass the annual quantity of 110,000 CY and began operation in 1990 (Gerbert et al., 1992). The system consists of a crawler crane mounted jet pump operating on the south side beach, a pump house adjacent to the south jetty, and piping across the highway bridge to transport sediment (Figure 2-21) (Boswood & Murray, 2001). The jet pump system creates an 18-ft deep, 48-ft diameter crater in the intertidal zone and is designed to pump at a rate of 200 CY/hr (Boswood & Murray, 2001). This final cost for this bypass system was $1.7 million and annual operating and maintenance costs are estimated to be $290,000 (Boswood & Murray, 2001).

Figure 2-21. Indian River Inlet Sand Bypass System (USACE, 2020)

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# APPENDIX B

## Technical Report: Numerical Modeling of Alternatives

# APPENDIX B

## Numerical Modeling Technical Report

This appendix presents the technical inputs and findings from the numerical modeling of Project alternatives.

## 1. Model Selection

The numerical model chosen to evaluate the effectiveness of each concept option was the Littoral Processes and Coastline Kinetics (LITPACK), part of the MIKE suite of modeling applications developed by Delft Hydraulic Institute (DHI). LITPACK is designed to model long term shoreline evolution for the purpose of optimizing and evaluating the design and development of coastal works. This model is regularly updated, and the most recent version (2020) is used for the project. The model is known as a 1-contour line model and requires that the beach profile shape remains relatively constant as is moves seaward or shoreward seasonally so that change in beach volume is directly related to shoreline change (USACE, 2014). The model couples hydrodynamic and sediment transport models to calculate littoral drift rates and the coastline position across the model domain over the simulation period.

To assess long term effects of sediment movement effectively for this project, a model that could resolve transport and hydrodynamic conditions around offshore and nearshore structures such as groins and detached breakwaters was needed. LITPACK allows for offshore breakwaters, groins, and revetments to be included in the model, and resolves transport around them better than other 1-line models for a long simulation period (USACE, 2014).

# 1. Introduction

A numerical model was developed to aide in the selection of a preferred beach nourishment and sand retention alternative for the City of Oceanside. A primary objective of the modeling effort was to evaluate the ability of sand retention structures to retain and prolong the performance of beach fills. The 2012 Regional Sand Beach Project II (RSBP II) nourishments that occurred in Oceanside and Carlsbad were used to validate the model and evaluate effectiveness of sand retention structures. Using site-specific data, the integrated hydrodynamic, wave and sediment transport model was set up to encompass the entire Project Area and nearshore environment. Using the coupled model, multiple configurations of groins and artificial reefs were simulated.

## 1.1 Challenges with Modeling Shoreline Morphology

Numerical modeling of shoreline morphology is imprecise because of the difficultly of mathematically describing the complicated dynamics of coastal processes. Modern computing power does not have the ability to resolve the fundamental physics behind coastal processes, and thus approximations are made for nearshore sediment dynamics based on broad and consequential assumptions like the 1-contour line model. While regions like the Project area can fit those assumptions reasonably well, inherent error in coastal modeling remains. The results of this model are intended to provide generalized long-term trends of accretion or erosion across the project area, not precise site-specific shoreline movement. The results of this model are one of many factors that will be considered in selecting the preferred sand retention system.

Successful shoreline modeling requires a robust model with highly accurate site-specific data that can capture the effects of a highly dynamic and variable area. California is also a highly complex and energetic coastline that has proved historically difficult to model due to lack of precise site-specific longshore transport values. The majority of California’s coastline is characterized by significant bi-directional longshore transport in response to a seasonal wave climate. Numerical models applied to California’s coastline have been employed at various locations with limited accuracy due to the challenges previously discussed.

A scaled 1:100 physical model of Oceanside was built and tested in 1980 by the USACE to study shoaling and wave conditions with sand retention devices installed in the model (USACE, 1980). While the model was meticulously created to mimic the conditions at Oceanside, it was unable to fully capture the entirety of the systems’ complexities and its results were presented as general outcomes. The approach taken to the task of validating and running the LITPACK model over the Project shoreline is to come as close as possible to the physical conditions in the Project area while recognizing the inherent limitations of the model. The results presented in this report should be used only as one of many tools in choosing a preferred design option to move forward with.

## 1.2 Model Domain

The model domain stretches from the Southern side of the Oceanside Harbor to the Agua Hedionda Lagoon north jetty as shown in Figure 1. This encapsulates the entire project area and is limited by the model’s ability to simulate the effects of the Harbor.


**Figure 1 Project and Model Domain Area**

# 2. Model Setup

## 2.1 Waves

LITPACK allows for waves measured in deep water to be used in the model. LITPACK computes a wave transformation to the nearshore internally, provided the coastline is relatively straight and the offshore contours are quasi-parallel. For this model, the Coastal Data Information Program's (CDIP) offshore wave buoy data was used. The Oceanside buoy (Station 045) is located at a water depth of 238 m (780ft) and provides a continuous measured dataset from May 1997 through to present day. Another potential source of wave data is the Wave Information Studies (WIS) hindcast dataset provided by the USACE. The locations of both stations are shown in Figure 2. There are some differences between the wave directions of these two data sources; WIS data suggests that waves coming from the west are more frequent, while CDIP has recorded that swells from the southwest are more common. The team chose to use the CDIP data set for the model over the WIS hindcast data as it measures waves in real time and is closer to the project shoreline as shown in Figure 2.

The CDIP dataset contains mean wave direction, peak wave period, and significant wave height every thirty minutes. The dataset contains holes of hours or days interspersed within the dataset where maintenance work was done, or data was not recorded. To resolve the larger data gaps, missing values were averaged to the nearest neighbor, which is acceptable as the typical long period swells on the west coast take many hours or days to decay as they originate far from the coastline. Discrete isolated data gaps over the course of the years of data used were deemed too small to affect the long-term sediment transport rates, as the seasonal changes were still captured, and only small portions of swell events were excluded from the data. A wave rose for CDIP Station 045 over the simulation period is shown below in Figure 3.

The waves internally transformed by LITPACK to the nearshore are treated as a representative wave climate for the model domain, which is appropriate due to the project area's straight coastline and nearshore parallel bathymetry contours. This provides for the wave climate being relatively homogenous across the project area.


**Figure 2    Offshore wave buoys and project area**

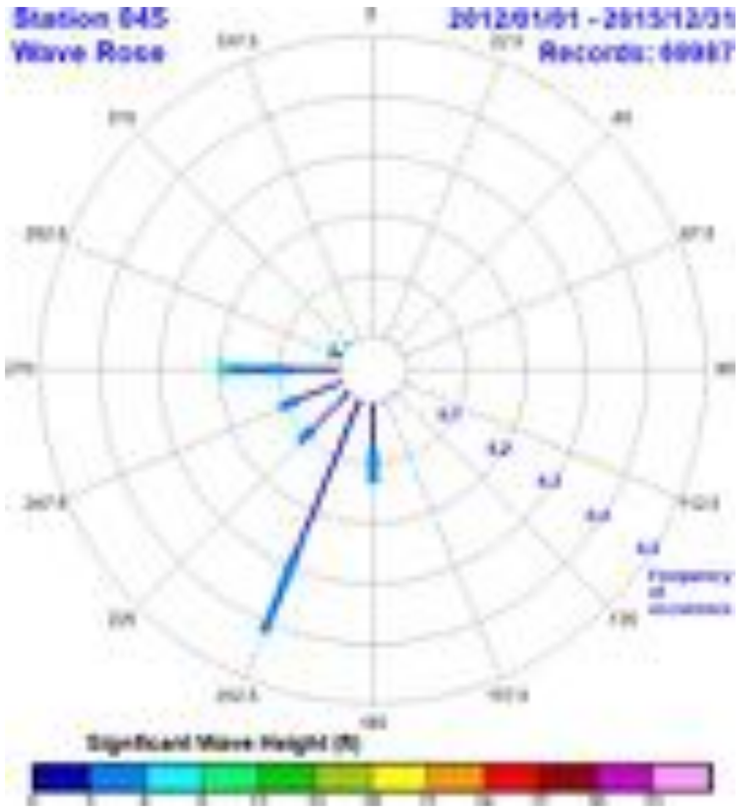


**Figure 3 CDIP Station 045 Wave Rose for Model Simulation Period 2012-2016**

### 2.2 Water Levels

Water levels were described by a six-minute interval time series of tide data pulled from the La Jolla tide buoy, NOAA Station #9410230, shown in Figure 2. The water levels do not vary significantly between the project area and the buoy and are assumed to be constant over the project domain. All water levels use North American Vertical Datum of 1988 (NAVD88) as their datum to be consistent with all other spatially referenced data used.

### 2.3 Bathymetry

The model relies on nearshore bathymetry data to calculate hydrodynamic conditions and longshore sediment transport rates (DHI 2020) along the study area. Beach profile shape and shoreline orientation are the primary factors used to describe nearshore bathymetry.

#### 2.3.1 Beach Profiles

Nearshore bathymetry profiles perpendicular to the coast were specified for areas of significant erosion and accretion according to historical shoreline positions. Bathymetry profiles were extracted from a topobathy digital elevation model (DEM) created from lidar and imagery datasets by the California Coastal Conservancy collected from 2009 to 2011. The vertical and horizontal accuracy were reported to be 15 and 300 cm;

respectively. The vertical datum used was NAVD88. The profiles extend seaward to 150 feet of depth, and landward to around +12 feet NAVD88 at a 5 ft resolution. 150 feet of depth corresponds to intermediate depth for the largest waves in the simulation time, where refraction begins to occur. The extracted data was smoothed using a moving average to minimize model error in sediment transport and refraction due to sudden profile changes. Profiles were taken out to the intermediate depths for the largest waves during the simulation time so that the model could accurately refract waves to the coast from deep water. The angle at which the profiles were set was taken as perpendicular from the traced shoreline. A figure of the profile locations is shown below in Figure 5. The profile angles and orientation definition as defined by the LITPACK User Manual (DHI 2020) are shown below in Figure 6 and Table 3.1. Figure 8 shows the profiles' position along the coastline.

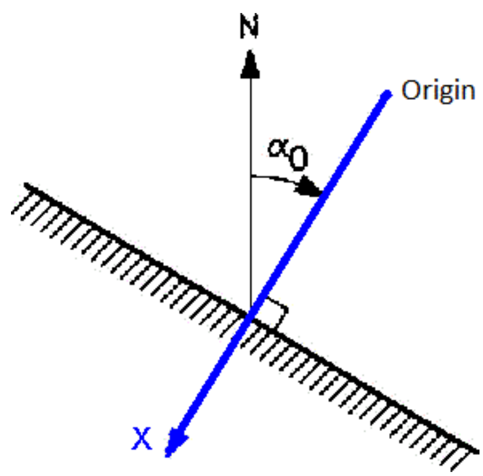


**Figure 4 Definition of Coastline orientation $\alpha\alpha_{00}$ and cross-shore profile alignment (DHI 2020)**

**Table 1.1. Bathymetry Profile Angles**

| Profile Number | Profile Angle $\alpha\alpha_0$ (clockwise from True North) |
|---|---|
| Profile 1 | 238.38 |
| Profile 2 | 237.38 |
| Profile 3 | 236.37 |
| Profile 4 | 235.37 |
| Profile 5 | 235.37 |
| Profile 6 | 234.36 |
| Profile 7 | 234.36 |
| Profile 8 | 233.35 |

#### 2.3.2 Shoreline Baseline

The coastline in LITPACK is specified in relation to a baseline which has a fixed position and orientation. The shoreline position is then described as a series of perpendicular distances from the baseline. The baseline must be near shore-parallel to the coastline's general orientation as shown in Figure 7 (DHI 2020).

The shoreline used in the model was traced in ArcMap using historical imagery pulled from the NOAA Data Access Viewer. Several shoreline years were traced to understand erosional and accretional patterns in the study area. The 8/23/2010 shoreline year was chosen as the start of the simulation for a number of reasons, but most notably its position in relation to two large scale regional beach nourishment projects. The sediment from the 2001 RSBP beach nourishment had eroded away, and the RSBP II project was set to begin in the Fall and Winter of 2012. This is described in further detail in Section 4. Once traced, the shoreline was brought into MIKE Zero's bathymetry editor to extract perpendicular distances from a set baseline, shown in Figure8.

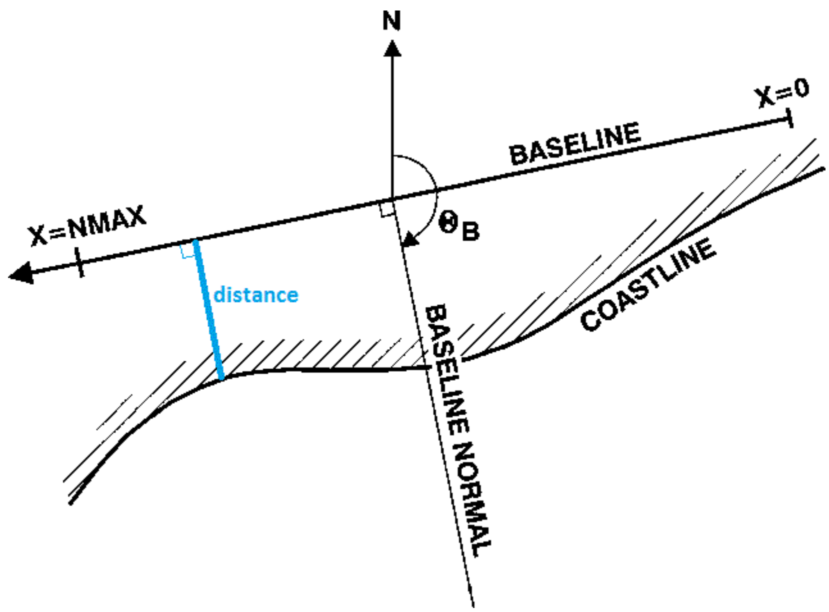


**Figure 5 LITPACK definition of a shoreline position (DHI 2020)**

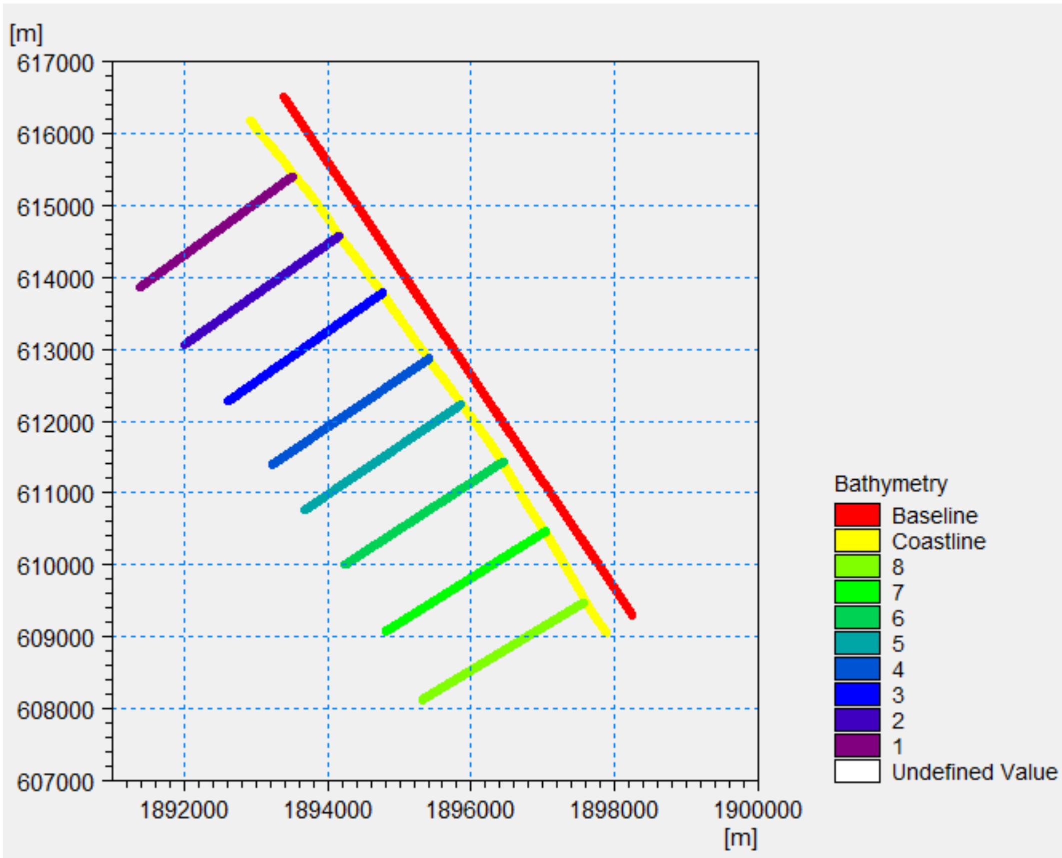


**Figure 6 Coastline and beach profile position relative to baseline**

## 2.4 Sediment

### 2.4.1 Sediment Properties

The median grain diameter (D50) of the sediment varies along the cross-shore profiles in the project area, with larger diameters (~0.5 mm) found close to shore and finer grained (~0.1 mm) sand deposited near the depth of closure (USACE 2018). Grain size is assumed to remain relatively constant over time as the wave climate and sand sources have not changed over the past decade, so there is no major mechanism to change the gradation in the nearshore. The grain size varies slightly over the longshore and that is reflected in the data as the USACE sampled in 2018 at multiple transects in the project area. This was also shown in the Moffat & Nichol Sampling Analysis Plan Results Report (M&N 2016). The results of this are shown in Table 3.2 and Figure 6. The sediment sampling done by the USACE and M&N showed the sediment to be poorly graded/well sorted, and thus the sediment was defined as uniform sand for each point along the profile.

**Table 3.2. Oceanside Sediment Characteristics (M&N, 2016)**

| | Reach | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sediment Characteristics | A | B | C | D | E | F | G | Santa Margarita |
| $D_{50}$ Range (mm) | 0.1 to 0.5 | 0.1 to 0.4 | 0.1 to 0.3 | 0.1 to 0.3 | 0.1 to 0.2 | 0.1 to 0.2 | 0.1 to 0.2 | 0.1 to 0.2 |
| % Fines | 0.6 to 54.7 | 0.7 to 64.2 | 0.4 to 67.6 | 0.4 to 73.3 | 0.7 to 79.6 | 1.2 to 53.9 | 1.4 to 78.9 | 1.0 to 77.7 |

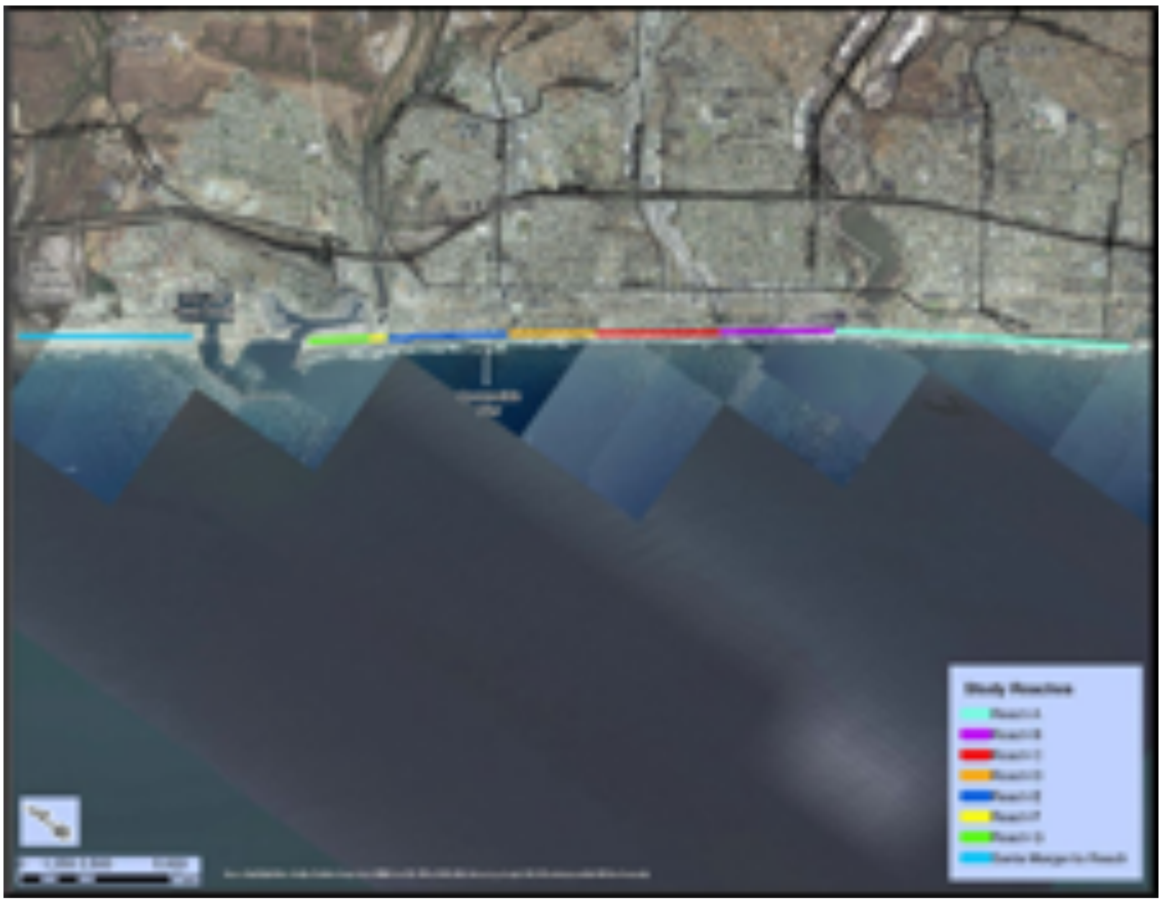

**Figure 7 2016 SAPR Shoreline Reaches (M&N, 2016)**

### 2.4.2 Bed Parameters

Bed parameters describe the processes near the bed (DHI 2020) such as porosity ripples, critical shield's parameter, and inertial coefficients. These were left as default values as they covered the range of sediment properties in the project area.

# 3. Model Validation

Validation of a model is an important step to evaluate the model's ability to simulate observed shoreline changes. Validating a model is achieved by running a simulation of a past event and comparing the results to existing measured data of the same event with the purpose of verifying that the model can reasonably predict outcomes of future events. Once the validation model is set up and run, calibration of the input parameters may be needed to align the validation results to the measured results.

## 3.1 Calibrating Littoral Drift

Littoral drift rates across the project area were calibrated to get within the range of values displayed below in Table 4.1**.** The values shown in the table were not measured specifically in the project area domain, but rather for the whole littoral cell, which spans 60 miles (Patsch & Griggs, 2006). The large range and uncertainty associated with measured and estimated littoral drift rates necessitated an iterative approach to calibrating the model. A set of parameters would be run, and the model shoreline would be compared to the measured shoreline, at which point the parameters would be reassessed and rerun.

**Table 4.1. Longshore Sediment Transport Estimates**

| Location | Net Drift | Direction | Source |
|---|---|---|---|
| Oceanside Littoral Cell | 146,000 | South | Patsch & Griggs, 2006 |
| | 254,000 | South | Inman & Jenkins (1983) |
| | 102,000 | South | Hales (1978) |
| | 175,000 | South | USACE, 2016 |
| | 215,000 | South | Marine Advisors (1961) |
| | 250,000 | South | Inman (1976) |
| | 194,000 | South | Hales (1979); Inman & Jenkins (1985); Dolan et al. (1987) |
| Oceanside Harbor Southside | 106,000 | South | USACE, (1991); Tekmarine, Inc., (1978) |

The coastline orientation was also calibrated for each profile to test sensitivity of the model to this parameter and get accurate transport rates. Because the mean wave direction was 228 degrees, and the coastline is nearly perpendicular to this direction, the sediment transport rate and direction were highly dependent on the coastline orientation. The profile orientations (measured clockwise in degrees from True North) ranged from 239 degrees on the southern end of the project area to 233 degrees on the northern end. The differences in coastline orientation caused an increase of net southern transport from the northern to the southern end of the project area. The model predicted longshore net transport rates of 68,000 cubic yards per year (cyy) on the Northern end of the project area to 130,000 cyy on the southern end.

## 3.2 Validating Model

The shoreline changes due to the 2012 Regional Sand Beach Project II (RSBP II) were used validate the model. RSBP II was a sand replenishment project that delivered sand to select beaches in San Diego county. Oceanside received a total of 293,000 cubic yards from 10/05/2012 to 10/20/2012 distributed from Buccaneer

Beach to Hayes Street. North Carlsbad received 218,000 cubic yards from 11/24/2012 to 12/07/2013 distributed from the Buena Vista Lagoon mouth to Carlsbad Village Drive (SANDAG 2012) as shown in Figures 10 and 11. Using georeferenced aerial imagery, it was verified that the RSBP II sand stayed within the project area until about 2016 as shown in Figure 11. The same period was modeled in the simulation to try and match the general trends of erosion and accretion within the project area with the measured trends. The LITPACK model simulation starts on January 1st, 2012 and runs until March 22nd, 2016.

The measured shoreline change shows accretion along the southern end of the project shoreline, Reach E in Figure 12. From Reach D until the southern half of Reach A the shoreline is largely erosional. The northern half of Reach A is accretional.

The LITPACK model was run using the calibrated littoral drift rates and simulated sand sources at the same rates and locations as the RSPB II beach fill. The LITPACK model shows accretion from the Northern half of Reach E to Reach B. This is due to the RSBP II fill in the LITPACK model eroding much slower than the measured shorelines show. To improve agreement with the measured shoreline, the LITPACK model parameters were recalibrated with the following changes shown in Table 4.2 below.

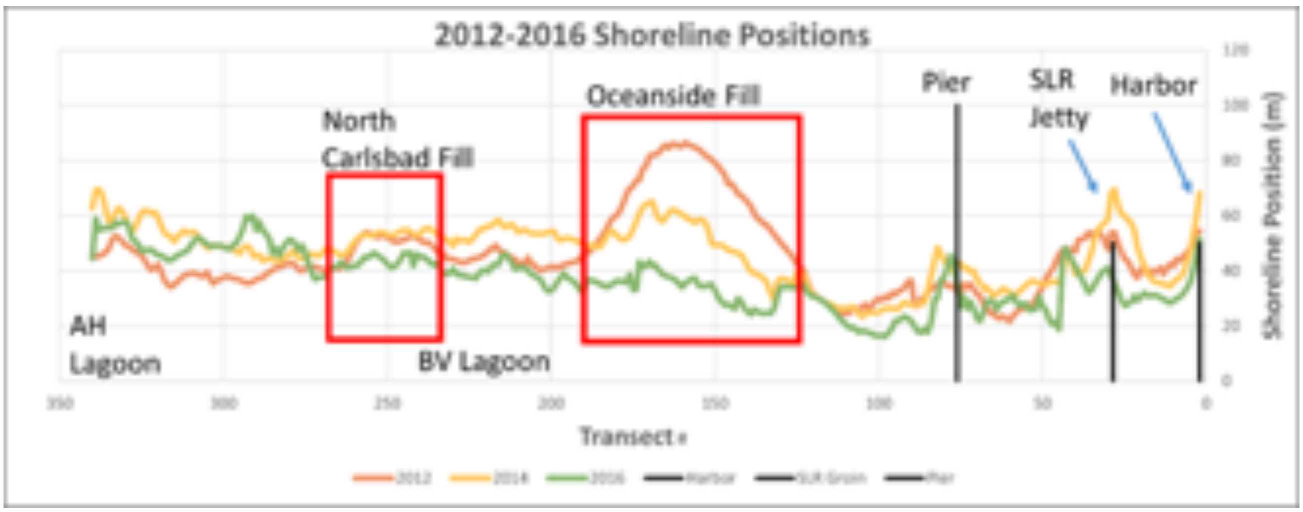


**Figure 8 2012-2016 Measured Shoreline Positions and RSBP II Fill Locations**

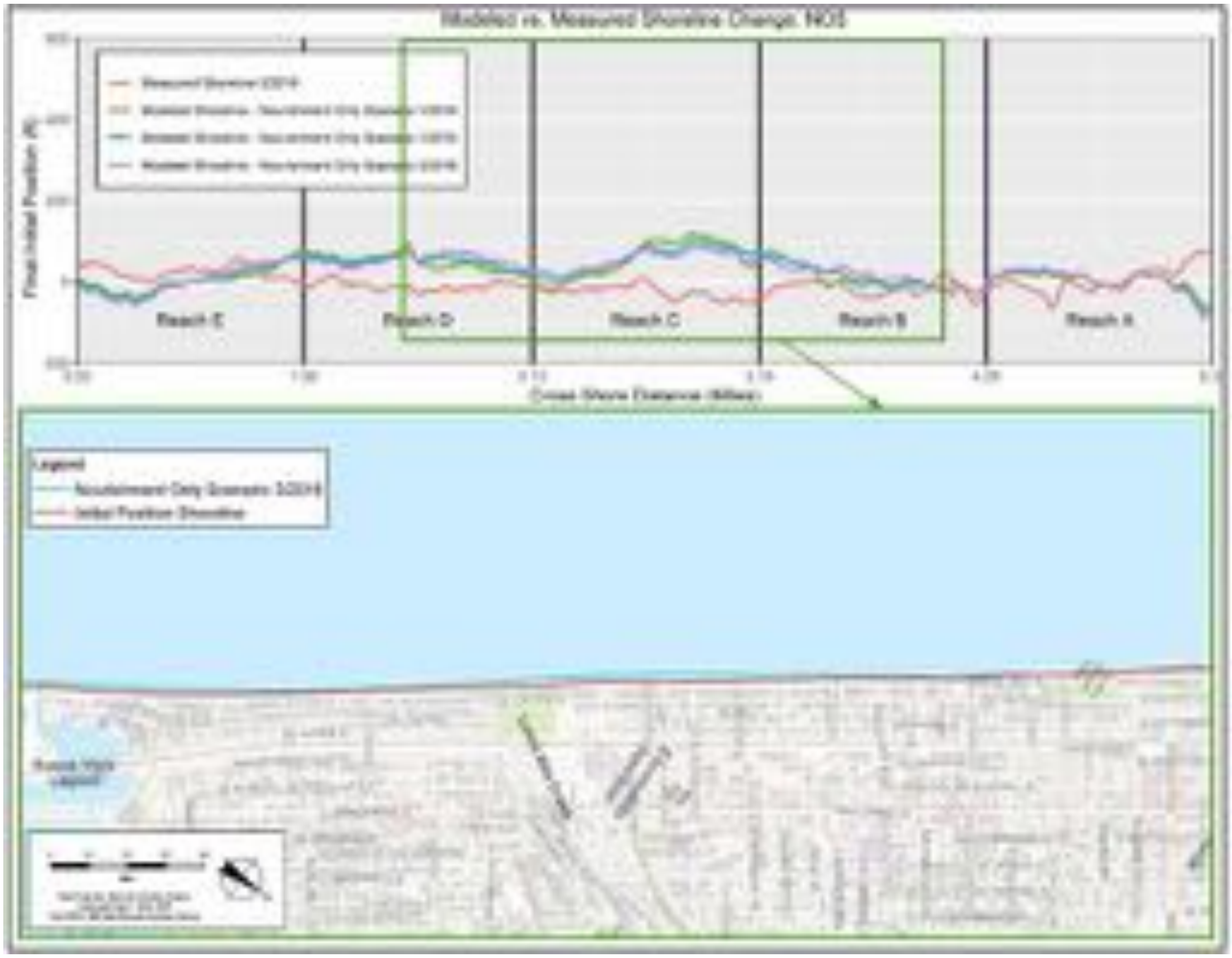


**Figure 9 Nourishment Only Scenario: Shoreline Change and Position**

**Table 4.1 List of parameters changed to improve validation**

| Parameter | Notes |
| --- | --- |
| Bathymetry | - Profiles extended from 50 to 150 ft depth<br>- Shoreline resolution increased from 25 to 10 meters<br>- Profile 4 used as representative bathymetry profile<br>- Smoothed bathymetry using a moving average |
| Sediment Data | - Sediment data for Profile 4 used as representative sediment distribution |
| Wave Data | - Waves internally transformed to 150 ft depth |
| Structures | - San Luis Rey groin and Agua Hedionda jetties excluded from model<br>- Shoreline protection / Rock revetment resolution increased to 50 points |
| Baseline Shoreline Position | - Increased resolution from 25 meters to 10 meters<br>- Smoothed initial coastline using a moving average |

The difficulty in obtaining well validated results with the LITPACK model came from two main sources: the errors associated with simplifying a complex region down to a 1-line model, and the uncertainty of the available data describing the project area. The historical source of erosion in the project area is the lack of sediment in the local littoral cell due to updrift impoundment by the Oceanside Harbor. The model is incapable of resolving the complicated dynamics of the harbor structures and their effect on sediment supply. The LITPACK model assumes that the sediment supply is infinite (DHI 2020), resulting in a relatively balanced sediment budget within the model domain and a more stable shoreline than the actual shoreline.

As described in the previous section, the uncertainty in local littoral transport rates that the model was calibrated to is a probable source of error. The 100,000 cubic yard per year range in the net longshore transport estimates is significant and will affect how the model simulates shoreline change.

The boundaries of the model domain proved difficult to model. The model shoreline is bounded by the harbor to the north and the Agua Hedionda Jetties to the south. Because those structures were not included in the model, the modeled shoreline behaves differently than the measured results and predicts erosion on both ends of the domain. As such, the model was calibrated to best reflect measured conditions within the vicinity of the project study area, from Tyson Street to Buena Vista Lagoon. The model-predicted longshore transport within this region increases from 88,000 cyy to 114,000 cyy from Tyson Street to the Buena Vista Lagoon respectively as shown in Figure 10 and was considered appropriate for the purposes of this study.

# 4. LITPACK Sand Retention Device Modeling

In accordance with the scope of services, multiple scenarios were modeled: one “Nourishment Only Scenario” (NOS) that doubled as the model validation, and two sand retention configurations representing groins and artificial reefs. The NOS functions as an assessment of the efficacy of a sand replenishment project alone with the same volume and placement location of the RSBP II. The modeled sand retention devices were simulated using the same data as the NOS so that the model results could be compared to the NOS’s results. The sand retention devices were modeled with the same volume of sand as RBSP II, but the placement locations were modified to reduce downdrift impacts. The sand retention devices modeled were a groin field and artificial reef field respectively. As the purpose of this study is to recommend an implementable pilot project, the full groin and artificial reef layouts stretching from Tyson Street to Buena Vista Lagoon were narrowed down to pilot projects and modeled separately. The position, sizing and model results of the sand retention devices are described in the sections that follow.

The only existing structure that was included in the model was the section of the revetment that would be fronted by the sand retention devices. From Tyson Street to Buena Vista Lagoon the model treats the shoreline as nonerodable. The geospatial position of the revetment was extracted in ArcMap. Although the entire backshore is armored and can be treated as non-erodible, only the subsection fronting the sand retention devices was included. This was done to examine the potential extents of shoreline change updrift and downdrift of the sand retention systems.

## 4.1 Scenario 1: Full Groin Field Layout

### 4.1.1 Modeling Approach

The modeled groin field layout was designed using guidance from the 1980 U.S. Army Corp of Engineers (USACE) study, Design of Structures for Harbor Improvement and Beach Erosion Control, which modeled and tested different layouts of groins in the area using a scaled down 3-dimensional physical model of the harbor and surrounding beaches. After testing ten different layouts of groin fields, the study found that ten 800-foot-long groins spaced 1000 feet apart proved to be the most effective at retaining sand. To cover the entire project area, the groin layout for the purposes of this study was comprised of twelve 600-foot-long groins spaced at around 1000 feet. This placement and spacing combined the USACE study findings with guidance on length to spacing ratios described in the Coastal Engineering Manual (USACE, 2006). The 600-foot length considers the prefill beach width to be 100 feet, resulting in an active groin length of 500 feet. There is some variation in spacing of the groins because they were placed at street ends or areas that would not inhibit public beach access.

The two southernmost groins were tapered to 400 feet and 300 feet long respectively to mitigate downdrift impacts based on findings from the USACE’s physical modeling study (1980). The southernmost groins were tapered as the net longshore transport direction is south and more sediment will be able to bypass the groin system to continue downdrift of the structures to mitigate erosional effects. The spacing of the last two groins was kept at 1000 feet after sensitivity tests were run on downdrift effects with 600 and 400 foot spacing respectively, and no significant differences in retention and downdrift impacts were noticed.

The Oceanside RSBP II placement volume of 293,000 cy was used as the prefill placement and was distributed evenly throughout the groin field. Note that the actual prefilling of a groin field would be much larger, on the order of 1 million cy to adequately fill the entire 12 groin compartments to the desired 100-foot width. The Oceanside RBSP II volume was used to be able to compare retention performance of the structures against the NOS. The result of providing a much smaller prefill than would be needed is a less effective groin field, and more pronounced downdrift impacts because there is less sand available to bypass the groins. Instead of starting the prefill at the placement dates of RBSP II, the fill was included at the start of the simulation to accurately portray how the groin field would operate.

The North Carlsbad RSBP II placement volume of 293,000 cy was used as groin bypass placement amount. The placement location was optimized through sensitivity tests to provide an adequate level of downdrift protection. The final placement location used was from the southern limits of the Buena Vista Lagoon outlet to Pacific Avenue in Carlsbad (approximately 900 feet).

#### 4.1.2 Results and Analysis

The model predicted retention of sand throughout the groin field with accretion of sand in fillets on both sides of each groin. Although spread over a larger area, the Oceanside prefill stayed in the system and was well retained by the groins. The model simulation indicated a fairly uniform distribution of sand throughout the groin field, except for the final year of the simulation in which significant accretion occurs updrift of the northernmost groin. The results illustrated in the final year are likely due to model limitations and do not reflect a realistic outcome. The final simulation year (2015-2016) had a more energetic wave climate which increased the modeled sediment transport rates. Since the model does not simulate the Oceanside Harbor structures and the groins are modeled as impermeable structures, the amount of accretion predicted upcoast of the groin field is likely overestimated. In reality a more uniform distribution of sand through the groin system would be expected, similar to what is observed in groin fields along the southern California coast. A more uniform distribution of sand throughout the groin system would also lessen the potential for downdrift erosion since more sand would be moving through the system.

LITPACK reports accumulated volume for each point along the shoreline in its outputs. This is useful for comparison of the full sand retention buildouts of the groins and the breakwaters to the NOS, as they all have the same fill volumes. When compared to the accumulated volume of the NOS, the full groin layout retained 175% more sand within the fill placement area based on the 2015 predicted shoreline position.

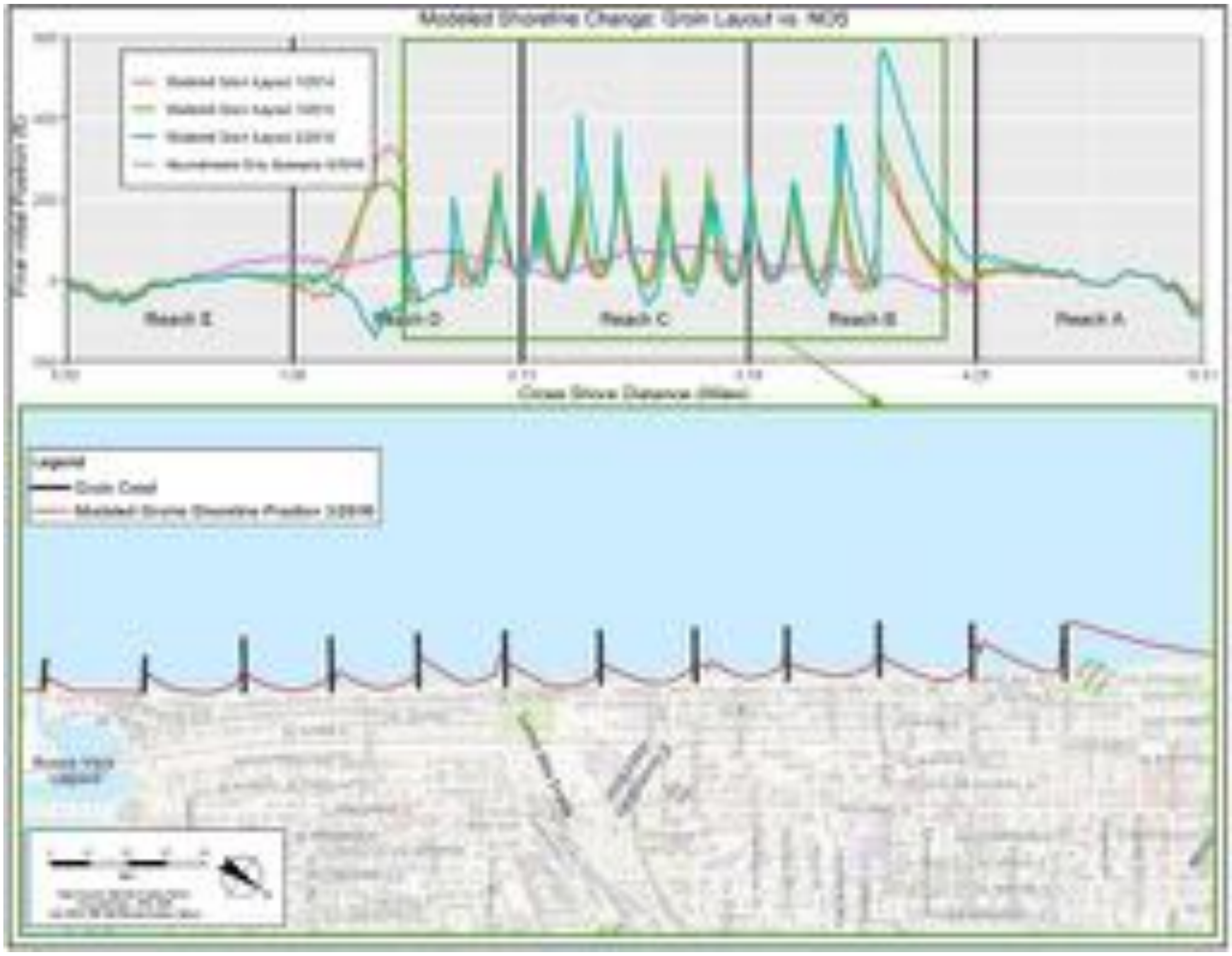


**Figure 10 Groin Field: Shoreline Change and Position**

## 4.2 Scenario 2: Groin Field Pilot

### 4.2.1 Modeling Approach

The groin field pilot was laid out with the goal of showing an effective sand retention project that could be expanded over time. A series of four groins were modeled to capture the effects in three compartments. The middle compartment in the four-groin system can be analyzed semi-independently of the boundary effects, which is why the pilot was not comprised of two or three groins. The boundary compartments invariably will show changes due solely to being located at the boundaries, whereas the middle compartment is somewhat shielded from these effects. Retention performance of a larger groin field could be reasonably assessed from this pilot configuration.

The length and spacing of the groins were the same as the full groin layout, since the goal is that the structures can remain, if successful, and be expandable to the full groin field discussed above. The downdrift groin in the pilot was not tapered for this same reason. The pilot groins and downdrift area were prefilled with the same

293,000 cy placement volume as the Oceanside fill in RSBP II. The prefill was distributed evenly from Tyson Street at the northernmost groin to Forster Street just downdrift of the southernmost groin. Of the total prefill amount, the 3,000-foot-long groin prefill area received 235,000 cy of prefill and the 750 feet of downdrift area received 58,000 cy of prefill within the model.

### 4.2.2 Results and Analysis

Like the modeling of the full groin layout, the model predicts uniform retention of sediment throughout the groin field. The initial fill volume was largely retained within the pilot groin system with accretion of sand in fillets upcoast of each groin. The beach area retained remained relatively stable throughout the model simulation with significant increases in beach width in each groin compartment relative to the initial shoreline. Downdrift erosion was predicted to extend roughly a half mile south of the groin field indicating the importance of a monitoring and management plan to mitigate these potential impacts.

The model results indicate the pilot configuration would retain a much larger beach area within the initial placement zone in comparison to a Beach Nourishment only scenario (i.e. RBSP II). The beach width gained from RBSP II in the original placement area was about 50 feet when averaged over the three-year period following initial placement. The model results suggest 100-150 feet of beach width gains when averaged over the model simulation.

While these results are promising, the model limitations must be acknowledged including the inability to simulate the Oceanside Harbor structures and their influence on sediment supply to the study reach. The groins are also simulated as impervious structures which may result in more retention than would occur in reality if these structures are comprised of larger diameter armor stone. These model limitations (infinite supply of sand and impervious groins) likely result in an overestimate of the beach width retained within the pilot system. Additional analysis of the groin field pilot would involve sensitivity analyses on the placement of initial fill and subsequent fill in the vicinity of the groin field along with variations in groin length and spacing.

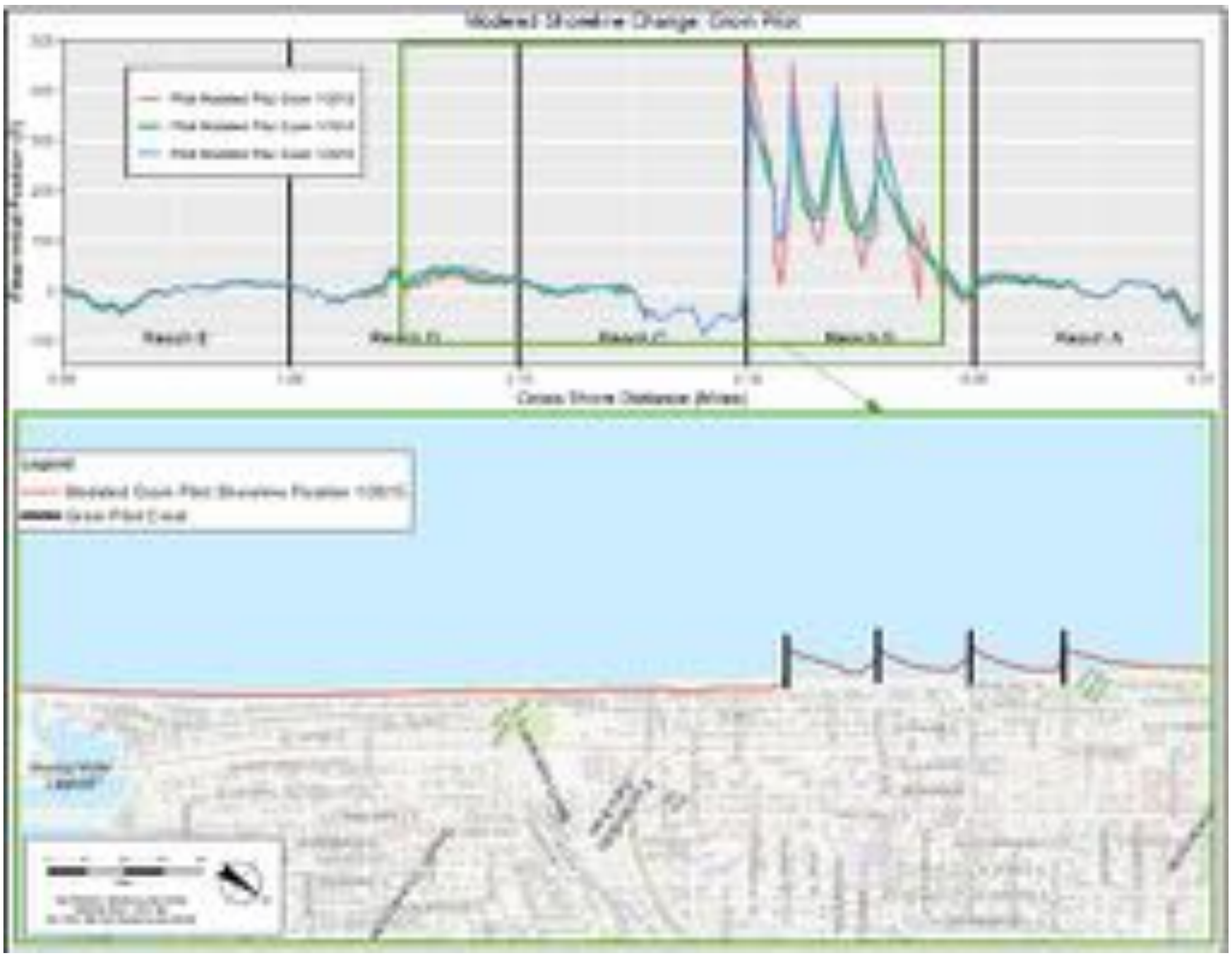

**Figure 11 Groin Field Pilot: Shoreline Change and Position**

### 4.3 Scenario 3: Artificial Reef Buildout

#### 4.3.1 Modeling Approach

The basis for design and placement of the artificial reefs came from guidance from the Coastal Engineering Manual (CEM) as well as the USACE study referenced in section 6.1. The USACE study tested offshore breakwater placements off Oceanside beach and reported positive results with a series of detached offshore breakwaters. Length, spacing and distance from shore were based on CEM guidance for detached offshore breakwaters. From Tyson Street to Buena Vista Lagoon, six reefs with 600-foot-long crests, spaced at 1,200 feet alongshore and placed 1,000 feet offshore. They were designed to attain a salient in the lee of the structures, to allow for sand bypassing in the longshore direction. While the formation of a tombolo may result in larger increases of beach width immediately behind the structure, it would impede the flow of entrained sediment downdrift of the structures. The artificial reefs proposed are functionally the same as detached breakwaters, but with design elements to enhance the likelihood of surfable waves breaking off the structure. LITPACK only has the capability to model offshore breakwaters, so the artificial reefs were modeled as such. This was found to be acceptable as the hydrodynamics are similar enough for the purposes of assessing shoreline response.

The prefills used within the LITPACK model were the same amount and placement as the full groin layout described in section 6.1.1. Both the North Carlsbad and Oceanside RBSP II fill amounts were used as a downdrift prefill and project area prefill; respectively. This was done to provide a basis of comparison between the two model runs.

**Figure 12 Artificial Reef Full Layout Position**

#### 4.3.2 Results and Analysis

The model showed the formation of salient in the lee of each of the artificial breakwaters, with erosional effects between the structures as expected. The model simulation indicated a fairly uniform salient behind each reef structure with maximum predicted beach widths of 100-150 feet. Similar to the groin simulation, results in the final year suggest significant accretion occurs at each structure, especially updrift of the northernmost reef. The results illustrated in the final year are likely due to model limitations and may not reflect a realistic outcome. The final simulation year (2015-2016) had a more energetic wave climate which increased the modeled sediment transport rates. Since the model does not simulate the Oceanside Harbor structures and their effect on littoral sediment supply, the amount of accretion predicted in this final year is likely overestimated. The updrift salient retained more sand than those of the downdrift, potentially blocking some of the bypassing of the salient. Downdrift of the reef structures, the model predicted some erosion, but to a lesser extent than predicted for the groin field. Similar to Groins, the volume of sand accumulated within the artificial reefs (based on the 2015 model output), was 175% more than the NOS within the fill placement area.

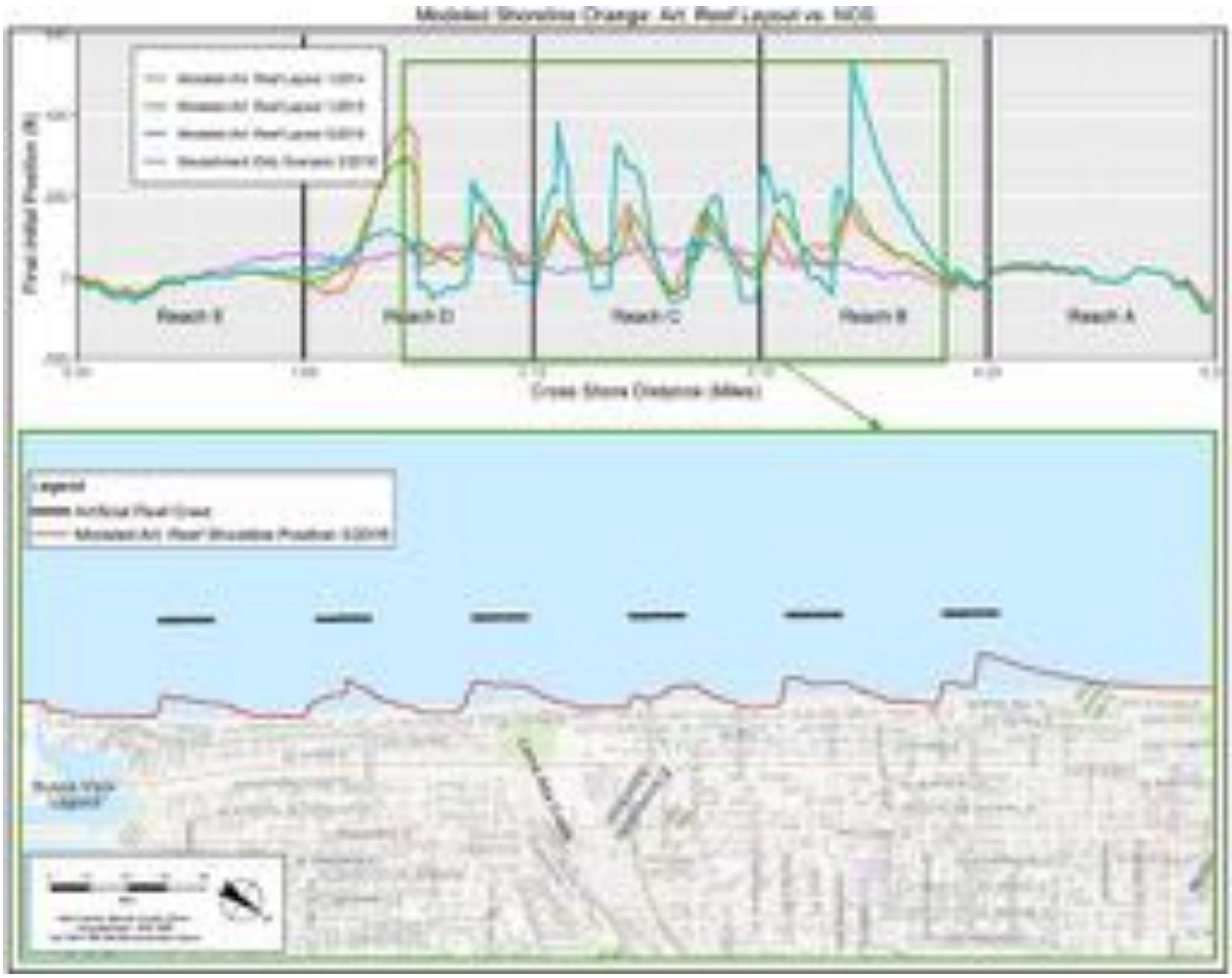


**Figure 13 Artificial Reefs: Shoreline Change and Position**

### 4.4 Scenario 4: Artificial Reef Pilot

#### 4.4.1 Modeling Approach

The artificial reef pilot project consisted of the northern two artificial reefs, spaced and sized the same as the full layout. Two reefs were modeled as opposed to one to show effects on the shoreline between the two reefs. A downdrift/prefill of the same amount and placement as the groin pilot was included in the LITPACK model (i.e. 293,000 cy placed from Tyson Street to Forster St. at the beginning of the model simulation). Of the total prefill amount, the 3,000-foot-long artificial reef prefill area received 235,000 cy of prefill and the 750 feet of downdrift area received 58,000 cy of prefill within the model. The distribution of prefill and downdrift fill was optimized to minimize downdrift impacts via sensitivity tests of placement extent.

**Figure 14 Artificial Reef Pilot Position**

### 4.4.2 Results and Analysis

The model predicted large salient formation in the lee of each reef structure, with retention benefits extending upcoast well beyond the influence of the offshore structures. As a result, the beach in between the reefs also experiences significant accretion. More downdrift erosion was predicted for the pilot configuration extending about a half mile past the structures in Reach C (Figure 18).

These model results suggest the reef structures would retain a much larger beach within the original placement area in comparison to a Beach Nourishment only scenario. The amount of beach area retained throughout the model simulation was comparable to the Groin Field Pilot results, except the planform distribution of sand would be different. Although the model predicted beach widths are quite large, these are subject to similar model limitations which may be contributing to an overestimate of the potential retention benefits.

Since these offshore reef structures have not been widely implemented in the Southern California region there is limited real world observations of how this system would function. Additional analysis of the Artificial Reef Pilot may involve two-dimensional modeling to simulate the complicated hydrodynamics that may result from these structures. This would provide another tool for estimating their ability to retain a sandy beach and the interaction between two or more artificial reef structures placed in series along the pilot study area.

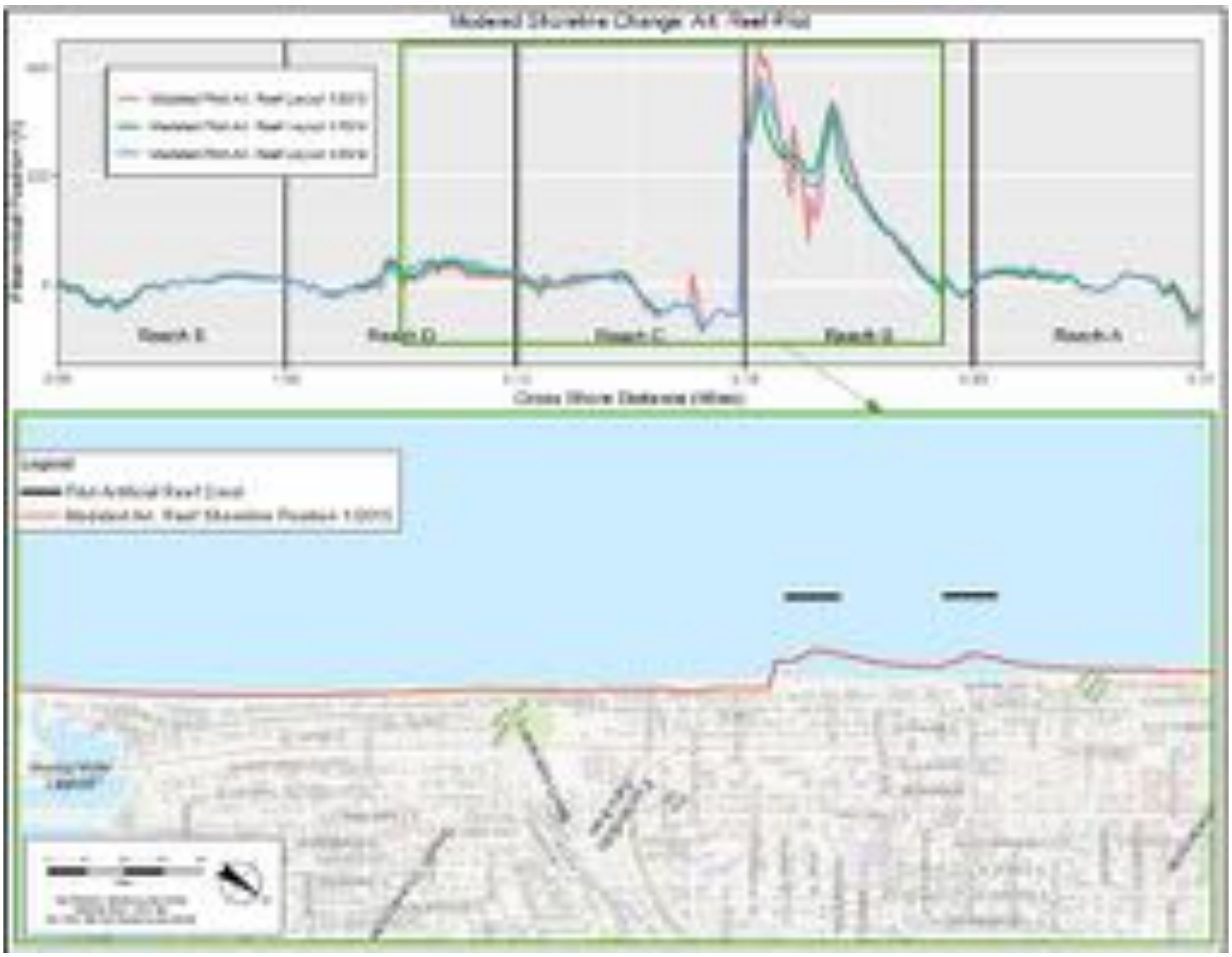


**Figure 15 Artificial Reef Pilot: Shoreline Change and Position**

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# APPENDIX C

**Detailed Multi-Criteria Analysis Results Table and Opinion of Probable Costs for Conceptual Alternatives**

GHD

**City Of Oceanside**
**Feasibility Analysis for Beach Sand Replenishment and Retention Device Project**
**Multi Criteria Analysis Weighted Scoring Matrix**

| Scoring | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| | Low | | Average | | High |

| Importance | Criteria | Basis of Evaluation | No Project | | Alternative 1 Beach Nourishment Progam | | Alternative 2 Groins | | Alternative 3 SLRR Groin Modifications | | Alternative 4 Multi-Purpose Artificial Reef | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Score (out of 5) | Weighted Score | Score (out of 5) | Weighted Score | Score (out of 5) | Weighted Score | Score (out of 5) | Weighted Score | Score (out of 5) | Weighted Score | |
| **40%** | **TECHNICAL PERFORMANCE** | | | | | | | | | | | | |
| 25% | **Creation/Restoration of Beach** | Overall performance of the system, pertaining to the long-term creation/restoration of a beach. (1= poor performance/no beach retained, 5 = Wide dry beach retained) | 1 | 2% | 2 | 4% | 5 | 10% | 2 | 4% | 4 | 8% | Reefs & groins provide most dry beach width added within Oceanside. BN offers some temporary benefits but longevity & width added (locally) are less reliable. |
| 25% | **Down Drift Impacts** | Ability to mitigate adjacent shoreline changes. (1= down drift erosion, 5 = increased sediment to down drift systems) | 1 | 2% | 5 | 10% | 3 | 6% | 5 | 10% | 3 | 6% | BN w/o structures improves down drift sediment supply. SR alts also improve downdrift sediment supply by could result in some localized down drift erosion which could be mitigated through sediment management measures. NP provides no reliable supply of coarse sand, so downdrift erosion will continue. |
| 25% | **Public Safety** | Ability to preserve safety of beach and ocean recreation through improved lifeguard access. (1= exisiting conditions, 5 = Project improves public safety) | 1 | 2% | 3 | 6% | 3 | 6% | 3 | 6% | 3 | 6% | Reefs provide stable beach width w/o lateral access issues. Groins pose some challenges to lateral access and would require additional lifeguard towers. Groins & reefs introduce potential hazards/currents which pose new risks for beach & ocean recreation. BN improves beach width but only temporarily, leaving long stretches of shoreline inaccessible. Pros & cons balance out between alternatives. Public safety concerns could be managed through design features and operational measures (not a significant differentiator). |
| 25% | **Sea Level Rise Adaptability** | Ability to be effective for up to 2ft of SLR. (1=not effective, 3=requires some adaptive measures, 5=effective, easily accommodate 2ft of SLR) | 1 | 2% | 2 | 4% | 4 | 8% | 2 | 4% | 5 | 10% | Reefs most effective in accomodating 2 ft SLR due to wave energy dissipation alongshore. Groins & BN provide some buffer to SLR due to incresed beach widths. |
| 100% | | **SUBTOTAL out of 40%** | | **8%** | | **24%** | | **30%** | | **24%** | | **30%** | |
| **20%** | **FINANCIAL** | | | | | | | | | | | | |
| 70% | **Life-cycle Costs** | Ensure the capital investment, O&M costs and adaptation costs provides the best value for the amount. (1 = highest life-cycle cost, 5 = lowest lifecycle cost) | 5 | 14% | 5 | 14% | 4 | 11% | 4 | 11% | 1 | 3% | Based on graduated scoring categories between highest and lowest ranked alternatives. |
| 30% | **In-direct economic benefits** | Indirect economic value provided by dry beach area available for coastal access and recreation (1 = no economic benefit from increased beach width, 5 = highest economic benefit from increased beach width) | 1 | 1% | 2 | 2% | 5 | 6% | 2 | 2% | 4 | 5% | Related to amount of sand retained within City of Oceanside and increased opportunities for tourism & beach visits |
| 100% | | **SUBTOTAL out of 20%** | | **15%** | | **16%** | | **17%** | | **14%** | | **8%** | |
| **40%** | **ENVIRONMENTAL** | | | | | | | | | | | | |
| 20% | **Biological Resources** | Ability to preserve and/or enhance marine biological resources. (1= negative, 5 = increased bio. Resources) | 1 | 2% | 3 | 5% | 4 | 6% | 3 | 5% | 5 | 8% | SR alternatives provide a more stable intertidal beach area. Groins and reefs occupy sandy sub-tidal habitat but also provide some rocky substrate to support marine bio habitat diversity. |
| 20% | **Surfing Resources** | Ability to preserve or enhance exisiting surfing resources (1= Does not preserve existing resources, 5 = Preserves and enhances surfing resources). | 1 | 2% | 3 | 5% | 4 | 6% | 3 | 5% | 4 | 6% | Groins & reefs scored higher because of potential to preserve and possibly enhance surfing resources. Beach nourishment will help preserve surfing resources but only temporarily and dependent on performance of each nourishment. BN may also cause temporary surfing impacts dependent on volume and grain size placed (i.e. Imperial Beach in RBSP II). |
| 20% | **Aesthetics** | Ability to preserve view corridors throughout Oceanside. (1= negative aesthetic, 5 = positive aesthetics) | 2 | 3% | 3 | 5% | 4 | 6% | 3 | 5% | 4 | 6% | Assuming aesthetics are linked to dry beach area. Stable sandy beach provides a better aesthetic than a rock revetment. |
| 20% | **Beach Recreation** | Ability to preserve and enhance recreational opportunities, partuicularly at high-use areas such as the Pier and South Strand reaches. (1= no project, 5 = increased rec. opportunities) | 1 | 2% | 3 | 5% | 5 | 8% | 3 | 5% | 5 | 8% | Groins & Reefs score highest due to increased area available for beach recreation (i.e. towel space) in most accessible locations |
| 20% | **Coastal Access** | Ability to enhance lateral beach access through the creation of stable dry beach areas. (1= Existing conditions (no beach), 5 = improved lateral access) | 1 | 2% | 3 | 5% | 4 | 6% | 3 | 5% | 4 | 6% | Groins & reefs provide stable beach for vertical access. Lateral access features would need to be incorporated into groins. BN only proviees both, but only temporarily and dependent on the performance of each nourishment. |
| 100% | | **SUBTOTAL out of 40%** | | **10%** | | **24%** | | **34%** | | **24%** | | **35%** | |
| | | **TOTAL out of 100%** | | **33%** | | **64%** | | **81%** | | **62%** | | **73%** | |

**City of Oceanside**

**Sand Retention Feasibility Study**

**Opinion of Probable Cost for Alternatives**

## Summary of Alternatives Opinion of Project Costs

Date: 6/25/2021

| Alternative | Item Description | Phase 1 (Initial - 2030) | Phase 2 (2030 - 2035) | Phase 3 (2035 - 2040) | Total |
|---|---|---|---|---|---|
| No Project | Initial Cost | $ 1,000,000 | $ - | $ - | $ 1,000,000 |
| | Beach Maintenance | $ - | $ 1,000,000 | $ 1,000,000 | $ 2,000,000 |
| | Adaptation | $ - | $ - | $ - | $ - |
| | **Total** | **$ 1,000,000** | **$ 1,000,000** | **$ 1,000,000** | **$ 3,000,000** |
| | | | | | |
| 1 Beach Nourishment | Initial Cost | $ 10,000,000 | $ - | $ - | $ 10,000,000 |
| | Beach Maintenance | $ - | $ 9,000,000 | $ 9,000,000 | $ 18,000,000 |
| | Adaptation | $ - | $ - | $ - | $ - |
| | **Total** | **$ 10,000,000** | **$ 9,000,000** | **$ 9,000,000** | **$ 28,000,000** |
| | | | | | |
| 2 Groins | Initial Cost | $ 32,000,000 | $ - | $ - | $ 32,000,000 |
| | Beach Maintenance | $ - | $ 7,000,000 | $ 7,000,000 | $ 14,000,000 |
| | Adaptation | $ - | $ - | $ 5,000,000 | $ 5,000,000 |
| | **Total** | **$ 32,000,000** | **$ 7,000,000** | **$ 12,000,000** | **$ 51,000,000** |
| | | | | | |
| 3 SLRR Groin Mods | Initial Cost | $ 16,000,000 | $ - | $ - | $ 16,000,000 |
| | Beach Maintenance | $ - | $ 9,000,000 | $ 9,000,000 | $ 18,000,000 |
| | Adaptation | $ - | $ - | $ 2,000,000 | $ 2,000,000 |
| | **Total** | **$ 16,000,000** | **$ 9,000,000** | **$ 11,000,000** | **$ 36,000,000** |
| | | | | | |
| 4 Multi-purpose Reefs | Initial Cost | $ 95,000,000 | $ - | $ - | $ 95,000,000 |
| | Beach Maintenance | $ - | $ 7,000,000 | $ 7,000,000 | $ 14,000,000 |
| | Adaptation | $ - | $ - | $ 39,000,000 | $ 39,000,000 |
| | **Total** | **$ 95,000,000** | **$ 7,000,000** | **$ 46,000,000** | **$ 148,000,000** |

## City of Oceanside
## Sand Retention Feasibility Study
### Opinion of Probable Cost for Alternatives

### Opinion of Costs for No Project
Date: 6/25/2021

| | | Phase 1 (Initial - 2030) | | | | Phase 2 (2030 - 2035) | | | | Phase 3 (2035 - 2040) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | Item Description | Qty | Unit | Rate | Amount | Qty | Unit | Rate | Amount | Qty | Unit | Rate | Amount |
| **Project Construction Costs** | | | | | | | | | | | | | |
| 1 | Mobilization (see note 1) | 1 | LS | $ - | $ - | | | | $ - | | | | $ - |
| 2 | Traffic Control | 1 | LS | $ - | $ - | | | | $ - | | | | $ - |
| 3 | Beach nourishment | 40,000 | CY | $ 15 | $ 600,000 | | | | $ - | | | | $ - |
| 4 | Maint. beach nourishment mobilization | - | LS | $ 2,500,000 | $ - | 0 | LS | $ 2,500,000 | $ - | 0 | LS | $ 2,500,000 | $ - |
| 5 | Maint. beach nourishment | - | CY | $ 15 | $ - | 40,000 | CY | $ 15 | $ 600,000 | 40,000 | CY | $ 15 | $ 600,000 |
| 6 | Adaptation | | | | | | | | | | | | |
| | **Project Construction Costs Total** | | | | **$ 600,000** | | | | **$ 600,000** | | | | **$ 600,000** |
| **Project Professional Services Items** | | | | | | | | | | | | | |
| 1 | Geotechnical Investigations | 0 | LS | $ 50,000 | $ - | 0 | LS | $ 25,000 | $ - | 0 | LS | $ 25,000 | $ - |
| 2 | Survey | 0 | LS | $ 25,000 | $ - | 0 | LS | $ 20,000 | $ - | 0 | LS | $ 20,000 | $ - |
| 3 | Design | 0% | % | $ 600,000 | $ - | 0% | % | $ 600,000 | $ - | 0% | % | $ 600,000 | $ - |
| 4 | Permits | 0% | % | $ 600,000 | $ - | 0% | % | $ 600,000 | $ - | 0% | % | $ 600,000 | $ - |
| 5 | Construction Management | 0% | % | $ 600,000 | $ - | 0% | % | $ 600,000 | $ - | 0% | % | $ 600,000 | $ - |
| | **Professional Services Total** | | | | **$ -** | | | | **$ -** | | | | **$ -** |
| | **Contingency** | **30%** | **%** | **$ 600,000** | **$ 180,000** | **30%** | **%** | **$ 600,000** | **$ 180,000** | **30%** | **%** | **$ 600,000** | **$ 180,000** |
| | **Project Total** | | | | **$ 780,000** | | | | **$ 780,000** | | | | **$ 780,000** |
| | **Project Total Rounded** | | | | **$ 1,000,000** | | | | **$ 1,000,000** | | | | **$ 1,000,000** |

Notes:
1 No Project assumes the City contributes $600k for additional harbor dredging once every five years. Work will be performed by USACE contractor so no mobilization cost is included.
2 Quantity and unit price of harbor dredging sand will vary. Assumption of $20/cy used to be consistent with other estimates.

**City of Oceanside**
**Sand Retention Feasibility Study**
**Opinion of Probable Cost for Alternatives**

## Opinion of Costs for Alternative 1 - Beach Nourishment

Date: 6/25/2021

| | | Phase 1 (Initial - 2030) | | | | Phase 2 (2030 - 2035) | | | | Phase 3 (2035 - 2040) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Item** | **Item Description** | **Qty** | **Unit** | **Rate** | **Amount** | **Qty** | **Unit** | **Rate** | **Amount** | **Qty** | **Unit** | **Rate** | **Amount** |
| **Project Construction Costs** | | | | | | | | | | | | | |
| 1 | Mobilization (see note 1) | 1 | LS | $ 2,500,000 | $ 2,500,000 | | | | $ - | | | | $ - |
| 2 | Traffic Control | 1 | LS | $ 150,000 | $ 150,000 | | | | $ - | | | | $ - |
| 3 | Beach nourishment | 300,000 | CY | $ 15 | $ 4,623,000 | | | | $ - | | | | $ - |
| 4 | Maint. beach nourishment mobilization | - | LS | $ 2,500,000 | $ - | 1 | LS | $ 2,500,000 | $ 2,500,000 | 1 | LS | $ 2,500,000 | $ 2,500,000 |
| 5 | Maint. beach nourishment | - | CY | $ 15 | $ - | 300,000 | CY | $ 15 | $ 4,623,000 | 300,000 | CY | $ 15 | $ 4,623,000 |
| 6 | Adaptation | | | | | | | | | | | | |
| | **Project Construction Costs Total** | | | | **$ 7,273,000** | | | | **$ 7,123,000** | | | | **$ 7,123,000** |
| **Project Professional Services Items** | | | | | | | | | | | | | |
| 1 | Geotechnical Investigations | 1 | LS | $ 50,000 | $ 50,000 | 1 | LS | $ 25,000 | $ 25,000 | 1 | LS | $ 25,000 | $ 25,000 |
| 2 | Survey | 1 | LS | $ 25,000 | $ 25,000 | 1 | LS | $ 20,000 | $ 20,000 | 1 | LS | $ 20,000 | $ 20,000 |
| 3 | Design | 5% | % | $ 7,273,000 | $ 363,650 | 5% | % | $ 7,123,000 | $ 356,150 | 5% | % | $ 7,123,000 | $ 356,150 |
| 4 | Permits | 8% | % | $ 7,273,000 | $ 581,840 | 5% | % | $ 7,123,000 | $ 356,150 | 5% | % | $ 7,123,000 | $ 356,150 |
| 5 | Construction Management | 5% | % | $ 7,273,000 | $ 363,650 | 5% | % | $ 7,123,000 | $ 356,150 | 5% | % | $ 7,123,000 | $ 356,150 |
| | **Professional Services Total** | | | | **$ 1,384,140** | | | | **$ 1,113,450** | | | | **$ 1,113,450** |
| | **Contingency** | **15%** | **%** | **$ 8,657,140** | **$ 1,298,571** | **15%** | **%** | **$ 8,236,450** | **$ 1,235,468** | **15%** | **%** | **$ 8,236,450** | **$ 1,235,468** |
| | **Project Total** | | | | **$ 9,955,711** | | | | **$ 9,471,918** | | | | **$ 9,471,918** |
| | **Project Total Rounded** | | | | **$ 10,000,000** | | | | **$ 9,000,000** | | | | **$ 9,000,000** |

Notes:

1 Beach Nourishment mobilization assumed to be lump sum amount of $2.5M but could vary depending on the type of marine equipment used

2 Beach nourishment assumes 300,000 cy initial plus 2 later individual 300,000 cy renourishment events

**City of Oceanside**
**Sand Retention Feasibility Study**
**Opinion of Probable Cost for Alternatives**

## Opinion of Costs for Alternative 2 - Groins

Date: 6/25/2021

| | | Phase 1 (Initial - 2030) | | | | Phase 2 (2030 - 2035) | | | | Phase 3 (2035 - 2040) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Item** | **Item Description** | **Qty** | **Unit** | **Rate** | **Amount** | **Qty** | **Unit** | **Rate** | **Amount** | **Qty** | **Unit** | **Rate** | **Amount** |
| **Project Construction Costs** | | | | | | | | | | | | | |
| 1 | Mobilization (% other items see note 1) | 5% | % | $ 13,067,171 | $ 653,359 | | | | $ - | | | | $ - |
| 2 | Traffic Control | 1 | LS | $ 150,000 | $ 150,000 | | | | $ - | | | | $ - |
| 3 | New rock groins | 44,128 | CY | $ 293 | $ 12,917,171 | | | | $ - | | | | $ - |
| 4 | Beach nourishment mobilization | 1 | LS | $ 2,500,000 | $ 2,500,000 | | | | $ - | | | | $ - |
| 5 | Beach nourishment | 300,000 | CY | $ 15 | $ 4,623,000 | | | | $ - | | | | $ - |
| 6 | Maint. beach nourishment mobilization | - | LS | $ 2,500,000 | $ - | 1 | LS | $ 2,500,000 | $ 2,500,000 | 1 | LS | $ 2,500,000 | $ 2,500,000 |
| 7 | Maint. beach nourishment | - | CY | $ 15 | $ - | 150,000 | CY | $ 15 | $ 2,311,500 | 150,000 | CY | $ 15 | $ 2,311,500 |
| 8 | Adaptation (see note 3) | | | | | | | | | 1 | LS | $ 3,200,000 | $ 3,200,000 |
| | **Project Construction Costs Total** | | | | **$ 20,843,529** | | | | **$ 4,811,500** | | | | **$ 8,011,500** |
| **Project Professional Services Items** | | | | | | | | | | | | | |
| 1 | Geotechnical Investigations | 1 | LS | $ 50,000 | $ 50,000 | 1 | LS | $ 25,000 | $ 25,000 | 1 | LS | $ 25,000 | $ 25,000 |
| 2 | Survey | 1 | LS | $ 25,000 | $ 25,000 | 1 | LS | $ 20,000 | $ 20,000 | 1 | LS | $ 20,000 | $ 20,000 |
| 3 | Design | 5% | % | $ 20,843,529 | $ 1,042,176 | 5% | % | $ 4,811,500 | $ 240,575 | 5% | % | $ 8,011,500 | $ 400,575 |
| 4 | Permits | 8% | % | $ 20,843,529 | $ 1,667,482 | 5% | % | $ 4,811,500 | $ 240,575 | 5% | % | $ 8,011,500 | $ 400,575 |
| 5 | Construction Management | 5% | % | $ 20,843,529 | $ 1,042,176 | 5% | % | $ 4,811,500 | $ 240,575 | 5% | % | $ 8,011,500 | $ 400,575 |
| | **Professional Services Total** | | | | **$ 3,826,835** | | | | **$ 766,725** | | | | **$ 1,246,725** |
| | **Contingency** | **30%** | **%** | **$ 24,670,364** | **$ 7,401,109** | **30%** | **%** | **$ 5,578,225** | **$ 1,673,468** | **30%** | **%** | **$ 9,258,225** | **$ 2,777,468** |
| | **Project Total** | | | | **$ 32,071,474** | | | | **$ 7,251,693** | | | | **$ 12,035,693** |
| | **Project Total Rounded** | | | | **$ 32,000,000** | | | | **$ 7,000,000** | | | | **$ 12,000,000** |

Notes:
1 Mobilization is 5% of all items except Beach Nourishment. Beach Nourishment mobilization assumed to be lump sum amount of $2.5M but could vary depending on the type of marine equipment used
2 Beach nourishment assumes 300,000 cy initial plus 2 later individual 150,000 cy renourishment events
3 Adaptation of groin structures assumes 25% of the initial line item cost for modifications at end of pilot phase.

**City of Oceanside**
**Sand Retention Feasibility Study**
**Opinion of Probable Cost for Alternatives**

## Opinion of Costs for Alternative 3 - SLRR Groin Mods

Date: 6/25/2021

| Item | Item Description | Phase 1 (Initial - 2030) Qty | Unit | Rate | Amount | Phase 2 (2030 - 2035) Qty | Unit | Rate | Amount | Phase 3 (2035 - 2040) Qty | Unit | Rate | Amount |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project Construction Costs** | | | | | | | | | | | | | |
| 1 | Mobilization (% other items see note 2) | 5% | % | $ 2,784,485 | $ 139,224 | | | | $ - | | | | $ - |
| 2 | Traffic Control | 1 | LS | $ 150,000 | $ 150,000 | | | | $ - | | | | $ - |
| 3 | Beach nourishment mobilization | 1 | LS | $ 2,500,000 | $ 2,500,000 | | | | $ - | | | | $ - |
| 4 | Beach nourishment | 300,000 | CY | $ 15 | $ 4,623,000 | | | | $ - | | | | $ - |
| 5 | SLR Groin mods (300' ext.) | 9,000 | CY | $ 293 | $ 2,634,485 | | | | $ - | | | | $ - |
| 6 | Maint. beach nourishment mobilization | - | LS | $ 2,500,000 | $ - | 1 | LS | $ 2,500,000 | $ 2,500,000 | 1 | LS | $ 2,500,000 | $ 2,500,000 |
| 7 | Maint. beach nourishment | - | CY | $ 15 | $ - | 300,000 | CY | $ 15 | $ 4,623,000 | 300,000 | CY | $ 15 | $ 4,623,000 |
| 8 | Adaptation (see note 3) | | | | | | | | | 1 | LS | $ 1,300,000 | $ 1,300,000 |
| | **Project Construction Costs Total** | | | | **$ 10,046,709** | | | | **$ 7,123,000** | | | | **$ 8,423,000** |
| **Project Professional Services Items** | | | | | | | | | | | | | |
| 1 | Geotechnical Investigations | 1 | LS | $ 50,000 | $ 50,000 | 1 | LS | $ 25,000 | $ 25,000 | 1 | LS | $ 25,000 | $ 25,000 |
| 2 | Survey | 1 | LS | $ 25,000 | $ 25,000 | 1 | LS | $ 20,000 | $ 20,000 | 1 | LS | $ 20,000 | $ 20,000 |
| 3 | Design | 5% | % | $ 10,046,709 | $ 502,335 | 5% | % | $ 7,123,000 | $ 356,150 | 5% | % | $ 8,423,000 | $ 421,150 |
| 4 | Permits | 8% | % | $ 10,046,709 | $ 803,737 | 5% | % | $ 7,123,000 | $ 356,150 | 5% | % | $ 8,423,000 | $ 421,150 |
| 5 | Construction Management | 5% | % | $ 10,046,709 | $ 502,335 | 5% | % | $ 7,123,000 | $ 356,150 | 5% | % | $ 8,423,000 | $ 421,150 |
| | **Professional Services Total** | | | | **$ 1,883,408** | | | | **$ 1,113,450** | | | | **$ 1,308,450** |
| | **Contingency** | **30%** | **%** | **$ 11,930,116** | **$ 3,579,035** | **15%** | **%** | **$ 8,236,450** | **$ 1,235,468** | **15%** | **%** | **$ 9,731,450** | **$ 1,459,718** |
| | **Project Total** | | | | **$ 15,509,151** | | | | **$ 9,471,918** | | | | **$ 11,191,168** |
| | **Project Total Rounded** | | | | **$ 16,000,000** | | | | **$ 9,000,000** | | | | **$ 11,000,000** |

Notes:

1 Assumes similar head section geometry of groin alternatives applied to end of existing SLR groin.
2 Mobilization is 5% of all items except Beach Nourishment. Beach Nourishment mobilization assumed to be lump sum amount of $2.5M but could vary depending on the type of marine equipment used
3 Beach nourishment assumes 300,000 cy initial plus 2 later individual 300,000 cy renourishment events
4 Adaptation of groin structure assumes 50% of the initial line item cost for modifications at end of pilot phase.

**City of Oceanside**
**Sand Retention Feasibility Study**
**Opinion of Probable Cost for Alternatives**

## Opinion of Costs for Alternative 4 - MP Reefs

Date: 6/25/2021

| | | Phase 1 (Initial - 2030) | | | | Phase 2 (2030 - 2035) | | | | Phase 3 (2035 - 2040) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Item** | **Item Description** | **Qty** | **Unit** | **Rate** | **Amount** | **Qty** | **Unit** | **Rate** | **Amount** | **Qty** | **Unit** | **Rate** | **Amount** |
| **Project Construction Costs** | | | | | | | | | | | | | |
| 1 | Mobilization (% other items see note 1) | 5% | % | $ 51,939,013 | $ 2,596,951 | | | | $ - | | | | $ - |
| 2 | Traffic Control | 1 | LS | $ 150,000 | $ 150,000 | | | | $ - | | | | $ - |
| 3 | MP Reefs armor stone | 230,000 | CY | $ 225 | $ 51,789,013 | | | | $ - | | | | $ - |
| 4 | Beach nourishment mobilization | 1 | LS | $ 2,500,000 | $ 2,500,000 | | | | $ - | | | | $ - |
| 5 | Beach nourishment | 300,000 | CY | $ 15 | $ 4,623,000 | | | | $ - | | | | $ - |
| 6 | Maint. beach nourishment mobilization | - | LS | $ 2,500,000 | $ - | 1 | LS | $ 2,500,000 | $ 2,500,000 | 1 | LS | $ 2,500,000 | $ 2,500,000 |
| 7 | Maint. beach nourishment | - | CY | $ 15 | $ - | 150,000 | CY | $ 15 | $ 2,311,500 | 150,000 | CY | $ 15 | $ 2,311,500 |
| 8 | Adaptation (see note 3) | | | | | | | | | 1 | LS | $ 25,900,000 | $ 25,900,000 |
| | **Project Construction Costs Total** | | | | **$ 61,658,964** | | | | **$ 4,811,500** | | | | **$ 30,711,500** |
| **Project Professional Services Items** | | | | | | | | | | | | | |
| 1 | Geotechnical Investigations | 1 | LS | $ 50,000 | $ 50,000 | 1 | LS | $ 25,000 | $ 25,000 | 1 | LS | $ 25,000 | $ 25,000 |
| 2 | Survey | 1 | LS | $ 25,000 | $ 25,000 | 1 | LS | $ 20,000 | $ 20,000 | 1 | LS | $ 20,000 | $ 20,000 |
| 3 | Design | 5% | % | $ 61,658,964 | $ 3,082,948 | 5% | % | $ 4,811,500 | $ 240,575 | 5% | % | $ 30,711,500 | $ 1,535,575 |
| 4 | Permits | 8% | % | $ 61,658,964 | $ 4,932,717 | 5% | % | $ 4,811,500 | $ 240,575 | 5% | % | $ 30,711,500 | $ 1,535,575 |
| 5 | Construction Management | 5% | % | $ 61,658,964 | $ 3,082,948 | 5% | % | $ 4,811,500 | $ 240,575 | 5% | % | $ 30,711,500 | $ 1,535,575 |
| | **Professional Services Total** | | | | **$ 11,173,613** | | | | **$ 766,725** | | | | **$ 4,651,725** |
| | **Contingency** | **30%** | **%** | **$ 72,832,577** | **$ 21,849,773** | **30%** | **%** | **$ 5,578,225** | **$ 1,673,468** | **30%** | **%** | **$ 35,363,225** | **$ 10,608,968** |
| | **Project Total** | | | | **$ 94,682,350** | | | | **$ 7,251,693** | | | | **$ 45,972,193** |
| | **Project Total Rounded** | | | | **$ 95,000,000** | | | | **$ 7,000,000** | | | | **$ 46,000,000** |

Notes:

1 Mobilization is 5% of all items except Beach Nourishment. Beach Nourishment mobilization assumed to be lump sum amount of $2.5M but could vary depending on the type of marine equipment used

2 Beach nourishment assumes 300,000 cy initial plus 2 later individual 150,000 cy renourishment events

3 Adaptation of reef structures assumes 50% of the initial line item cost for modifications at end of pilot phase.

# APPENDIX D

**Scripps Institute of Oceanography Scientific Monitoring Plan**

**March 08, 2021**

**Scientific Monitoring Plan – DRAFT**

Submitted by Dr. Adam Young, Laura Engeman, Scripps Institution of Oceanography

# 1. Introduction

Our understanding is that the City of Oceanside is considering various sand retention and sand replenishment strategies to help combat the effects of chronic erosion of their shoreline. These strategies consist of artificial reefs, groins and various mechanisms to redistribute or deliver sand to southern Oceanside beaches. The City's approach for this Project would be to pilot a recommended strategy to show proof of concept before implementing the full strategy. The pilot project would be carefully monitored for physical, biological and social performance for a period of time before moving forward. SIO was engaged by GHD to support the Project in the development of a scientific baseline and monitoring strategy/framework for this Project. A scientific baseline survey was conducted on January 14, 2021 of both the beach and nearshore profile.

The project area is assumed to extend from the Oceanside Pier to Buena Vista Lagoon where the beach retention or nourishment strategies are expected to be deployed. Given this reach, our proposed monitoring area would extend from the Oceanside Harbor to Agua Hedionda Lagoon.

# 2. Purpose

To develop a suite of scientifically robust monitoring strategies that would help inform the understanding of beach processes and changing conditions in Oceanside. If implemented, the monitoring program would evaluate beach response to a sand replenishment or sand retention pilot project and inform management actions (e.g., structure modification or where to place sand).

The monitoring strategies leverage available data and resources to support the evaluation of the proposed sand retention and nourishment strategies and are specifically focused on monitoring potential downdrift impacts (i.e., how any neighboring beaches may be affected by these strategies). The proposed monitoring plan does not address biological monitoring.

# 3. Proposed Sand Retention and Nourishment Project Overview

## 3.1 Sand Retention Pilot Project:

The proposed sand retention pilot project would install 4 groins or two artificial reefs south of the Oceanside Pier. (Figure 1).

*Figure 1 Example configuration in Oceanside.*

## 3.2 Sand Replenishment Sediment Management Option:

The proposed sand replenishment project would use a series of underground pipelines with a mobile bypass system or other method to redistribute sand within the City. This option would source sand from areas where sand is abundant and transport it to areas of need. The replenishment strategy would also seek to modify the federal maintenance dredging program placement regime to either 1) place sand further south within the City or to 2) place sand in the fall when the predominate longshore current is to the south. (Figures 2).

*Figure 2 Potential sites for Oceanside sand sourcing*

# 4. Proposed Sand Retention and Replenishment Pilot Monitoring Plan

## 4.1 Sand Retention and Replenishment Monitoring Strategy

The proposed monitoring strategies seek to answer the following questions:

1. Pilot sand retention and/or replenishment pilot performance – has the pilot resulted in increased beach widths and/or sand volume as compared to baseline?
2. Downdrift and sand sources impacts – has the sand retention pilot impacted adjacent or neighboring beaches as compared to baseline conditions and has the sand replenishment pilot impacted beaches were sand was sourced?
3. How has the sand retention and/or sand replenishment pilot responded to extreme oceanographic conditions (waves, tides, sea levels, runup, overtopping) during the study period? (i.e. response to extreme conditions compared with other nearby beach areas and pilot response to extreme conditions over time as beach width/volume potentially expands)
4. How has the pilot impacted recreation (passive and active uses of the beach) and public safety?

Each monitoring approach is assigned a relative importance score (ranging low to high) to address the overall task and objectives. Some monitoring approaches are complementary and/or redundant and the relative importance score depends on what monitoring approaches are selected.

### 4.1.1 Routine Monitoring

**(Relative importance = High)** Topographic surveys should be pre and post construction, and then conducted monthly or quarterly to capture annual maximum and minimum elevation conditions. Bathymetric surveys should be conducted quarterly to monitor offshore sand elevations throughout the study area and around the harbor mouth. These surveys might consist of a combination lidar, jet ski GPS based surveys, ARGUS, etc. These surveys can be compared to historical survey data to determine regional sediment changes and effectiveness of the project. Pre and post nourishment surveys could be timed with quarterly or monthly routine surveys.

**(Relative importance = Med-High)** Community-conducted surveys: If topographic surveys are run only on a quarterly basis, it is suggested that monthly community beach surveys be conducted to provide more frequent assessments of sediment changes.

**(Relative importance = low)** Seasonal sand sampling (or photo-based grain size analysis) should be conducted to monitor potential change is grain size distribution than can influence beach morphology, runup, and surfing conditions.

Routine monitoring should continue for a minimum of 5 years to monitor the site in a range of wave conditions and evaluate potential long-term impacts.

### 4.1.2 Extreme Event Monitoring

**(Relative importance = med-high)** Routine surveys should be supplemented by post storm event surveys to capture beach storm response and response elevated wave and tide conditions. Backshore flooding and damage should be documented with field observations.

Topographic surveys should be conducted post storm events. These surveys might consist of a combination lidar, jet ski GPS based surveys, ARGUS, etc. These surveys can be compared to ongoing survey data to determine regional sediment changes and effectiveness of the project. CDIP and SIO-MOP data would provide information on tide/wave/wind conditions to evaluate relative storm intensity.

**(Relative importance = Med-High)** Community-conducted surveys: If topographic surveys are not possible, it is suggested that community beach surveys be conducted to provide an assessment of post-storm sediment conditions. Community surveys, lifeguard reports, and surfline cameras could also be used to document post storm field conditions.

### 4.1.3 Downdrift and Sand Source Impacts

**(Relative importance = High)** Detailed analysis and monitoring should be conducted downdrift of project locations to evaluate impacts to neighboring beaches. Downdrift impacts are particularly important for any sand retention strategies. For the proposed sand replenishment pilots, detailed analysis and monitoring should also be conducted at sand removal locations to evaluate impacts.

### 4.1.4 Oceanographic Analysis

**(Relative importance = Med)** Potential changes to nearshore wave energy and currents that could impact sediment dynamics and recreation activities should be monitored. Monitoring could consist of a combination or offshore and in situ sensors, video monitoring (Argus video), etc.

### 4.1.5 Recreational Impact

**(Relative importance = High)** Impacts to recreation such as swimming, surfing, boating, and beach activities should be documented quantitatively if possible. For example, methods to count the number of people in video images could be developed for a quantitative metric of beach use. Monitoring should include safety issues such as rip currents and dangers associated with any new hard structures. Monitoring techniques could include a combination of field documentation, video monitoring, etc.

***Table 1 Monitoring strategies and metrics***

| Name | Monitoring question this helps inform? | Monitoring Goal | Metric/ Analysis | Monitoring Approach | Potential leveraged resources |
|---|---|---|---|---|---|
| Routine Monitoring | 1,2,4 | Compare and evaluate sediment accretion and retention following the implementation of the pilot sand retention strategy (“Baseline and As Built Conditions”) and pre/post sand replenishment conditions | Change in beach sand volume and beach width before and post sand retention structure construction and before and after sand replenishments.<br><br>Changes in sand size distributions | Pre and post baseline surveys of beach topography<br>Monthly or quarterly topographic beach surveys and quarterly bathymetry<br><br>Monthly community-conducted beach surveys<br><br>Sand Sampling<br><br>Argus video | SIO LiDAR seasonal surveys (2017-2021) of Oceanside if continued.<br><br>SIO quarterly LiDAR (subaerial topography) and jet-ski (nearshore bathymetry) surveys could be expanded to include Oceanside<br><br>The piloted community-led monthly beach width monitoring with GPS if continued.<br><br>Historical and ongoing beach surveys (SANDAG’s regional shoreline monitoring program, historical airborne lidar, etc). |

| Name | Monitoring question this helps inform? | Monitoring Goal | Metric/ Analysis | Monitoring Approach | Potential leveraged resources |
|---|---|---|---|---|---|
| Extreme Event Monitoring | 3 | Evaluate beach and backshore response to large coastal events to determine performance of strategies and additional nourishment/ maintenance needs | Change in beach sand volume and/or beach width<br><br>Wave runup and overtopping<br><br>Comparative response to other north county beaches<br><br>Evidence of overtopping, flooding, and backshore damage | Post event topographic survey<br><br>Post event community-beach width surveys<br><br>Post storm field inspection to document (photos, etc.) overtopping, flooding, backshore erosion, and infrastructure damage<br><br>Argus Video | CDIP buoys<br><br>SIO-MOP Data<br><br>Surfline Cameras<br><br>Lifeguard Logs/Reports<br><br>If continued, the piloted community-led program could be expanded to also conduct post-event monitoring of beach width. |
| Downdrift Impacts | 2 | Evaluate sediment downdrift impacts<br><br>Evaluate sand source impacts (if applicable) | Compare sediment accretion on adjacent beaches, offshore, sand source locations (if applicable), and around the harbor mouth | Monthly or quarterly topographic beach surveys and quarterly bathymetry to evaluate sediment volume changes | Seasonal SIO LiDAR surveys of Carlsbad beaches if continued<br><br>Agua Hedionda Lagoon monitoring<br><br>Potential Buena Vista Lagoon monitoring<br><br>Historical and ongoing beach surveys (SANDAG's regional shoreline monitoring program, historical airborne lidar, etc). |
| Oceanographic Analysis | 3 | Evaluate changes in wave and currents | Waves<br><br>Currents | Monitor wave energy and nearshore currents<br><br>Argus video | CDIP buoys<br><br>SIO MOP Data |
| Recreational Impacts | 4 | Evaluate recreational benefits and/or impacts | Surfing conditions<br><br>Rip currents<br><br>Changes in days beach accessible | Video monitoring of surf conditions, number of people in the water and on beach | Surfline daily reports and cameras<br><br>Community monitoring program if continued |

| Name | Monitoring question this helps inform? | Monitoring Goal | Metric/ Analysis | Monitoring Approach | Potential leveraged resources |
| --- | --- | --- | --- | --- | --- |
| | | | Changes in monthly average beach area (towel availability) | Monthly or topographic beach surveys<br><br>Lifeguard rip current monitoring<br><br>Community-led monthly surveys of beach width and days when beach completely submerged | |

## 4.2 Example of Scientific Monitoring Strategies:

### 4.2.1 Sand Retention Pilot Project:

- Quarterly topographic surveys (lidar) from Oceanside Harbor to Tamarack Beach
- Quarterly bathy Harbor to Buena Vista Lagoon, transects spaced max 200 m apart. Should include harbor mouth area. (Figure 3)
- Monthly topographic surveys Harbor to Buena Vista Lagoon
- Post storm event topographic monitoring and field inspection
- Offshore in situ current monitoring
- Argus video monitoring

### 4.2.2 Sand Replenishment Project:

- Quarterly topographic surveys (lidar) from Harbor to Tamarack
- Quarterly topographic surveys (lidar) from Santa Margarita River to Harbor – If sand is sourced from Camp Pendleton
- Quarterly bathy Harbor to Buena Vista Lagoon, transects spaced max 200 m apart. Should include harbor mouth area (Figure 3).
- Monthly topographic surveys Harbor to Buena Vista Lagoon
- Post storm event topographic monitoring and field inspection
- Pre and post topographic monitoring during sand shifting operations
- Offshore in situ current monitoring
- Argus video monitoring

*Figure 3 Survey transects used for the SIO January 2021 bathymetric survey.*

## 4.3 Annual Harbor Dredging and Additional Considerations:

The US Army Corps of Engineers dredges the Oceanside harbor to maintain safe vessel passage and typically places the dredged sand on the beaches south of the pier. The volume of dredge material varies but averages approximately 250,000 cubic yards per year (Figure 4). The City of Oceanside should coordinate with the US Army Corps of Engineers to develop a strategic approach for sand placement that compliments the potential groin and sand-shifting projects. For example, dredged sediment could help offset potential negative groin impacts identified through the monitoring program. Topographic and bathymetric surveys should be coordinated with the US Army Corps of Engineers dredging schedules to assist in monitoring placed dredged material and could also help inform dredge operations.

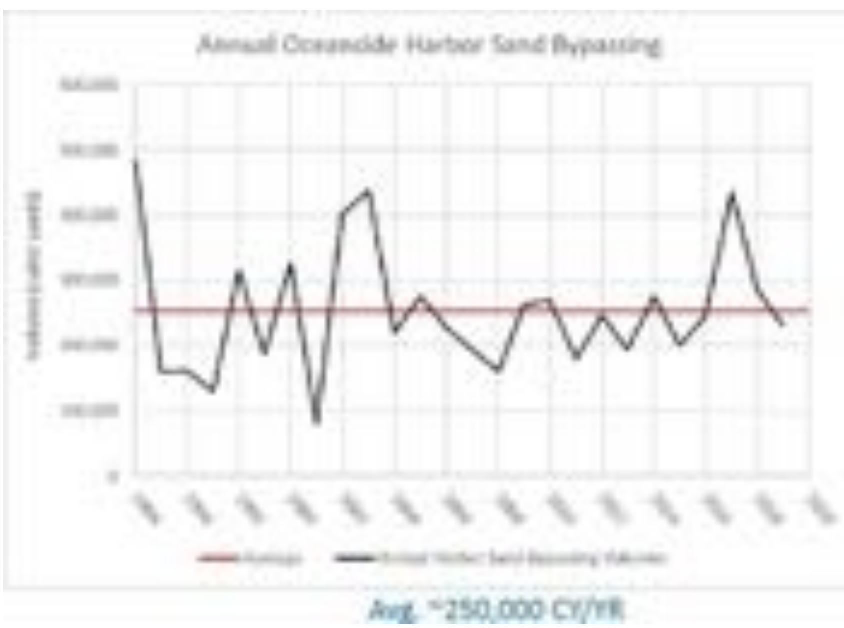


*Figure 4 Annual sand bypassing at Oceanside Harbor*