CARDIFF BEACH LIVING SHORELINE PROJECT

FINAL FEASIBILITY STUDY

Prepared by:

Moffatt & Nichol
1660 Hotel Circle North, Suite 500
San Diego, CA 92108

San Elijo Lagoon Conservancy
PO Box 230634, Encinitas
CA 92023-0634

Prepared for:

City of Encinitas
505 South Vulcan Ave.
Encinitas, CA 92024

California State Coastal Conservancy
1330 Broadway #1300
Oakland, CA 94612

FEBRUARY 2016

ES1. EXECUTIVE SUMMARY

The southernmost shoreline segment in the City of Encinitas between Restaurant Row and South Cardiff State Beach has been identified as being extremely vulnerable to projected rates of sea level rise (SLR) and coastal flooding. In the past, high tides and high surf caused over 42 road closures along this low-elevation barrier spit fronting the San Elijo Lagoon on which Coast Highway 101 (HWY 101) and numerous utility corridors are located. HWY 101 also provides critical protection for the San Elijo Lagoon and emergency access to Solana Beach.

Under a grant from the California State Coastal Conservancy (CSCC), the City of Encinitas has contracted with a consultant team to analyze the feasibility of dune restoration concepts along this vulnerable segment of shoreline. A total of four Stakeholder Workgroup meetings were conducted during concept development in order to collaborate on constraints and opportunities and to build consensus around an alternative. Workgroup meetings were attended by members of the CSCC, California Coastal Commission (CCC), State Parks, San Elijo Lagoon Conservancy (SELC), Scripps Institute of Oceanography (SIO), Department of Fish and Wildlife (DFW), the San Diego Association of Governments (SANDAG), U.S. Army Corps of Engineers (USACE), and the Surfrider Foundation. Three alternatives were considered during design, as follows:

- Alternative 1 - Exposed Cobble Dune: Consisted of an exposed cobble face constructed from approximately 5,000 cubic yards (cy) of imported sand and 15,000 cy of reconfigured and imported cobble to form the proposed section.
- Alternative 2 - Sand Dune: Dune constructed purely of imported sand. Approximately 20,000 cy of sand is needed to construct this Alternative.
- Alternative 3 - Buried Cobble Dune: Hybrid of Alternatives 1 and 2 that consisted of a cobble core buried with imported sand. This Alternative would consist of approximately 10,000 cy of imported sand and 10,000 cy of reconfigured or imported cobble to form the proposed section.

Based on the results of a site-specific numerical modeling effort and in coordination the Stakeholder Workgroup, the Project Team determined that a modified Alternative 3 is preferred. The Alternative would: 1) reconfigure/repair the existing rip rap into an engineered revetment form; 2) reconfigure existing cobble into a dune core; 3) create a sand dune feature to be planted/seeded with native habitat; and 4) create pedestrian improvements along HWY 101.

The Preferred Alternative would meet established Project goals and objectives in the short-term by reducing the vulnerability of HWY 101 to undermining and flooding, create dune habitat and beneficially reuse export sand from the San Elijo Lagoon Restoration Project (SELRP). Periodic maintenance of the Project due to erosion events is anticipated in the form of dune nourishment. Dune nourishment could be accommodated by the annual San Elijo Lagoon inlet dredging.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

The City of Encinitas (City), in partnership with the San Elijo Lagoon Conservancy (SELC), the California State Coastal Conservancy (SCC), and California State Parks, proposes to create a dune system on the seaward side of Highway 101 (HWY 101) on Cardiff State Beach to serve as a natural sea level rise (SLR) adaptation approach to protect a vulnerable segment of the roadway while providing native dune habitat. The highway has been damaged and flooded on numerous occasions in the past as a result of extreme wave events and high tides. Increased still water levels associated with projected SLR would result in increased frequency and severity of flooding and damage to the highway.

Coastal dune systems have been found to provide multiple benefits by providing coastal habitat and storm damage reduction during extreme events. The Cardiff Beach Living Shoreline Project (Project) proposes to beneficially re-use export materials generated from the San Elijo Lagoon Restoration Project (SELRP) or another opportunistic source for the dune construction. The SELRP is proposed to be restored with work beginning in winter 2017 and continuing through 2019. Construction of the Project is estimated to yield approximately one million cubic yards (cy) of export material. The sandy export material from this Project has been determined to be beach compatible and a number of different placement options are being considered. A portion of these materials are proposed to be used for this Project to construct the dune system. The dune would be created along the back beach to minimize impacts to the existing recreational beach.

The proposed Project area spans 2,900 linear feet (about 0.5 mile) of shoreline, from the Chart House Restaurant to the north to just before the South Cardiff State Beach Parking Lot to the south (Figure 1 and Figure 2). Moffatt & Nichol (M&N) and the SELC are under contract with the City to prepare a feasibility study to evaluate viable dune restoration options for the site. The Project is being funded through a grant from the SCC.

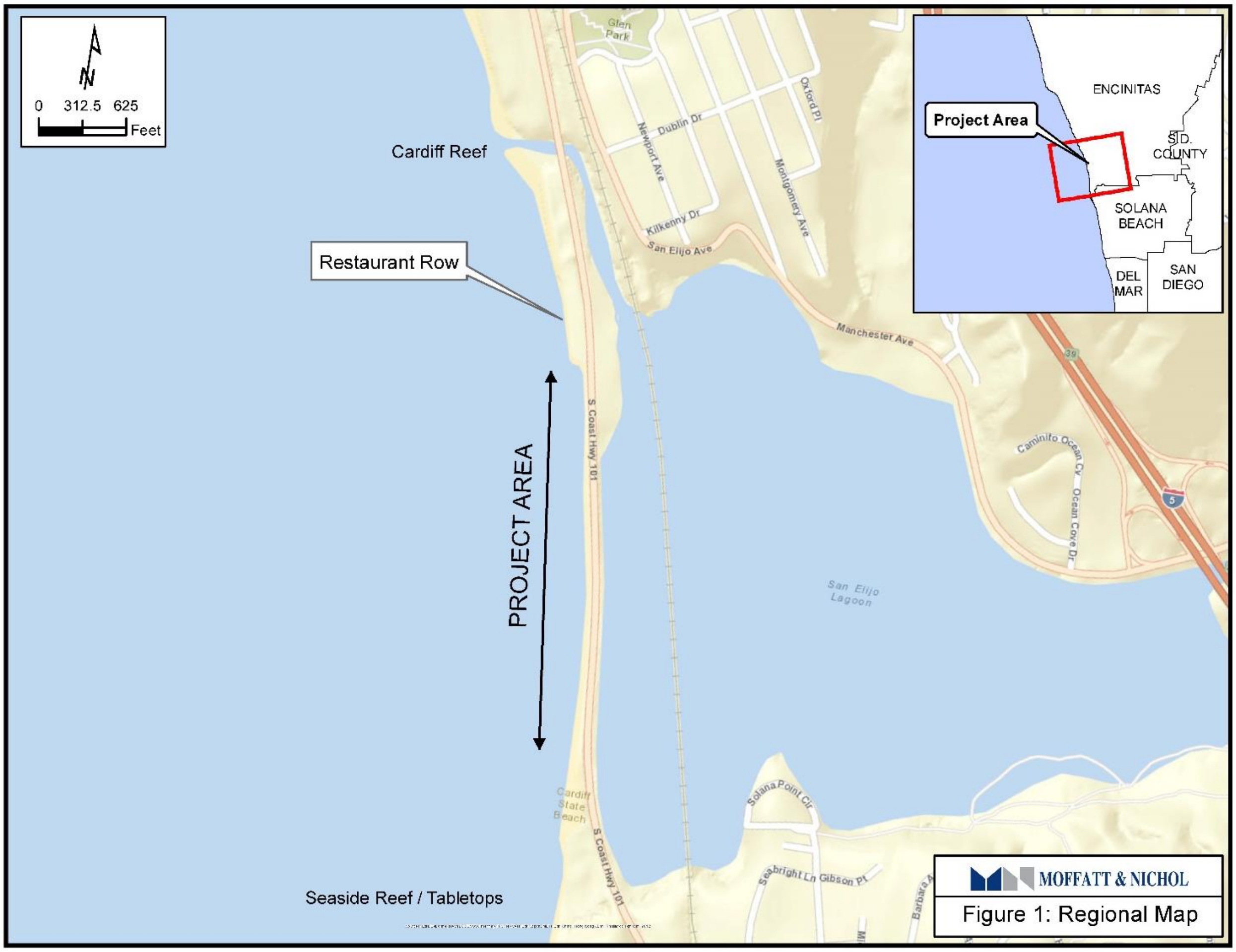


Figure 1: Project Vicinity

Figure 2: Project Location

2. EXISTING SITE CONDITIONS

The Project area consists of a low-lying, cobble and sand barrier spit fronting the San Elijo Lagoon. The beach is backed by a natural cobble berm and rip rap. The beach has been nourished twice recently (2001 and 2012) as part of the Regional Beach Sand Project, as administered by the San Diego Association of Governments (SANDAG). These nourishment projects, in combination with a relatively benign wave climate, have resulted in a wide, sandy beach at this location. So much so, that the cobble berm and a portion of the rock riprap are currently buried by sand. Beach conditions during the 1998 El Niño as compared to present day, is shown in Figure 3.

Figure 3: Project Site Conditions (Left - Eroded Conditions during the 1998 El Niño. Right – Existing Conditions (9/2015)

The average beach width at the time of this report is approximately 100 feet, from the back beach to the mean high water line. The back beach (at the toe of the existing riprap) is at an average elevation of 12 feet (NAVD88). The crown elevation for HWY 101 along the Project reach varies from +15.5 to +18 feet NAVD88 from north to south.

Development in the vicinity of the proposed Project includes the Chart House restaurant to the north and South Cardiff State Beach parking lot to the south. Public vehicle parking exists parallel to HWY 101 along about a 1,000-foot reach of the Project area, which starts at Chart House and continues south.

The beach is owned and operated by State Parks. State Parks patrols the Project area beach with vehicles and utilizes one vehicular beach access point located within the north end of the Project Area. This access point will be accommodated in the Project design.

3. Project Goals and Objectives

The Project's goal is to develop a natural SLR adaptation approach to protect a vulnerable segment of Cardiff Beach by beneficially re-using export materials generated from the SELRP or another opportunistic sand source. The objectives of the Project are to:

- Decrease the vulnerability of HWY 101 and the San Elijo Lagoon to impacts from future rates of SLR through construction of a natural protective dune system;
- Provide an environmentally sensitive and beneficial reuse option for compatible dredge materials generated from the SELRP; and
- Create native dune habitat.

During project development, the Project's goals and objectives were revised as follows.

- Goals
  - Protect HWY 101 from SLR and storm events using nature-based features (i.e. living shoreline);
  - Utilize opportunistic sand sources to construct / maintain dune feature; and
  - Create native dune habitat.
- Objectives:
  - Create approximately 3 acres of sand dunes that are heterogeneous in structure (i.e. incorporate cobble & sand) with 10% or less absolute cover of woody perennial species, less than 5% absolute cover of non-native plant species, and native herbaceous species richness of four and achieving 10-30% native herbaceous cover, in proportion to reference site conditions for a given year.
  - Create sand dunes that will persist (albeit dynamically) for approximately 50 years (maintenance may be required).
  - Beneficially re-use native sediment from the lagoon mouth opening (approx. 25,000 cy / year).
  - Protect the highway from flooding and degradation now (i.e. El Niño events).
  - Protect the highway from flooding and degradation from storms and sea-level rise over the next 50 years.

4. SCOPE OF WORK

The scope of this study includes the following tasks:

1. **Concept Development:** Concept development is envisioned to consist of the following subtasks:
    a. Data Gathering & Assimilation - Research dune restoration projects and natural dune systems within the region. Review of dune restoration projects will focus on successes, challenges and lessons learned.
    b. Develop Dune Concepts and Probable Estimate of Construction Cost – Develop conceptual-level dune restoration concepts (assumed a maximum of 3) in collaboration with the Project Team and Partners. The dune concepts would focus on constructability, sustainability, and resilience while maintaining project goals and objectives. Schematic plan views, sections, cost estimates and renderings will be developed for the concept alternatives. The preferred alternative would be designed to the 30% level.
    c. Impact Analysis Report – Prepare a report that discusses potential Project impacts including visual impacts from HWY 101 (a scenic highway), sand placement/rip rap burial logistics, potential sand/dune erosion impacts (as evaluated through various site-specific numerical models), protection from wave run-up (also evaluated through site-specific modeling), beach access impacts, bike lane/pedestrian impacts and HWY 101 impacts (e.g. sand blowing from elevated dune).
2. **Seed Collection & Bulking**: Collect native coastal dune plant seeds for the proposed dune planting. Seed species to be collected and bulked include Abronia umbellata, Acmispon prostrates, Camissoniopsis cheiranthifolia subsp. Suffruticosa, Chaenactis glabriuscula var. orcuttiana, and Nemacaulis denudata var. denudate.
3. **Resource Agency Permitting:** Identify necessary permits for concept alternatives. Draft permit applications of Preferred Alternative.
4. **Prepare CEQA Compliance Document:** Work toward CEQA compliance document. Prepare project description and analyze the potential impacts associated with the proposed Project.

Results of Tasks 1 through 3 are presented in this report.

5. HISTORICAL PERSPECTIVE

HWY 101 was originally constructed by Caltrans in 1912 and was later realigned in 1926 to its present day location. HWY 101 and Interstate 5 (I-5) are the only two north to south arterials in this area of San Diego County. Thus, HWY 101 is critical to regional transportation, emergency evacuation, and homeland security. HWY 101 is currently owned and maintained by the City and supports approximately 20,000 average daily trips (ADT).

The highway has been damaged and flooded in the past when large wave events coincide with high tides. Such events occurred in late January and February of the 1983 El Niño. These events resulted in extensive beach erosion, flooding and undermining of the highway and projectile cobble that broke some windows along restaurant row (Kuhn and Shepard 1985). The rip rap in place along the beach was found to be ineffective in protecting the buildings and ½ ton boulders were thrown onto the highway by the waves (Kuhn and Shephard 1985). Larger rip rap has been placed in front these buildings since this event.

The January and February 1998 El Niño storms also resulted in major damage to this reach of shoreline. HWY 101 was temporarily closed or resulted in limited access more than 20 times during this season due to flooding or undermining (M&N 1998). A March 2010 storm also resulted in limited access along HWY 101 due to flooding and undermining in one section that prompted emergency repairs. Photographs of this event are provided in Figure 4.

Two beach nourishment projects have taken place at the Project site recently, which placed a total of 190,000 cy (Table 1). Additionally, the site has been identified as a receiving beach for two programs that aim to offset sediment losses in the region. These programs are the Coastal Regional Sediment Management Plan for the San Diego region (M&N et al. 2009) and the City's Opportunistic Beach Fill Program (M&N 2015). These programs are summarized in Table 1. The beach nourishment events and programs were taken into account during Project design (e.g. establishing baseline conditions for the site-specific model).

Table 1: Beach Nourishment Projects and Programs at Cardiff State Beach

Project	Lead Agency	Year	Nourishment Volume (cy)	Description
Regional Beach Sand Project I	SANDAG	2001	101,000	Placement of 101,000 cy from offshore borrow site.
Coastal Regional Sediment Management Plan	SANDAG & Coastal Sediment Management Workgroup	2009	NA	Proposed receiving beach for all identified sediment sources (offshore and opportunistic).
Regional Beach Sand Project II	SANDAG	2012	89,000	Placement of 89,000 cy from offshore borrow site.
Opportunistic Beach Fill Program Amendment	City	2015	NA	Site is identified as a receiving beach for opportunistically derived sand (i.e. upland, lagoon restoration, etc.)
TOTAL			190,000	

Flooding of HWY 101

Flooding of HWY 101

Wave-induced Undermining of HWY 101

Wave Attack on Revetment Fronting Restaurant Row

Figure 4: Coastal Flooding and Undermining in the Study Area (March 2010 Event)

6. BEACH WIDTH CHANGE

Beach width change was evaluated at the Project site at two historical beach profile transects within the study area (Figure 5). Beach width data were acquired from Coastal Frontiers Corporation (CFC) and Scripps Institution of Oceanography (SIO) for this analysis. CFC has collected beach profile data since 1997 at SD-0630 and 2000 at SD-0625. Biannual data collection at both transects began in 2000. Higher spatial and temporal resolution data have been collected at the site by SIO since 2007. SIO uses RTK methods affixed to jet skis and ATV to acquire topographic and bathymetric data from Cardiff Reef to Seaside Reef. In order to compare the longer CFC data record with the newer and more frequently-collected SIO data, 3D surfaces were created from SIO's survey data. Profiles were then sampled from these 3D surfaces at the two historic CFC monitoring transects.

Findings from the analysis suggest that beach widths at the Project site have varied from approximately 50 to 250 feet in width at the northern transect (Figure 6). Strong to moderate El Niño events in 1998 and 2010, respectively, are evident in the beach width data record and are shown in red. Enhanced beach widths, as a result of nourishment projects in 2001 and 2012, are apprerent in the data record and are shown in green.

Beach width at the southern transect has varied from approximately 0 to 250 feet from year 2000 to present (Figure 7). The beach width minimum was associated with the 2010 El Niño event. Damage to HWY 101 in the vicinty of this transect was experienced at that time. The maximum beach width occurred in 2013, which corresponds to the 2012 beach nourishment project.

Based on review of suvey data of the beach over the past 18 years, the mean sea level beach width along this reach averages from about 150 to 200 feet. This appears approximatley 100 feet wider than conditions experienced in the late 1990's early 2000s.

Figure 5: Beach Profile Locations

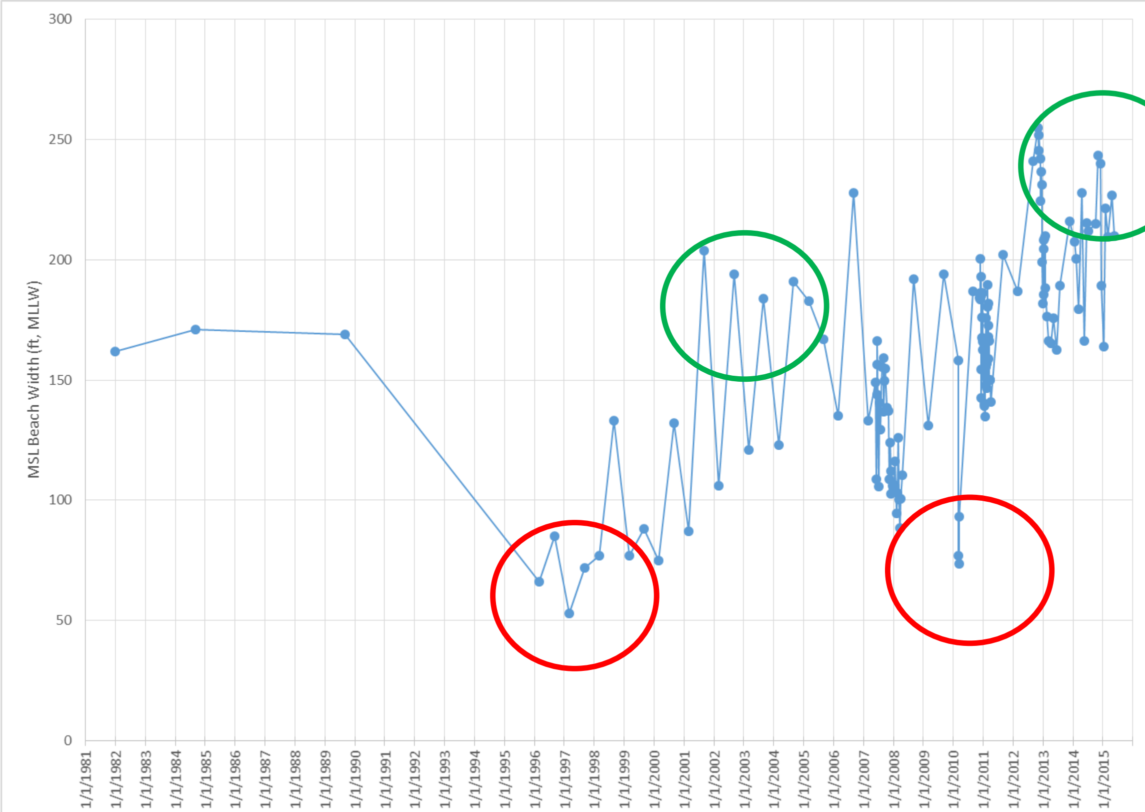


Figure 6: Beach Width Change at the Northern Transect (SD-0630)

El Niño Events (Red); Beach Nourishment Events (Green)

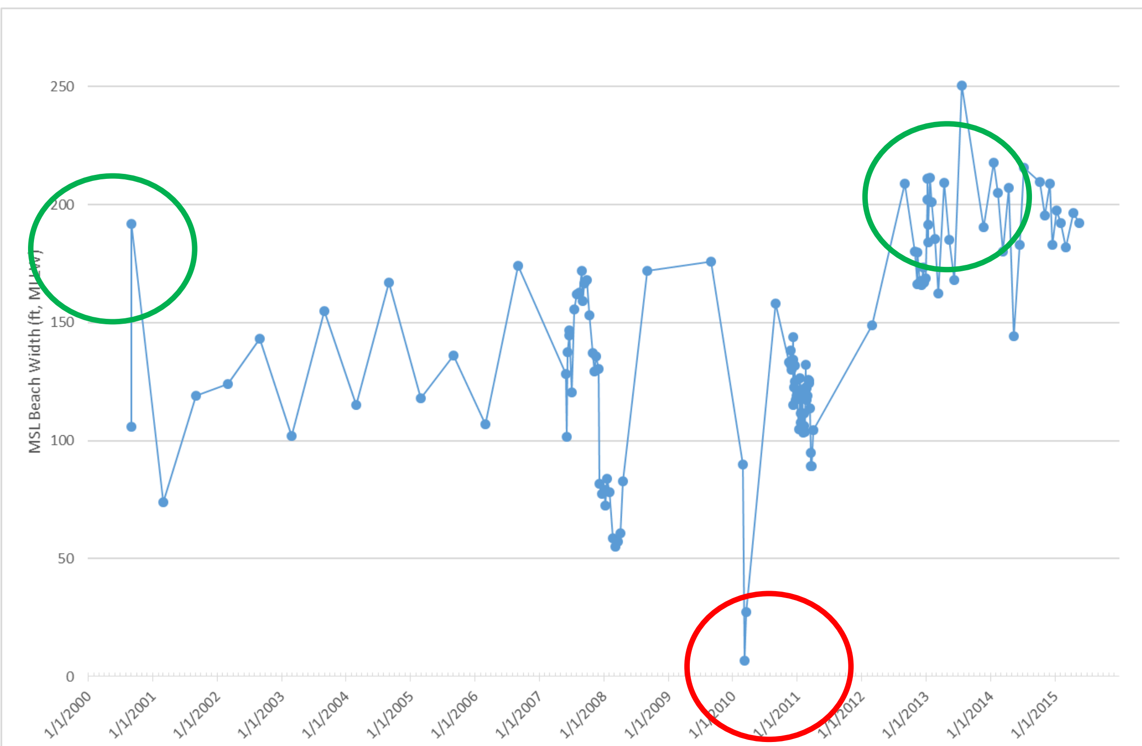


Figure 7: Beach Width Change at the Southern Transect (SD-0625)

El Niño Events (Red); Beach Nourishment Events (Green)

7. Nearshore Habitats

Offshore waters adjacent to the Project area are within a State Marine Conservation Area (SMCA) regulated by the Department of Fish and Wildlife (DFW). A SMCA is a Marine Protected Area (MPA) that may allow some recreational and/or commercial take of marine resources (restrictions vary). An allowance for dredging and fill exists within this SMCA. However, close coordination with the DFW will be needed during permitting of the proposed Project to avoid or minimize impacts to the SMCA.

Beach nourishment projects have the potential to impact nearshore biological resources through direct sediment burial and localized and short-term increases in turbidity. Offshore vegetation and hard substrate (indicative of nearshore reefs) in the vicinity of the Project site are shown Figure 8. Nearshore reef habitats are predominately to the north and south of the site with the exception of the habitat provided by the San Elijo Joint Powers Authority (JPA) ocean outfall pipe located central to and offshore of the Project site. The primary substrate in nearshore and intertidal areas seaward of the Project site is sand. These habitat areas also provide important forage areas for sport and commercial fisheries stock.

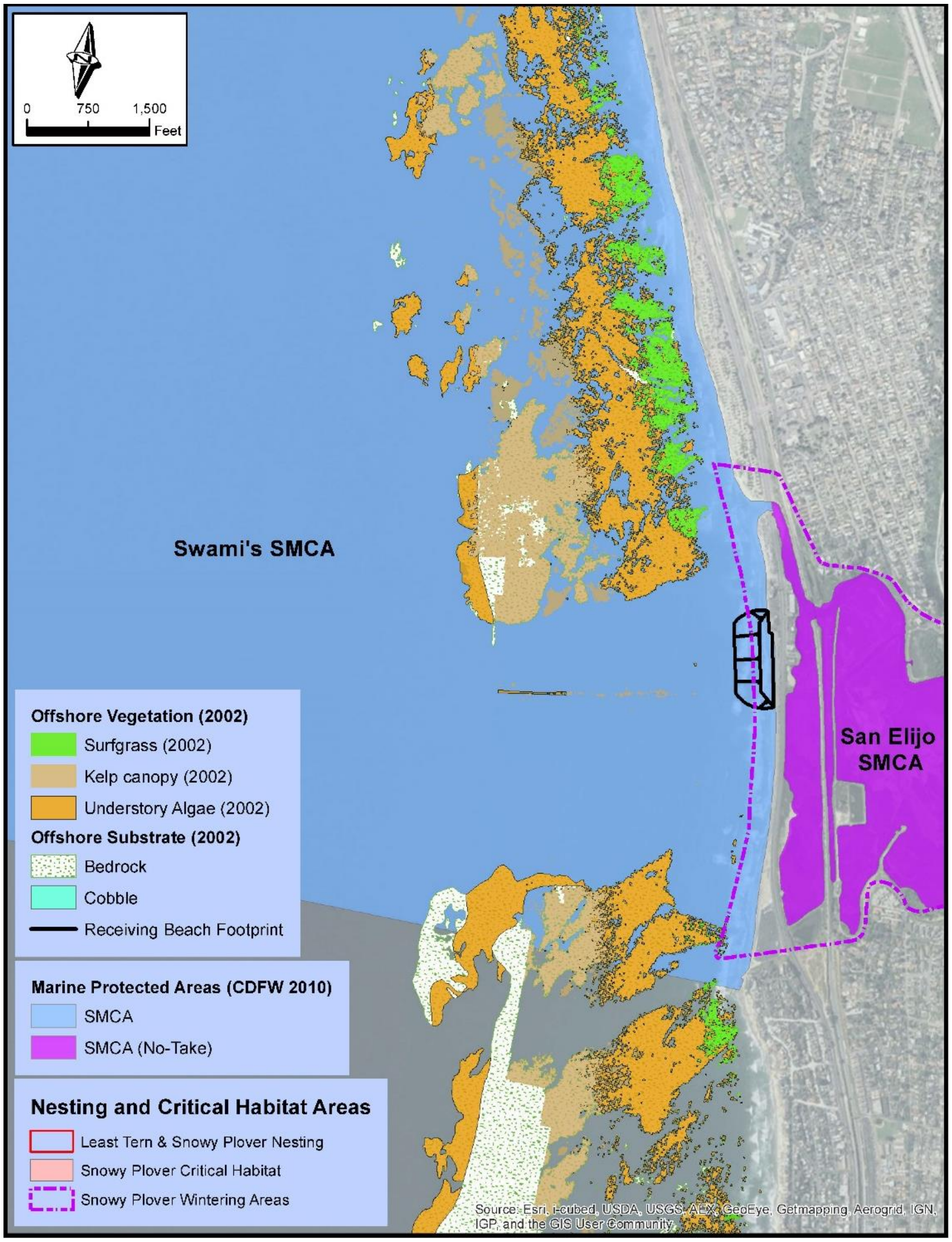


Figure 8: Biological Resources in the Project Area

8. DATA GATHERING AND ASSIMILATION

Several projects and studies were reviewed to support the design of the concept alternatives. These references are summarized below.

8.1. Surfer's Point Living Shoreline Project – Ventura, California (Buenaventura 2003)

The Surfer's Point Living Shoreline Project constructed a cobble berm and vegetated dunes in 2012 to restore the severely eroded shoreline just south of the Ventura River mouth, as shown in Figure 9. The project added 30,000 cy of cobble to the beach derived from the Santa Clara River. The 6- to 18-inch diameter cobble was formed into an 8-foot thick cobble berm. The cobble was then buried beneath 15,000 cy of sand that was then formed into dune features. The dunes were stabilized with native plant species and backed with a pedestrian trail and a parapet wall. The project also incorporated an element of managed retreat that reclaimed approximately 60 feet of land, which was previously occupied by a parking lot and a bike path.

Figure 9: Surfer's Point Living Shoreline Design (venturariver.org)

Since planting was completed in 2012, the dunes have been found to be stable and well-established with native species (Figure 10). Sterile rice straw was used during planting to stabilize the sand while vegetation was being established. The dune planting has also been effective at preventing blowing sand.


Pre-Project Condition


Removal of Parking Lot


Excavation of Retreat Zone/Cobble Berm


Importing of 6- to 18-inch Diameter Cobble


Construction of Cobble Berm


Construction of Parapet Wall

Constructed Dune with Established Plantings

Sterile Rice Straw used to Stabilize the Sand while Vegetation Established

Figure 10: Surfer's Point Construction Photos

8.2. Surfer's Point – Cobble Berm Test Section (Buenaventura 2003)

A cobble berm test section was constructed and monitored at Surfer's Point prior to the project being fully constructed. The test was conducted in September 2000. Two sections of varying berm face slopes were constructed with cobble from the Ventura River for a performance comparison. The section with a 5:1(H:V) slope held shape throughout the winter storms, whereas the section with a 3:1 (H:V) slope berm face flattened out. A 5:1 (H:V) slope was recommended for the project's berm face for stability.

8.3. Cobble Berm Design Guidelines (Buenaventura 2003)

Design considerations for gravel, cobble, and/or boulder (gcb) berms are provided for the Surfer's Point Project through analysis of five naturally-occurring, prototype berms (Del Mar, Cardiff, Batiquitos Lagoon, South Carlsbad and Emma Wood State Beach). Characteristics such as the crest elevation, gcb clast size, bermface slope, porosity, and bermface to shore platform were analyzed relative to the prototype berm's short-term and long-term response to a wave climate. A summary of the study's findings are as follows:

- Clast size – Berm stability increases with clast size.
- Size distribution – A more uniform gcb size is more stable than a wide range of sizes.
- Berm porosity – The berm should be limited to cobbles and/or boulders without including sand or gravel to promote water infiltration.
- Crest elevation – Allowance of some overtopping during the most extreme wave events increases the stability of the berm.
- Base elevation of the berm – The lower surface of the berm should be at or below the scour limit of the fronting shore platform. If this scour limit cannot be meet, a scour apron should be placed in front of the berm to prevent undermining.

- Compatibility with sand replenishment – The gcb is not incompatible with sand replenishment; however, the sand should not be placed atop the berm.

The study finds that a comparatively small gcb volume and footprint is needed to provide the same level of protection as a large sand replenishment. Cobble berms are commonly associated with sandy beaches in Southern California, thus, would be compatible for artificial use in the region.

8.4. C Street Cobble Berm (Venturariver.org)

Given the success of the Surfer's Point project, the City extended the cobble berm feature along 800 feet of shoreline to the east of the initial project. The project's goal was to effectively widen the beach and protect the bike path and other infrastructure from costly coastal damage. The project entailed the placement of 4,800 cy of cobble and 1,000 cy of sand topping. In addition, existing concrete and other debris encountered by this work would be removed (Figure 11). The project is recognized as a temporary fix (assumed approximately 10 years) that will require periodic maintenance in the form of future cobble nourishment.

Figure 11: C Street Cobble Berm Construction in 2014 (Venturariver.org)

8.5. Alternative Shore Protection Strategies (Dare 2003)

The study provides a concise guide of emergent technology options for shoreline management, based on theory and experience with their use. The five technologies reviewed include beach scraping, beach dewatering, cobble berms / dynamic revetments, artificial dunes, and artificial surfing reefs. The alternative concept, design, applications and management considerations are discussed for each. Since cobble berms and artificial dunes are components being considered as part of the proposed Project, findings relating to these features are summarized below.

Cobble berms are inexpensive to construct, natural in appearance, offer shoreline protection and are flexible under the attack of waves. However, storm waves can turn cobbles into projectiles that can result in damage to landside properties. Because of this potential, the use of cobble berms is safest backed by bluff or substantial dune or sufficient buffer to landside development. Other considerations include cobble berms offer less protection than a traditional revetment or seawall, require maintenance and do not provide the same protection as a sandy beach.

Coastal sand dunes provide shore protection for upland properties by sheltering them from storm surges and waves, and indirectly as an erodible supply of sand for the fronting beach. For this reason, construction of artificial dunes is frequently a component of beach nourishment projects. Geotextile tubes or bags are sometimes used as the core of an artificially constructed dune to provide protection that is greater than a natural dune and to protect the base of the dune during moderate wave attack. Due to the durability of these bags being uncertain, it is not recommended to depend on them for a source of long-term protection without maintenance.

8.6. Design with Nature (Komar and Allen 2010)

The study discusses the performance of a cobble berm and dune constructed in 2000 at Cape Lookout State Park, Oregon. The design consisted of a cobble berm and high vegetated back dune reinforced with sand-filled geotextile bags. Construction monitoring of the berm and dune showed the crest height to be approximately 3.3 to 6.6 feet below the recommended elevation that was intended to prevent wave overtopping. Although the northern end of the design was overtopped multiple times, the berm and dune have generally remained stable and have effectively protected the campground backing the dune (Figure 12).

Long-term monitoring of the project has shown a large reduction in the volume of cobbles following winter storms, as well as loss of sand and vegetation cover of the foredunes. The dune was nourished with sand in the summer of 2008 and the need for maintenance of the dunes were evident a decade after construction. Since then, it has been recommended to raise the dunes to the suggested elevation.

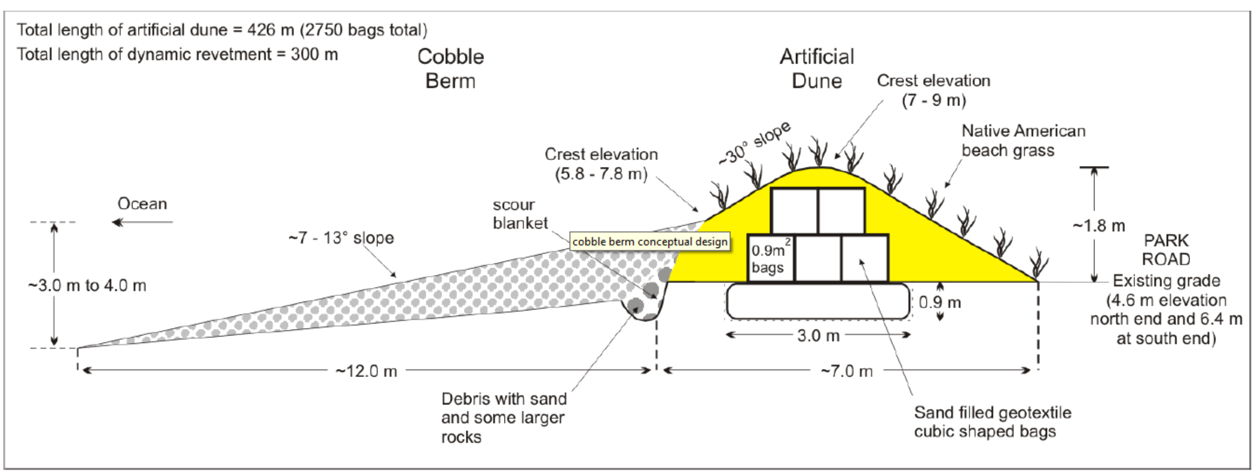


Figure 12: Cape Lookout Living Shoreline Design

8.7. Performance of Cobble Berms in Southern California (Everts et al. 2002)

This article focuses on the performance of the naturally-occurring cobble berm on beaches north and south of the Batiquitos Lagoon inlet. The cobble berm at these locations showed an out-of-phase seasonal fluctuations in sand and cobble. Specifically, during the winter, the sand retreated from the shoreline and the cobble accumulated, whereas the contrary occurred during the summer. The long-term change in the volume of cobbles may be inversely proportional to the volume of sand in the littoral cell. The cobble berm accreted during the strongest El Niño winter in the 20th Century and a very intense storm in 1988. The study found that a comparatively small volume of cobbles with a relatively small footprint is needed to provide the same level of protection as a large volume of sand.

Although cobble berms have performed well in Southern California, there is a lack of quantitative design guidance for their use for coastal protection on a sandy coast. For example, the optimum void ratio has not yet been determined; however, a few design elements have been determined. Larger clasts require less volume to provide coastal protection due to the decreased tendency to mix with sand. Higher cobble berms provide greater protection from property flooding; however, lower berms allow for some overwash that can be beneficial to stabilization. One way to optimize both flood protection and stability is to increase the width of the cobble berm.

8.8. Hurricane Sandy, Performance Evaluation Study (USACE 2013)

This report discusses the performance of USACE coastal protection projects along the east coast following Hurricane Sandy, which made landfall in the summer of 2012. The effectiveness of eight federal projects with and without dune features were compared. Federal beach nourishment projects with dune features were not overtopped during Hurricane Sandy, and thus resulted in less damages due to flooding. Federal projects that just involved a beach nourishment component were overtopped and resulted in more significant damages related to flooding. It was recommended that all federal beach nourishment projects evaluate the addition of a dune feature due to their economic benefits associated with coastal storm damage reduction.

8.9. Existing Utilities Research

Existing utilities along the Project area were researched to determined potential conflicts with the construction of the Project. Only two existing utilities were located within the Project area, as outlined below.

- San Elijo Joint Powers Authority (JPA) / Sewer Outfall: 36-inch concrete outfall line oriented perpendicular to shoreline.
- SDG&E – Gas: 4-inch supply line along the west edge of HWY 101 right of way.

These utilities are shown in the 30% design plans provided as Attachment B. A condition was set on RBSP II to place steel plates over the JPA's pipeline during all heavy equipment passing over the beach in that location in order to protect the underground pipeline. This condition will be carried into the design of this project. More information regarding the location and depth of the SDG&E gas line will be defined in a future task (final engineering design).

8.10 Dune Restoration Biology

Native coastal dune habitat restoration has been accomplished over large areas (> 5 acres) in northern California (Sawyer and Pickart 1998), but only attempted at small sites in southern California (SELC 2014). A dearth of published material exists on the subject. SELC relied upon experiences and lessons from northern California to help guide its efforts in San Elijo Lagoon Ecological Reserve, immediately east of HWY. 101.

The principal concepts borrowed from those efforts were invasive plant control and management of organic material left by those invasive plants. For all projects assessed, restoration was performed on existing dunes with existing invasive plant infestations. While the concepts are still important for this site, they may not be directly applicable given that introduced sand is being proposed as substrate upon which habitat restoration will occur.

The following references were reviewed to inform the Project's dune habitat creation:

Jones, W. 2010. Action Plan for the Conservation of Orcutt's Pincushion (*Chaenactis glabriuscula* var. *orcuttiana* (E. Greene) H. Hall) at Ballona Lagoon, Venice, California; Ballona Lagoon Phase III Enhancement Project (E6000776). Los Angeles Department of Water and Power.

Orcutt's Pincushion is a rare dune plant that is now present at very few sites in California, with one exception being the dune strand in the West Basin of San Elijo Lagoon Ecological Preserve. Based on the review of this study in Ballona Lagoon, it is anticipated that there may be early difficulties in propagating these plants in a pure dune creation project.

Lithgow, D. et. al. 2014. Restoration of Coastal Dune Index to Assess the Need and Viability of Coastal Dune Restoration. Elsevier; Amsterdam

The so-called "ReDune" index was tested on 31 sites along approximately 600 kilometers of the Gulf of Mexico in the state of Veracruz, Mexico. While developed as a prioritizing tool for evaluating the potential success of restoration (36 indicators), its value for this project resides in the identified design elements, stressors and impacts that either contribute to, or detract from the, the potential success of the recovery of a natural dune ecosystem. This includes anthropogenic influences such as direct, physical human pressure as well as an "interest in restoration" among surrounding communities. Identified elements, or "indicators", presented by the authors that have either a positive or negative influence on restoration success will inform restoration activities for the Project such as placement of fencing (affecting sediment dynamics), shaping the created dune and trail/pathway design that minimizes disturbance.

Native Solutions. 2005. Dune Habitat Restoration Plan, Marina Dunes Preserve, Marina, CA. Prepared for: Monterey Peninsula Regional Parks District; Monterey, CA

The goal of this restoration plan is to describe existing biological resources at Marina Dunes Preserve and to define procedures and standards for restoration of the native coastal landscape. The restoration program described will significantly improve habitat value by increasing the quantity and diversity of native species, as well as expanding the corridor of restored dunes around the Monterey Bay; it explores weed eradication, sand re-contouring and augmentation, sand stabilization, protective fencing and seed collection – all elements relevant to the proposed Project at Cardiff State Beach.

Novoa, A. et. al. 2014. Constraints to Native Plant Species Establishment in Coastal Dune Communities Invaded by *Carpobrotus edulis*: Implications for Restoration. Elsevier; Amsterdam

Ice Plant is a formidable invasive plant species that has already been identified as a problem on or in close proximity to the Project Site. This paper examines, at active restoration sites and in laboratory studies, the potential reasons that re-vegetation efforts with indigenous dune plants are constrained, from the standpoints of germination, propagation, survival and diversity, due to previous infestations of the subject invasive plant. The author's results showed that the desired direction of natural regeneration of soil can be speeded up by removing C. edulis litter from restored sites, combined with over-seeding of appropriate typical dune species. Otherwise, ruderal species will continue to compete more effectively with the desired native species and the plant species diversity of the restored area will likely remain markedly lower than in natural, non-invaded areas, not achieving the ultimate goal of dune restoration.

Point Reyes National Seashore. 2015. Coastal Dune Restoration Environmental Assessment. National Park Service; Washington D.C.

This comprehensive, 598-page document describes landscape-scale restoration in close proximity to multiple land uses and discusses numerous restoration approaches and methods as dictated by various access, resource and threatened-species protection and monitoring requirements based upon the varying topographies, existing flora, fauna and hydrologic conditions examined. Its value, for a variety of topics, is in the breadth of information presented and the number of dune references cited. It will serve as a valuable reference as the Project goes forward.

San Elijo Lagoon Conservancy. 2014. Project Final Report: Coastal Dune Habitat Restoration in the San Elijo Lagoon Ecological Reserve. U.S. Fish and Wildlife Service Agreement No. 81430-8-J013; Document No. F08AC00290.

Describes on-going restoration in the West Basin of the San Elijo Lagoon Ecological Reserve in close proximity to the Project Site. It is the primary source of seed stock for the palette intended for planting in the Project's dune creation. Site protection strategies, monitoring methods and the systematic removal and control of a monotypic stand of native vegetation interfering with potential nesting activities of protected birds and the natural propagation of dune plants provide guidance for a maturing dune environment.

Sapphos Environmental, Inc. 2004. Los Angeles/El Segundo Dunes Habitat Restoration Plan. Prepared for: U.S. Department of Transportation, FAA; Hawthorne, CA

A small restoration project in southern California that shares with the Project poor connectivity issues with related habitats and must deal with continued human pressure. It's value to the Project is in presented methods of reclamation of habitat from long-installed infrastructure.

Sawyer, J.O. and A.J. Pickart. 1998. Ecology and Restoration of Northern California Coastal Dunes. CNPS Press; Sacramento, CA.

An early practical guide to coastal dune restoration in northern California. It provides general information on planning such projects, revegetation strategies and was particularly helpful in developing SELC's approach to the removal and control of a large Arrowweed (*Pluchea sericea*) infestation on the SELER dune strand. While an example included in the book was an invasive plant that is not an issue in arid southern California (European beachgrass), the removal of the nutrient-rich layer of soil left behind after eradication activities made it much more difficult for the Arrowweed to re-invade areas that had been cleared for nesting habitat. This was valuable confirmation of a successful method, even though derived from a different species, in a system of entirely different hydrology.

WRA, Inc. 2013. Conceptual Foredune Creation and Enhancement Plan: Broad Beach Restoration Project, Malibu, CA. Prepared for: Moffatt & Nichol; Long Beach, CA

The Broad Beach Restoration Project is intended to stabilize the Malibu shoreline in a sustainable way to protect existing residences, on-site sewage treatment systems and other structures. It is also similar to the Project in that beach nourishment has been proposed as a complimentary shoreline stabilization measure. Both foredune creation and enhancement are addressed. A secondary goal is to create, enhance and protect high conservation value habitat at Broad Beach, as well as restore areas where such habitat previously existed and was removed by wave action. Beyond specific project restoration methods, this plan deals with post-construction monitoring and adaptive management strategies, including those confronting the dynamic nature of dune systems (ex. sand erosion and displacement due to wind and wave action).

9. CONCEPTUAL ALTERNATIVES

Three concept alternatives were developed within this feasibility study. These alternatives are presented in this section. A preferred alternative was determined through close coordination with the Project team members and stakeholder groups and is presented in Section 11.

9.1. Common Design Features

All three alternatives occupy the same footprint and design template, though vary in composition. The basis and components of common design features is described in this section.

9.1.1. Sandy Dune Habitat

The concepts all include dune habitat created from the import of beach compatible fill. The fill will be placed in a hummock profile to mimic a natural dune system. Sand will be derived from the SELRP or another opportunistic source. Once the sand has been formed by the contractor, the dunes will then be seeded with native plant seed collected from the San Elijo Lagoon or neighboring lagoons. Sand gradation of both the receiving beach and the sand source material will be compared and assessed to confirm compatibility prior to construction.

Coarse to medium-grained sand (> 0.250mm median diameter) should be used to foster growth of native plants and use of the area by native fauna. This gradation is similar to the native beach sand and is also ideal from a shore protection perspective. Sand granularity affects permeability, which, in turn, affects the chemical nature of the substrate to which native flora and fauna are adapted. At least 18 inches of sand cover will be achieved in all locations to allow for plant establishment.

The chemical nature of the substrate that is introduced will be considered from a biological habitat perspective. Time and precipitation may be needed to assist in the leaching of salts and other dissolved solids that may be a part of the introduced substrate. Irrigation may also be applied to shorten the time period for this condition to form, but it is not included in this Project at this time.

9.1.1.1. Public Access and Signage

An integrative approach to site design will be incorporated to facilitate management of recreational users and native habitat restoration areas. The goal is to maximize contiguous habitat-protected areas while not reducing ease of access to the beach. Habitat protection areas should be concentrated along the highway reach that is already signed “No Parking.” For the areas where parking is allowed, dune restoration site design should accommodate through-traffic that will concentrate foot traffic along designated routes. In some areas, plant pallets will be strategically selected to coincide with visitor traffic. Signage placement design will be coordinated with fencing (both symbolic and sand-capture fencing) so as to prevent fence damage and habitat impacts.

Because of the high frequency of use by the public and the sensitivity of habitat components, public outreach will be a major component of the project. Public outreach should consist of several integrated efforts:

- On-site signage that notifies and informs;
- Educational and interpretive signage at nearby high-use areas (Cardiff State Beach and South Cardiff State Beach);
- Media advisories that notify, inform, and educate the general community; and
- Coordination and synchronization with existing outreach being conducted by the SELC about the status of public access and restoration activities related to the SELRP and transit-oriented project effects.

9.1.1.2. Habitat Recruitment

The project includes native habitat restoration as a central goal. Native habitat in the Project area most closely resembles the remnant dune system adjacent to and directly east of HWY 101. Since the remnant dunes are protected by the highway berm and the railroad berm, the dune area is not subject to storm/wave action from the west nor lagoon flooding from the east. The highway berm also shields some wind energy; therefore, the remnant dunes are only nominally wind-affected.

While fauna is often the ultimate target of dune restoration, the principal activities are vegetation-related: controlling invasive vegetation and promoting native plant communities. The SELC has collected several key species from the remnant dune site (reference site) in the San Elijo Lagoon, and propagules are being fostered for this Project. Bulked seed to be used for future planting include:

- *Abronia umbellata* var. *umbellata* (Nyctaginaceae)
  - Beach sand verbena
  - California Native Plant Society (CNPS): rare, threatened or endangered, 1B.1
- *Acmispon prostratus* (Fabaceae)
  - Nuttall’s Acmispon
  - California Native Plant Society (CNPS): rare, threatened or endangered, 1B.1
- *Camissoniopsis cheiranthifolia* subsp. *suffruticosa* (Onagraceae)
  - Shrubby beach primrose
- *Chaenactis glabriuscula* var. *orcuttiana* (Asteraceae)
  - Orcutt’s yellow pincushion
  - California Native Plant Society (CNPS): rare, threatened or endangered, 1B.1
- *Nemacaulis denudata* var. *denudata* (Polygonaceae)
  - Coast woolly heads
  - California Native Plant Society (CNPS): rare, threatened or endangered, 1B.2

The Project will be designed to include regular and thorough invasive plant monitoring and control efforts. Starting with project implementation, monitoring and control efforts are recommended four times per year. After two years the effort may be reduced, but ultimately an on-going monitoring and control effort should be in place in perpetuity, for as long as native habitat protection is a goal of the Project. Some species expected to invade disturbed coastal strand areas are: *Carpobrotus edulis* (iceplant or sea fig), *Cakile maritime* (sea rocket), *Limonium perezii* (statice), Russian thistle, annual grasses, and *Dittrichia graveolens* (stinkwort).

Habitat protection zones should not be smaller than 250 feet of linear coastline. They should be protected from recreationist incursion by “symbolic” fencing and interpretive signage. Signage and fence upkeep will undoubtedly be a long-term maintenance tasks, both as a result of human intrusion and storm-event disturbances.

9.1.2. Cobble Berm

Cobble berms are naturally occurring features located at shorelines adjacent to river mouths or cobble-containing bluffs, which are both sources of cobble to the littoral cell. Due to the relatively large diameter of the cobbles, they are fairly stable at steep slopes and have been documented to accrete cobble during severe wave events (Everts et al 2002). Naturally occurring cobble berms exist on beaches adjacent to the Batiquitos Lagoon and at the Project site (during eroded conditions).

Cobble berms have been replicated (engineered) in a number of projects along the west coast (Oregon, Ventura and San Diego). The San Diego example is located along the southern portion of Imperial Beach (Figure 13 and Figure 14). This berm is constructed from naturally-occurring cobble that is present in the foreshore along this segment of beach in the winter months. An excavator was used to construct the cobble berm on the back beach to provide coastal overwash protection to the Tijuana Estuary and to prevent Tijuana River outlet migration. The berm has been successful at providing protection to the estuary with minimal maintenance.

An enhanced cobble berm feature was considered for the Project to increase the stability of the dune habitat area against wave attack. The berm would be constructed of existing and imported cobble of a similar size.

Figure 13: Cobble Berm in Imperial Beach

Figure 14: Crest Cobble Berm Looking South

9.1.3. Parapet Wall

A parapet wall feature was considered along the landward edge of the beach/existing pavement of HWY 101. This feature would serve to:

- Delineate the dune/HWY 101 boundary - Constrict access to fixed points along the reach of shoreline to protect proposed dune habitat;
- Provide limited scour protection for HWY 101 during extreme events; and
- Capture blowing sand.

The parapet wall is envisioned to be similar to in style to the existing seawall in the City of Carlsbad along Carlsbad Boulevard in the vicinity of Tamarack Beach (Figure 15). The proposed wall height would be optimized in consideration of views from HWY 101. Based on coordination with the City's Engineering Department, the wall would not exceed a height of 3 feet above the crown elevation of HWY 101 at any location. The wall depth would also be optimized to provide some protection of the HWY 101 sub-grade; however, being short of an engineered seawall.

Figure 15: Parapet Wall in the City of Carlsbad (source: Google.com)

9.1.4. Reconfigured Rip Rap

The existing unengineered rip rap provides limited protection from extreme wave events. The stone is undersized and is not keyed in, which reduces its effectiveness at shore protection. The Project proposes to fortify this feature to provide a last line of defense to the highway subgrade.

The condition of the rock rip rap varies along the Project site, as shown in Figure 16. The repair would entail reconfiguring existing stone (estimated to be 2-ton) and importing new stone where needed. Based on inspection of the site, it was estimated that no more than 10,000 cy of 2-ton stone is needed to form the proposed engineered revetment section.

Construction of the repair would entail excavating the existing rock and cobble and reforming existing materials and imported rock (as needed) into the proposed design section. The reconfigured rip rap would be buried by the sand dune feature; thus, the Project would provide an aesthetic benefit by softening the public views from the highway and beach.

Revetment in Fair Condition

Revetment in Poor Condition

Figure 16: Rip Rap along Project Area

9.2. Alternative 1 – Exposed Cobble Berm

The Exposed Cobble Berm Alternative was developed with the concept of dissipating wave energy on the seaward, exposed (cobble) face. The concept’s goals was to provide additional protection to the sandy dune habitat area. The alternative consists of approximately 5,000 cy of imported sand and 15,000 cy of reconfigured and imported cobble to form the proposed section. The alternative may potentially result in a negative aesthetic for some members of the public. The alternative would require importing a significant quantity of cobble to fill the proposed template. The proposed concept for Alternative 1 is shown in Figure 17.

9.3. Alternative 2 – Sand Berm

The Sand Berm Alternative is proposed to consist purely of sand; thus, would be the least costly to construct. An estimated 20,000 CY of sand import is needed to construct this alternative. As compared to Alternative 1, the sand berm would be more vulnerable to erosion during extreme wave events; therefore, may result in increased maintenance costs. A benefit of this alternative is that it would provide a source of sand to the beach as it erodes. Source sand characteristics for this alternative will be key for its longevity. A coarse to medium grain size sand would be preferred. The proposed concept for Alternative 2 is shown in Figure 18.

9.4. Alternative 3 – Buried Cobble Berm

The Buried Cobble Berm Alternative is a hybrid of Alternatives 1 and 2 in that it consists of a cobble berm core buried with imported sand. This alternative would consist of approximately 10,000 cy of imported sand and 10,000 cy of reconfigured or imported cobble to form the proposed section. The cobble will form a last line of defense in the event that sand on the seaward slope erodes. In this sense, the alternative includes what could be considered a sacrificial sand toe. Dune plantings would be minimized in the sacrificial toe area. The proposed concept for Alternative 3 is shown in Figure 19.

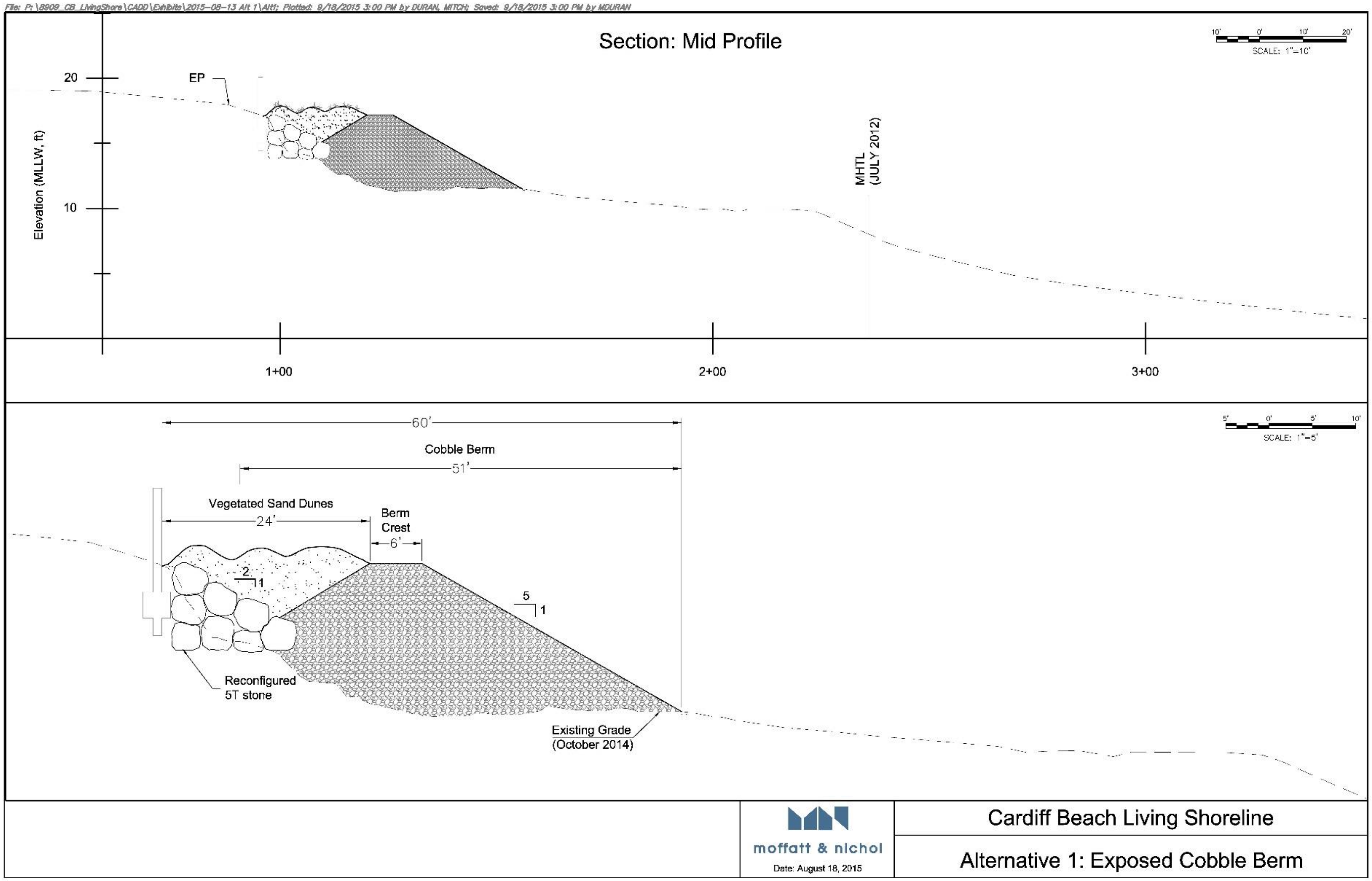


Figure 17: Alternative 1 – Exposed Cobble Berm

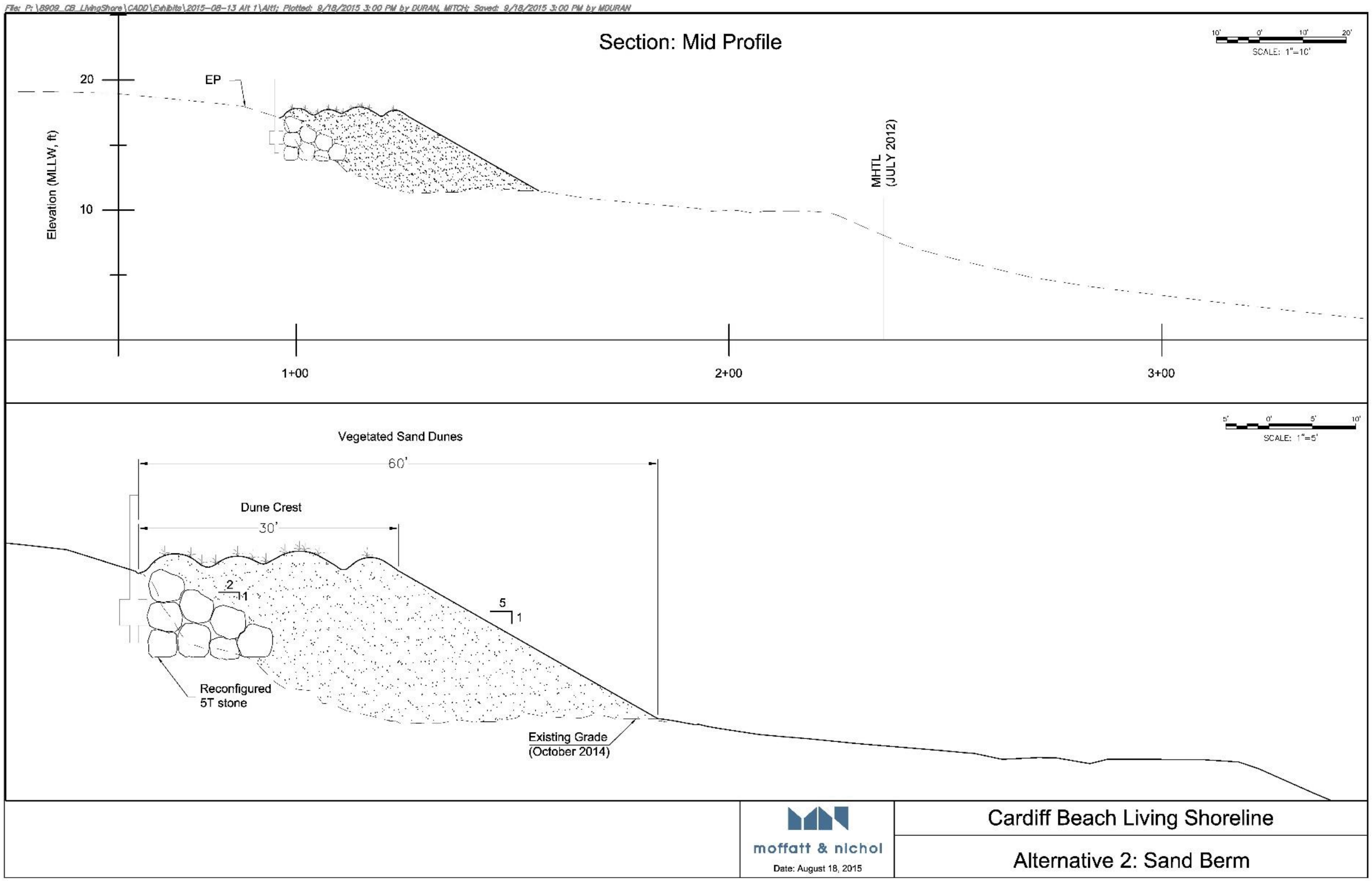


Figure 18: Alternative 2 – Sand Berm

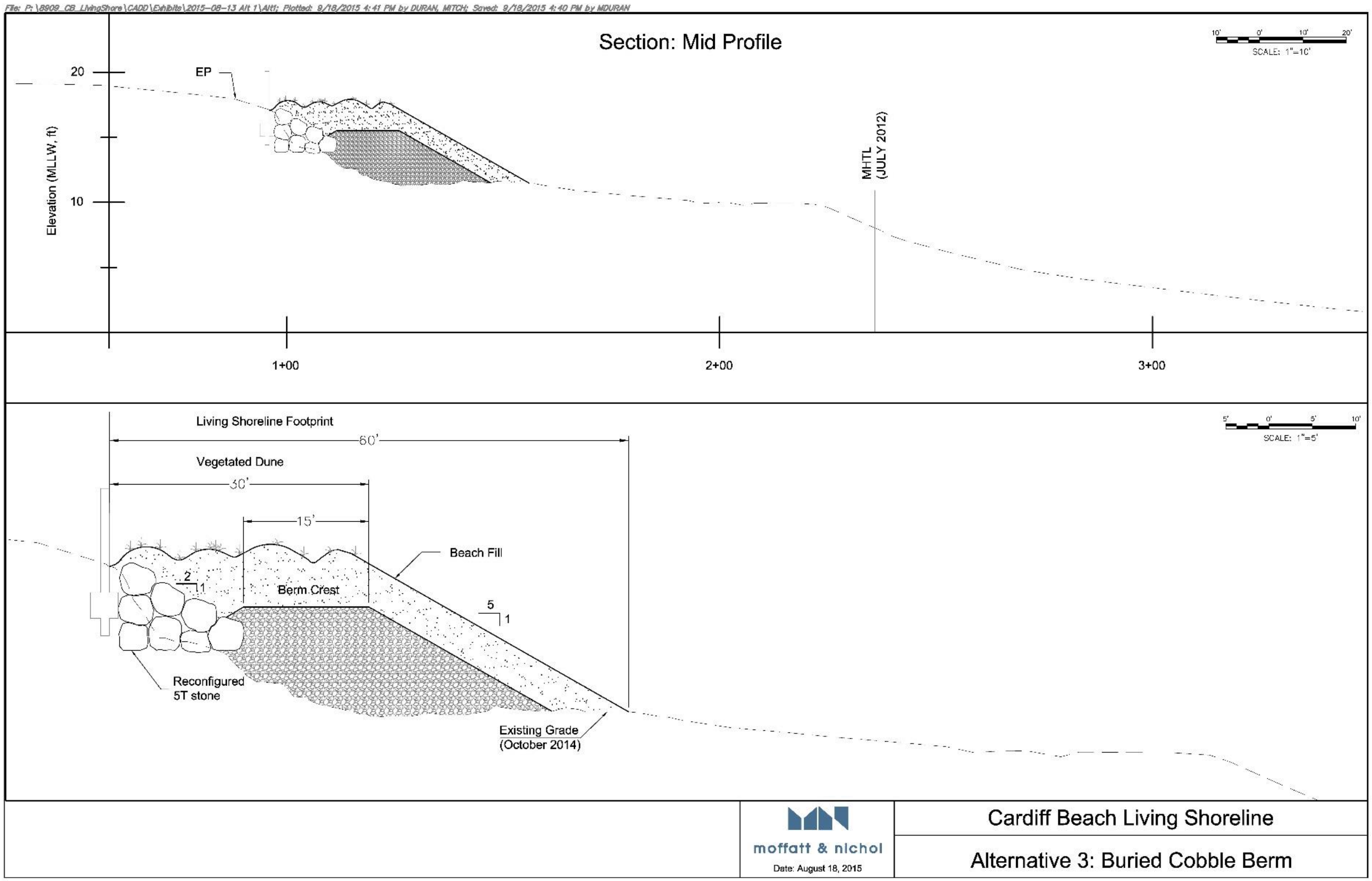


Figure 19: Alternative 3 – Buried Cobble Berm

10. Site-Specific Numerical Model

A site-specific numerical modeling effort was identified as being needed to predict the performance of the proposed Project under extreme oceanographic conditions (SLR, extreme waves and still water levels). Metrics to evaluate the performance of the Project were wave runup (elevation and limits) and beach width with and without the Project. The XBeach numerical model was selected for this analysis. XBeach is a two-dimensional model for wave propagation, long waves and mean flow, sediment transport and morphological changes of the nearshore area, beaches, dunes and back barrier during storms (Roelvink et al. 2015).

Experience has shown that structures/developments along the coast are more vulnerable to episodic storms rather than to long-term rates of recession. Therefore, the long-term profiles (adjusted for SLR) were combined with numerical modeling of storm events, using the model XBeach, to inform the analysis of coastal processes and erosion potential of beaches in the Project area.

The modeling effort analyzed three beach transects within the Project area (i.e. North, Mid, South). The transects were analyzed for the following wave events and SLR scenarios:

1. Modeled Wave Events
    a. Seas – Analyzed 43- and 100-year return period events.
    b. Swell – Analyzed 43- and 100-year return period events.
    c. Model calibration wave event (8 year seas storm)
    d. Successive Storm Event (43 yr + 8 yr seas event)
2. Sea Level Rise (4 scenarios)
    a. Existing
    b. 2050 Low and High SLR
    c. 2100 High

The sea events represent a local storm that typically has peak wave periods of less than 10 seconds. Whereas, the swell wave events are representative of strong and persistent distant wind events that typically have peak wave periods between 12 and 18 seconds. Another distinction is that sea events contain a broader spectrum of waves ranging from chop to larger period waves, while swell waves are often concentrated around a single long wave period.

Two project alternatives were selected for modeling along with the no project scenario. Alternative 1 (cobble berm) and the Alternative 2 (sand berm) were selected for modeling as they represent two extremes in terms of berm composition. Since Alternative 3 is a hybrid of

Alternatives 1 and 2 in terms of composition, the result would be between the Alternative 1 and 2 outcomes.

10.1. Oceanographic Conditions

Proper identification of the Project's oceanographic conditions is vital to the success of any coastal modeling effort. The water level components described in this section used measured datasets, whereas the wave conditions were described using hindcasted U.S. Army Corps of Engineers (USACE) data.

10.1.1. Tides and Sea-Level

The total water level experienced at the shore is often a combination of tides, non-tidal residuals (NTR) such as storm surge, sea level anomaly (SLA) due to concentrations of warm water often associated with El Niño, and wave setup. Wave setup is calculated and accounted for by the XBeach model, while the other contributors to the total water level are identified as a single input. The tide height, NTR, and SLA values chosen for the modeling effort are described in this section.

10.1.1.1. Tides

Tides at Cardiff Beach are semidiurnal in nature, which refers to two highs and two lows occurring per day. Water levels for the Project site were obtained from NOAA's La Jolla gage (Station 9410230) located on the Scripps Pier, which has been collected since 1924. These data are applicable to the San Diego region open-ocean coastline and are summarized in Table 2. A tidal record with the modeled storm arriving at approximately mean high water (MHW) was used for the XBeach simulations.

Table 2: Water Levels in La Jolla (1983-2001 Epoch)

Description	Datum	Elevation (feet, MLLW)
Highest Observed Water Level	Maximum	7.66
Highest Astronomical Tide	HAT	7.14
Mean Higher-High Water	MHHW	5.32
Mean High Water	MHW	4.60
Mean Sea Level	MSL	2.73
Mean Low Water	MLW	0.90
North American Vertical Datum of 1988	NAVD88	0.19
Mean Lower-Low Water	MLLW	0.00
Lowest Astronomical Tide	LAT	-1.88
Lowest Observed Tide Level	Minimum	-2.87

10.1.1.2. Non-Tidal Residuals

Non-tidal residuals (NTR) consist of components of the recorded water level not linked to astronomical tide. NTRs include water level responses to regional effects such as storm surge and changes in atmospheric pressure and typically occur on the order of days. Storm surge is an abnormal rise of water over and above the predicted astronomical tide, typically generated by a storm, and is generally the result of wind-induced set up along a shoreline. Atmospheric pressure changes result in water column expansion or retraction due to low and high pressure systems, respectively.

Return period NTR events within the La Jolla tidal record were identified through a statistical analysis of the tide gauge record. Results are summarized in Table 3. The data indicate the 50- and 100-year NTR events are 2.20 feet and 2.33 feet, respectively. Positive NTRs or storm surge is typically associated with short period sea events rather than swell events. However, in order to equally compare the effects of different wave conditions, the 100 year return period NTR will be used for all simulations.

Table 3: Extreme Non-Tidal Residual Return Period

Return Period (year)	Non-Tidal Residual Water Levels (feet)
5	1.64
10	1.84
25	2.03
50	2.20
100	2.33*

**Used for Modeling*

10.1.1.3. Sea Level Anomaly

A mean sea level anomaly (SLA) reveals the regional extent of anomalous water levels in the coastal ocean, which can indicate unusual water temperatures, salinities, average monthly winds, atmospheric pressures, and/or coastal currents. SLA occurs over periods of months and demonstrates the interconnectedness of the ocean with atmospheric systems. SLAs are typified along the U.S. Pacific Coast with climatic events such as the ENSO (NOAA, 2013). The SLA exceedance percentages for La Jolla are shown in Table 4. The 10% exceedance level was chosen for modeling.

Table 4: Extreme Sea Level Anomaly Return Period

% Exceedance	Sea Level Anomaly (feet)
25%	0.09
10%	0.19*
5%	0.26
1%	0.44

**Used for modeling*

10.1.1.4. Relative Sea Level Rise

The average global sea level is proposed to rise in the 21st Century in response to climate change (ice melt and thermal expansion of sea water). Global SLR projections do not translate directly into the amount of change observed at a specific shoreline location due to a number of oceanographic factors as well as vertical land motion. Relative SLR is a term used to describe sea level changes at a specific shoreline location, which accounts for these various factors.

Relative SLR observed at the La Jolla tide gauge from 1924 to 2013 is shown in Figure 20. Sea levels rose, on average, 2.02 millimeters per year, or 7 inches over this 89 year period.

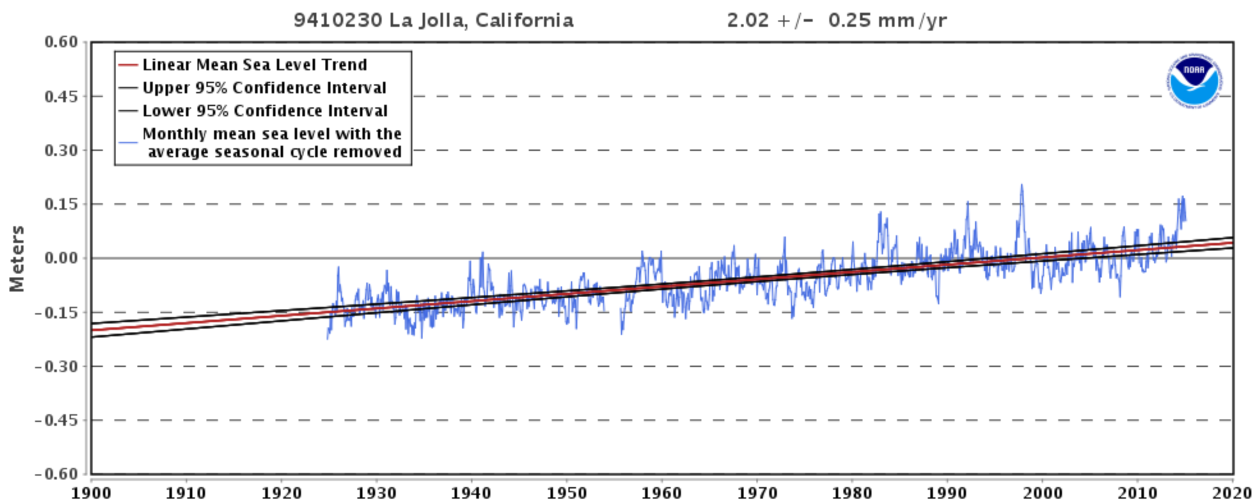


Figure 20: La Jolla Mean Sea Level Trend (Source: NOAA 2015)

The CCC recently released Sea Level Rise Policy Guidance (CCC 2015) that states that coastal planning documents and development projects should consider the potential effects of SLR, where applicable. Acknowledging the constantly improving nature of the supporting climate science, the guidance states that the best available science be used at the time of the SLR assessment.

The National Research Council's (NRC) 2012 report, titled *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future* is considered the best available science for the State of California (CCC 2015, CO-CAT 2013) at the time of this report. The NRC is a conglomerate of scientists and research organizations that act as an advisory group for government agencies. The NRC study predicts a 0.9-ft increase in relative SLR by 2050 and a 3.1-ft increase by 2100 in the Los Angeles region, which is the nearest projected location in the study to the Project site (Table 5).

Table 5: Relative SLR Projections for Los Angeles Region (Source: NRC 2012)

Year	Projected SLR (ft)	Projection Uncertainty (ft, +/-)	Low Range (ft)	High Range (ft)
2030	0.5	0.2	0.2	1.0
2050	0.9	0.3	0.4*	2.0*
2100	3.1	0.8	1.5	5.5*

**Projections were used for numerical modeling*

The projection values indicate the mean and the uncertainty (i.e., standard deviation) for a specific Intergovernmental Panel on Climate Change (IPCC) future greenhouse gas emission scenario (i.e., A1B). The A1B scenario represents a world of rapid economic growth and a balanced use of fossil and non-fossil energy sources. The ranges represent the means for the B1 (low fossil fuel emission scenario) and A1FI (high fossil fuel emission scenario). Note that the confidence in the projections, indicated by the uncertainty values, increases with the projection year as does the range between the low and high projections.

Year 2050 low, 2050 high and 2100 high SLR projections were used in this analysis.

10.2. Extreme Waves

Wave data for the Project site were obtained from hindcast developed by the USACE Wave Information (WIS) studies for Station 83106. The hindcast spans from 1980 to 2011 and estimates historic swell, seas, and total wave heights. The nearest physical wave measurement location is CDIP buoy 100. The station has an approximate 11-year record, recording from 2004 to 2015. The location of the hindcast station and the wave buoy is shown in Figure 21.

The orientation of the shoreline to the north-northwest and the California Channel Islands limit the direction from which waves approach. The directional wave data indicates that waves most commonly approach the site from the south-southwest. The largest waves approach the site from the west and west-northwest.

Many Southern California storm events are a combination of two distinct wave signals: long period swell and short period seas. The long period waves, or swell, are often a result of a distant storm cell that traveled over the Pacific Ocean with steady, high wind speeds over a significant fetch. The short period seas are a result of waves generated closer to the coastline. Wave records with two distinct sea and swell signals often described as being bimodal. Since bimodal wave events are often the result of two separate storms and travel in separate directions, describing a bimodal wave event with a single wave height, period, and direction can be misleading. Figure

22 Illustrates how the seas and swell varied over the course of a storm in January 2010. Table 6 lists numerous extreme storm events and the corresponding total of swell, and seas components. For 1998 and 2010 storm events, the maximum swell, maximum sea, and maximum total data records are listed separately.

Table 6: Extreme Storm Wave Events (Hindcast Station 83106 and CDIP Buoy 100)

Date of Storm	Total Significant Wave Height (feet)	Significant Wave Height of Swell (feet)	Peak Period of Swell (sec)	Significant Wave Height of Seas (feet)	Peak Period of Seas (sec)
March 2, 1983	18.1	16.1	17.7	9.6	8.3
March 2, 1985	14.7	3.7	14.7	14.3	10.0
February 15, 1986	15.4	14.9	19.5	3.3	6.2
January 18, 1988	23.8	9.3	16.1	21.9	10.0
February 3, 1998 2pm	14.1	10.6	12.1	9.3	9.1
February 4, 1998 8am	13.4	12.8	16.1	3.9	5.7
February 25, 2008	10.6	10.5	17.7	0.9	3.2
January 21, 2010 6pm	16.6	7.9	11.0	14.6	10.0
January 22, 2010 2am	14.3	13.5	11.0	4.9	6.2
January 22, 2010 2am	14.3	13.5	11.0	4.9	6.2
March 21, 2011	12.8	7.5	10.0	10.3	8.3
January 11, 2013	13.0	3.0	11.0	12.8	8.3

A statistical analysis was conducted on the offshore hindcasted wave data set to determine the various return period wave events. Based on the bimodal nature of Southern California wave events, the seas and swell signals were analyzed separately. As shown in Table 7, the 50- and 100-year return period local seas wave events are 18.8 feet and 21.8 feet, respectively (Figure 23).

Table 7: Significant Wave Height Return Period of Seas (Hindcast Station 83106)

Return Period (year)	Significant Wave Height (ft)
5	12.2
10	13.8
25	16.4
50	18.8
100	21.8

As shown in Table 8, the 50- and 100-year return period local swell wave events are 16.4 feet and 18.5 feet, respectively (Figure 24).

Table 8: Significant Wave Height Return Period of Swell (Hindcast Station 83106)

Return Period (year)	Significant Wave Height (ft)
5	11.7
10	12.8
25	14.6
50	16.4
100	18.5

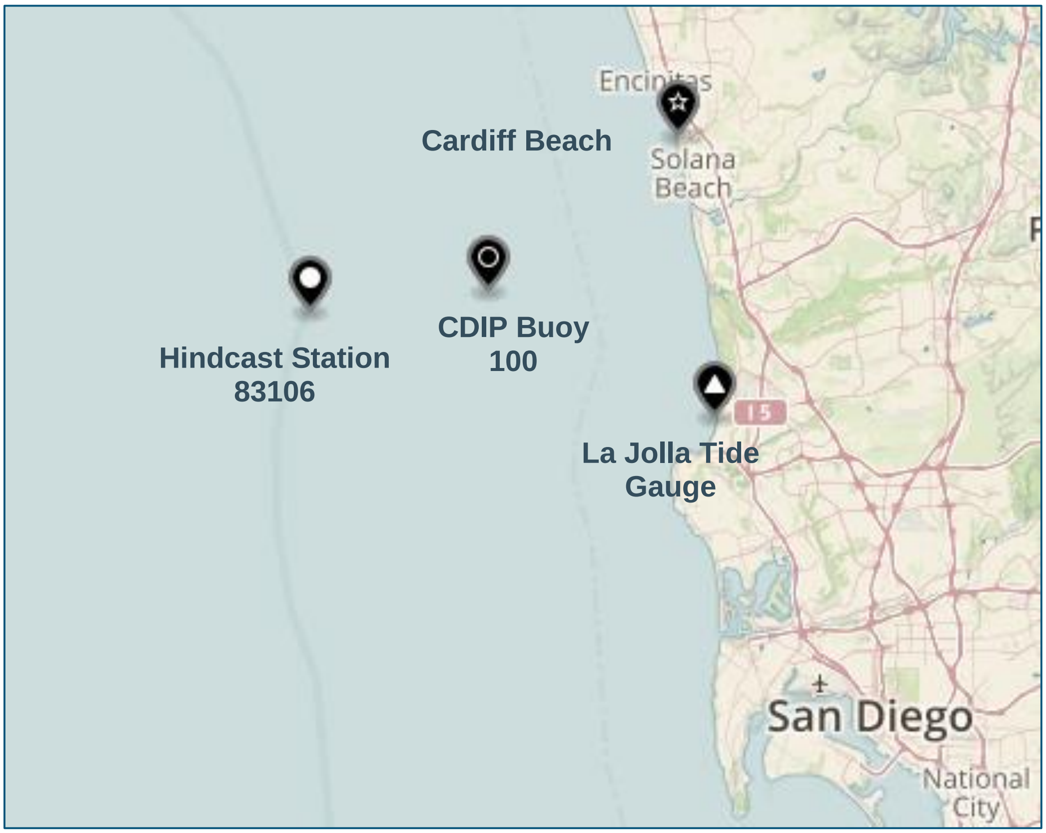


Figure 21: Wave Measurement Locations near the Project Site

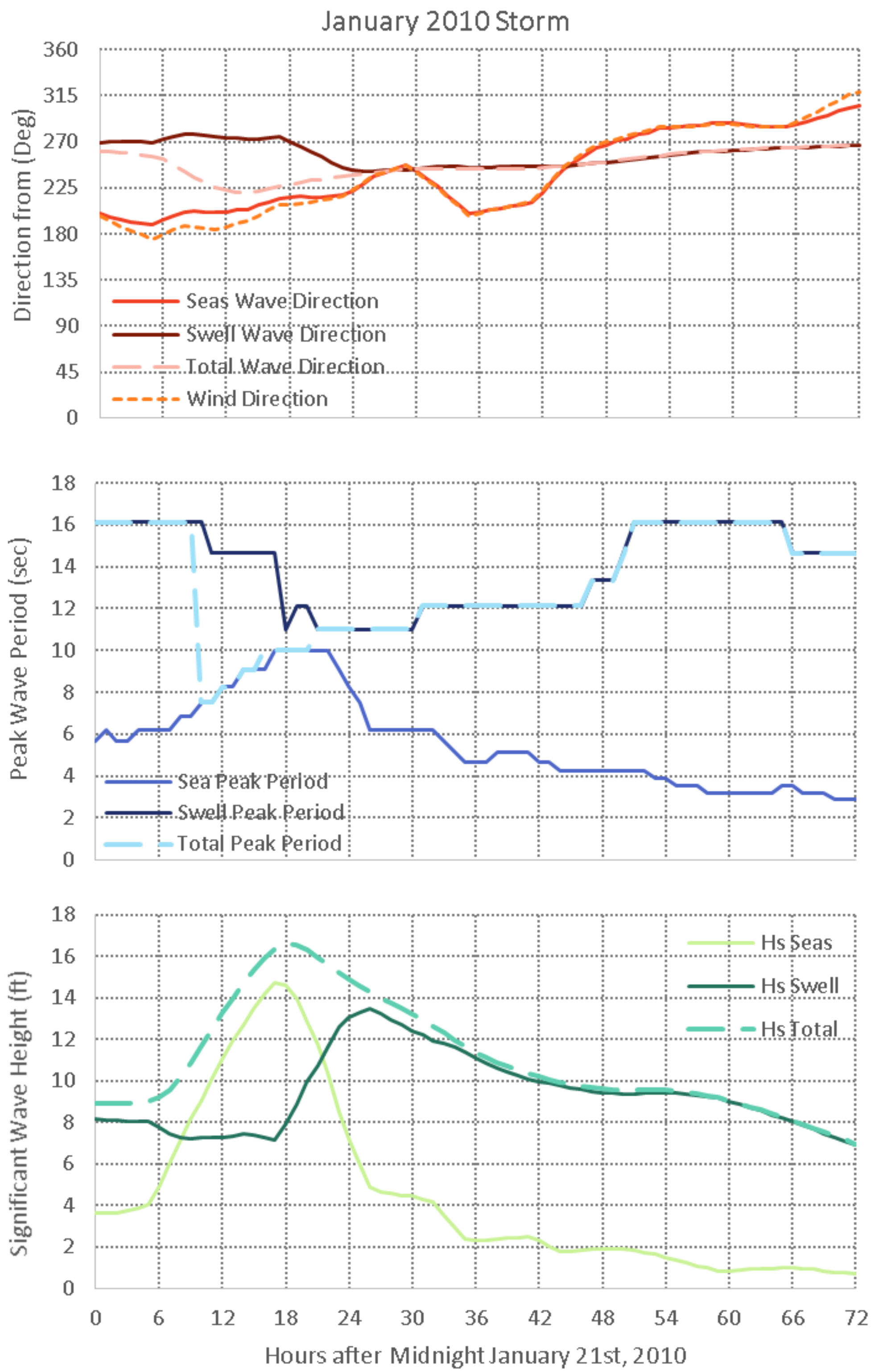


Figure 22: January 2010 Storm

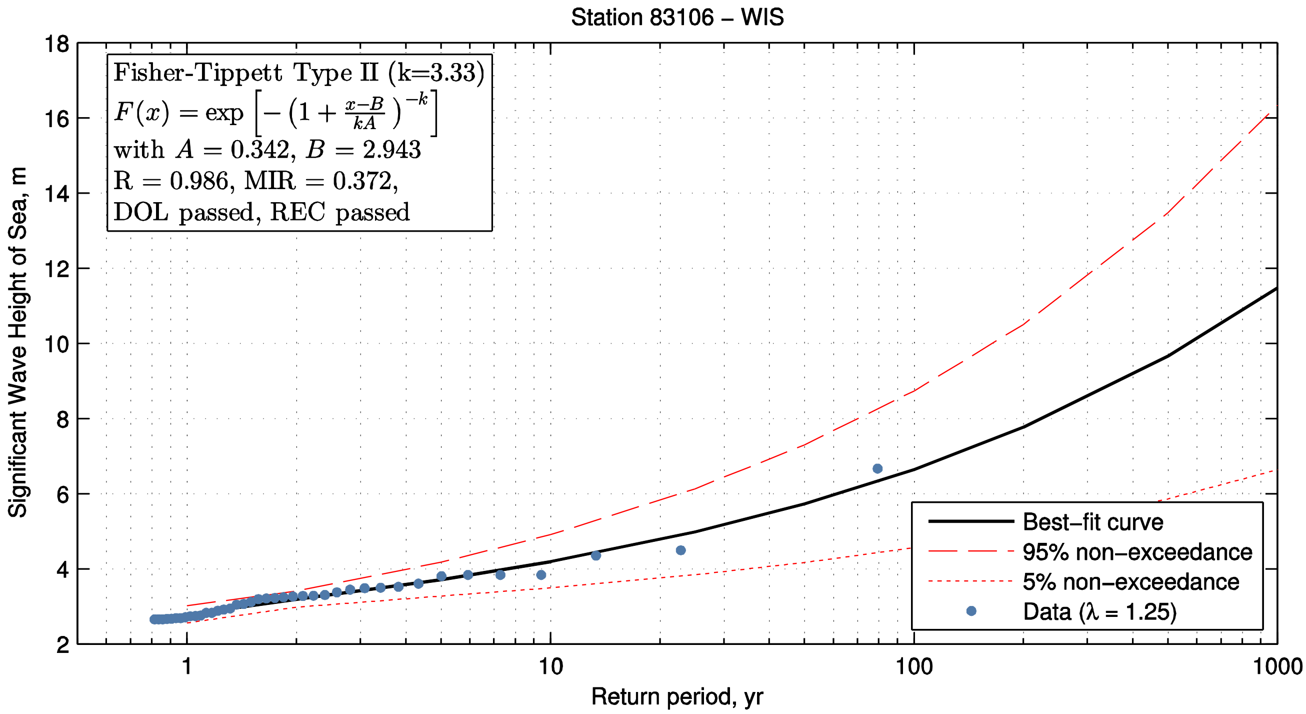


Figure 23: Return Period Curve – Local Seas Events

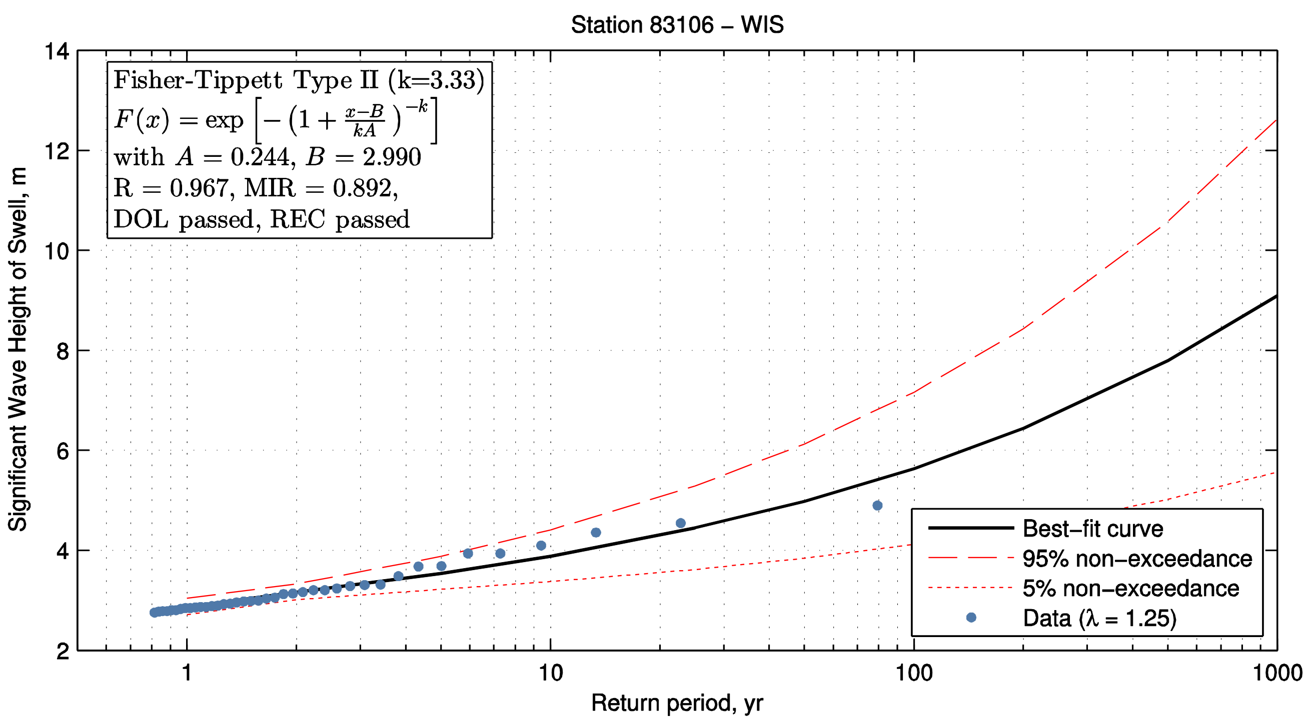


Figure 24: Return Period Curve – Swell Events

10.3. Model Configuration

The XBeach model (version 1.21.3667) was configured for Cardiff Beach and executed using a combination of synthetic and measured data. The various inputs and settings are discussed in the following sections.

10.3.1. Digital Elevation Model and Computational Grid

A digital elevation model was created of the study area by merging best available representative bathymetric and topographic data. Bathymetry data of the existing beach and nearshore conditions came from an October 15, 2014 Scripps Institution of Oceanography (SIO) survey of Cardiff Beach. The beach survey data was merged with a high resolution topographic survey collected in 2011 for the SELRP by KDM Meridian, Inc. The grid spacing on the beach was set to 2 feet and increased with distance offshore. The surveyed profiles were extrapolated to deeper water (>90ft depth). The approximate location of the three transects that were analyzed are shown in Figure 25.

Since SIO surveys Cardiff Beach frequently, some discretion on which data set to use to represent existing conditions was necessary. The October 2014 beach survey was chosen for the following reasons:

- The survey is the most recent summer profile available at the time modeling was initiated;
- The survey was taken at an adequate length of time after nourishment (i.e., about two years) so that the beach is at equilibrium. The continuation of beach nourishment in the City is assumed due to the recent renewal of the City's Opportunistic Beach Fill Program and proposed placement of export materials from the SELRP; and
- The wide summer beach allows for more potential erosion and allows the design team to better realize the difference between design alternatives, extreme storms, and SLR scenarios.

10.3.2. Beach Substrate

The existing beach sediments were modeled using three sediment classes distributed uniformly throughout the beach. Three sediment classes were defined using USCS definitions for gravel (referred to as cobble elsewhere in this report), coarse and medium sand, and fine sand. The concentration of each sediment class was defined using a geotechnical boring collected by Ninyo & Moore in 1998, which represented an eroded beach condition. This boring was used in order to characterize the underlying gravel at the site. The existing and proposed beach substrate variables used in the XBeach model are provided in Table 9.

Table 9: Modeled Beach Sediment Composition

Sediment Class	Concentration	D50 (mm)	D90 (mm)
Existing Beach Substrate			
Gravel	60%	33.0	47.0
Coarse-Med. Sand	10%	1.30	3.50
Fine Sand	30%	0.17	0.22
Gravel Berm (Alternatives 1 & 3)			
Gravel	100%	33.0	47.0
Sand Berm and Dune (All Alternatives)			
Coarse-Med. Sand	10%	1.30	3.50
Fine Sand	80%	0.17	0.22

The existing rip rap and roadway were set as non-erodible boundaries in the model. Thus, the beach was not allowed to retreat landward of these features. However, wave run-up could extend landward of these non-erodible features. Three vertical bed layers were used to model the no-project scenarios while eight layers were used to model the conceptual alternatives. The vertical spacing of the bed layers was set to one-foot. The porosity of mixed, sand-gravel beaches with over 30% sand are about as porous as pure sand (She et al. 2007). Without the ability to update the porosity as the model progresses, the porosity was set to a constant 0.0008 m/s. Two example profiles that demonstrate how the substrate was varied in the XBeach model are shown in Figure 26.

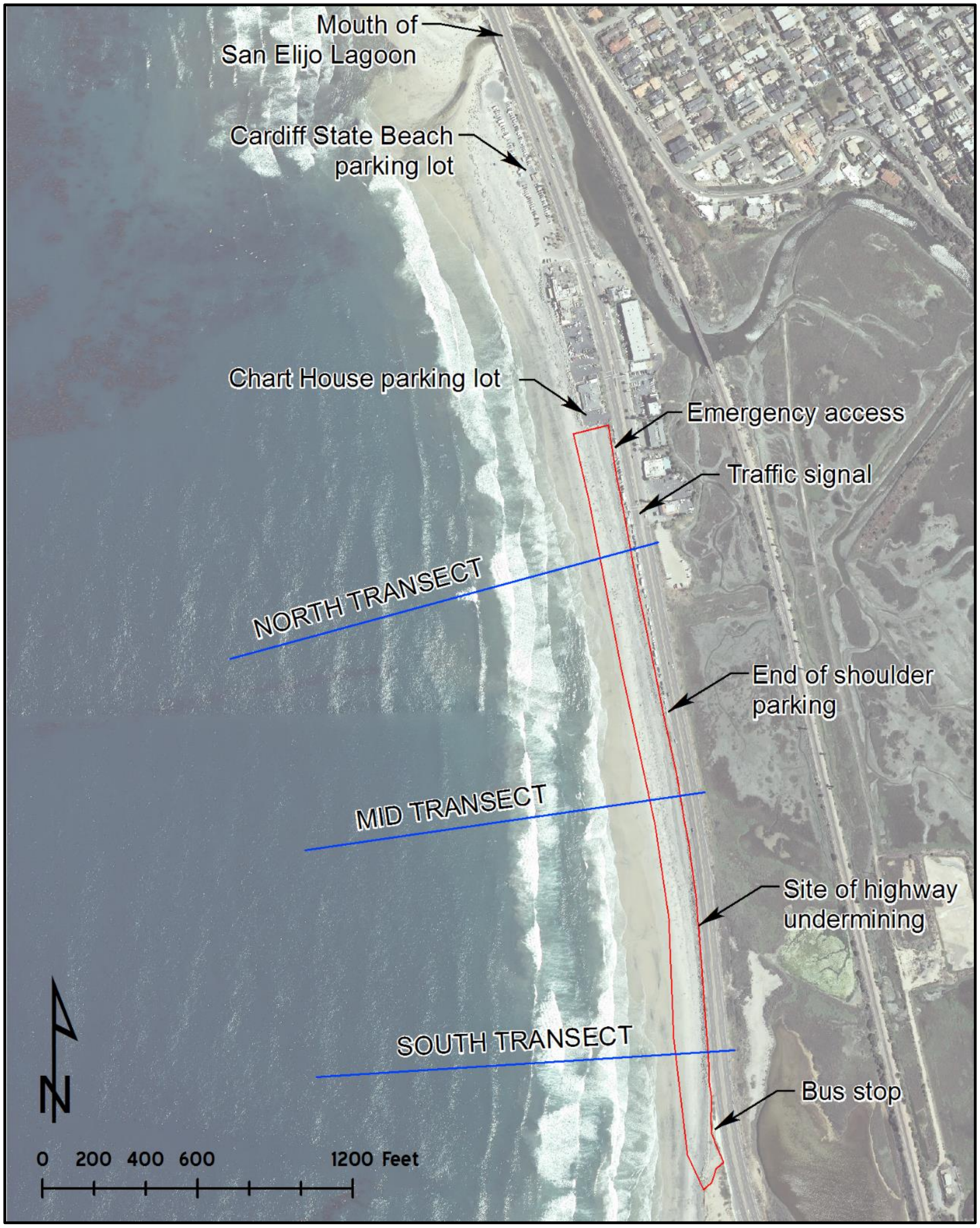


Figure 25: Model Transects

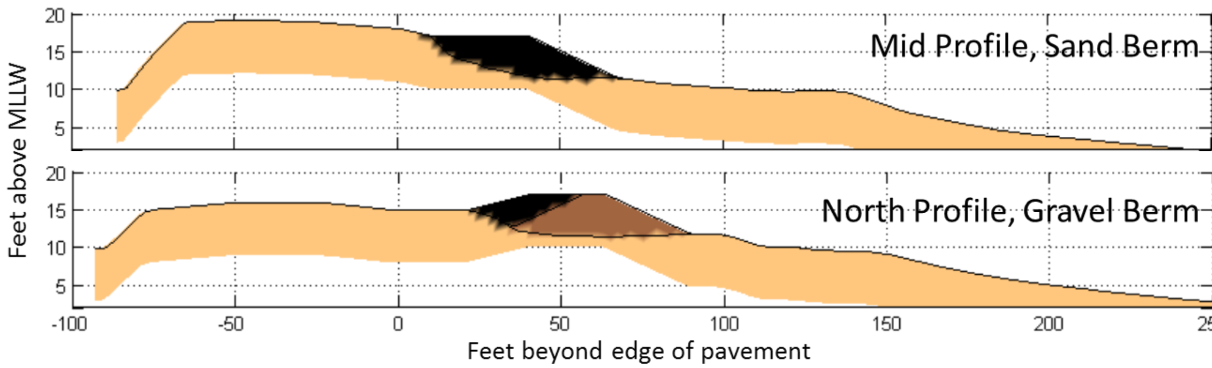


Figure 26: XBeach Model Substrate Variability with Design Alternatives

(Black: Sand, Brown: Gravel, Peach: Sand)

10.3.3. Long-term Beach Erosion

When analyzing beach conditions in future time horizons, the beach profile needs to be adjusted to consider its response to SLR. The long-term beach profile development with respect to SLR was modeled according to the Bruun Rule for this Project. The Bruun Rule hypothesizes that as the sea level rises, the shoreface will respond by moving landward and upward while balancing the amount of erosion on the upper beach with the amount of deposition further offshore. Figure 27 illustrates the long term adjustment of the middle Cardiff Beach profile. The adjusted profile results in a thin layer of deposition out to the depth of closure at -28 ft MLLW (CFC 2013).

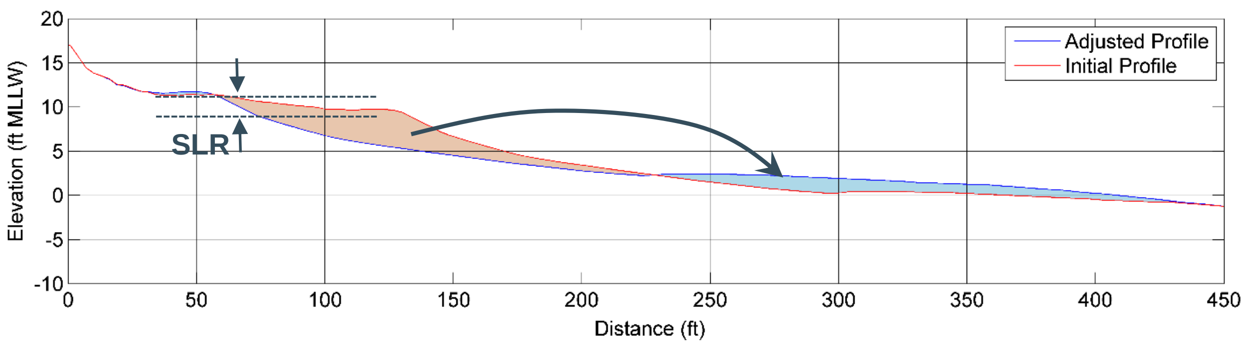


Figure 27: Long-Term Erosion (Brunn) Profile

10.3.4. Oceanographic Forcings

The XBeach model was run with a number of extreme wave events. The wave events used for modeling were shoaled from their offshore hindcast location to the model boundary. Using the shoaled significant wave height, a JONSWAP spectrum (i.e., distribution of wave energy with frequency within the ocean) is created by the XBeach model. The seas spectrums were created using a peak enhancement factor of 3.3, while swell events used a larger peak enhancement factor of 8 (Goda 2000).

Multiple wave forcing scenarios were used to evaluate the effect of wave height and period on wave runup and erosion with and without the proposed Project. The tidal record, SLA, and NTR were kept the same for the synthetic extreme storms, while the January 2013 (model calibration storm event) used measured data.

10.3.4.1. January 2013 Storm

The January 2013 storm measured a 8 to 9 year return period seas event and was used as a calibration event. The components of this event are shown in Figure 28. The peak of the storm arrived at a lower high tide of 3.9 feet. As the storm arrived, the peak period dropped to about 9 seconds. The highest recorded significant wave height was 13 feet.

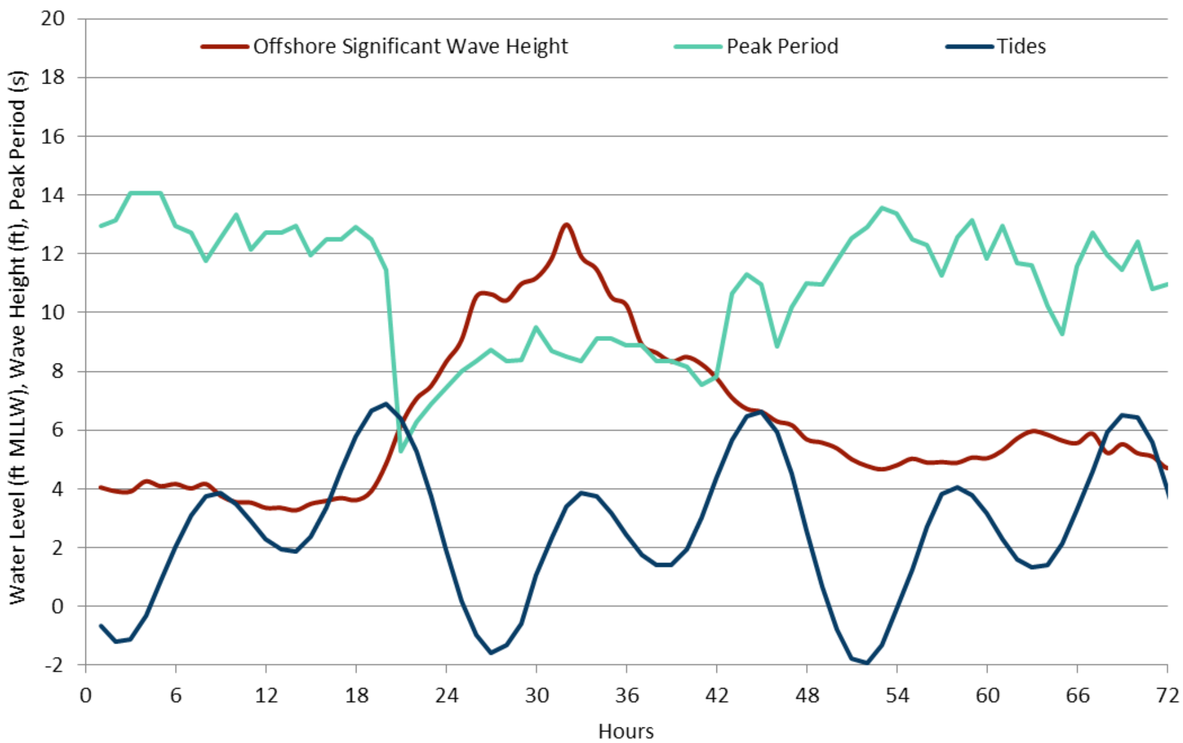


Figure 28: January 2013 Calibration Storm

10.3.4.2. Modeled Extreme Wave Events

The March 2011 wave event was used as the basis for four synthetic extreme storm events. The event was scaled to represent the 43 sea and swell events as well as a 100-year sea and swell event using the results of the extreme wave analysis. The hydrographs of all synthetic wave events are shown in Figure 29. Details on these modeled wave events are provided in Table 10.

Table 10: Modeled Extreme Wave Event Details

Wave Event	Offshore Significant Wave Height (Hso)	Peak Period (Tp, sec)
100-year Seas	21.8 ft	10s
100-year Swell	18.5 ft	16s
43-year Seas	18.1 ft	10s
43-year Swell	15.9 ft	16s
2013 Calibration	13.0 ft	Varies, 8-9s at peak of storm.

A 100-year wave event is powerful and their effect on the beach is quite extreme. Therefore, a less destructive, 43-year wave event was also used as a part of the analysis to understand the effects of more frequently occurring events on the beach and Project. The sharp (unrounded) 43-year return period is a result of a re-categorization of a model wave input. In the interest of modeling efficiency, the sharp 43-year return period model data was incorporated into the project analysis for more meaningful comparisons of wave runup and erosion.

The total water level (TWL), which combines a 4.7-foot tide record, 10% exceedance SLA, and a 100-year return period surge (or NTR) is shown in Figure 29. High and low SLR scenarios for the year 2050 and a high scenario for 2100 were modeled in addition to present day level.

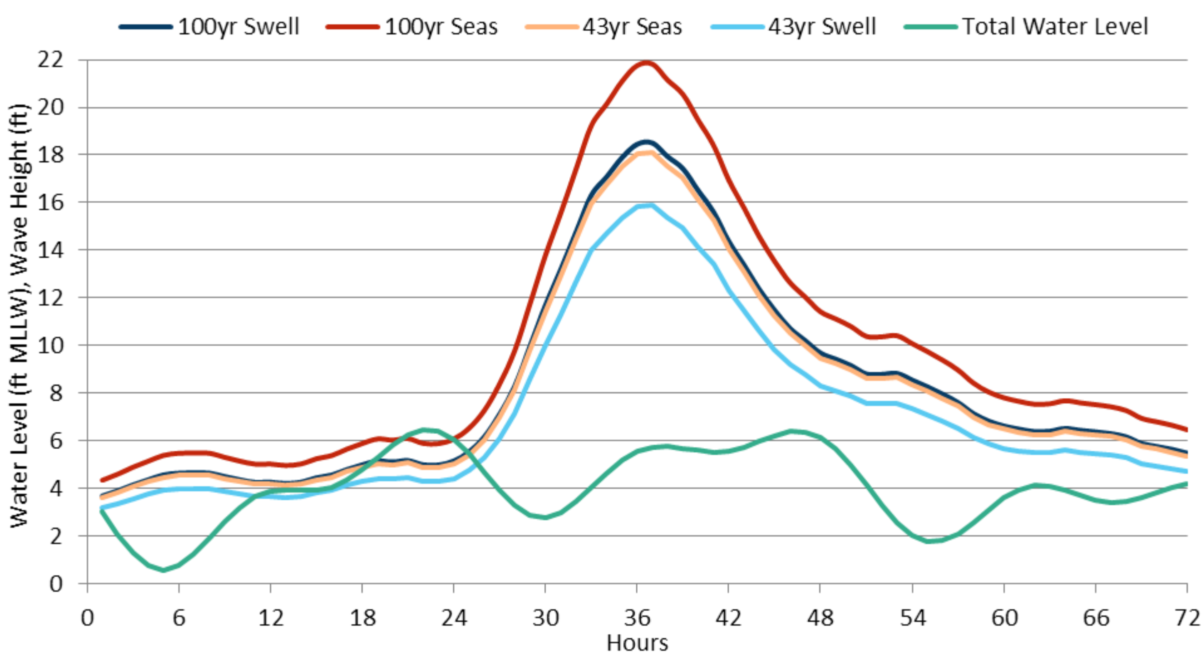


Figure 29: Model Hydrograph

10.3.5. Model Calibration

The XBeach model parameters were calibrated using profile surveys taken immediately before and after a January 2013 storm event. The input wave record was collected from CDIP buoy 100 and the tide record was collected from the La Jolla tide gauge (Figure 21). The peak offshore wave height was measured at 13.0 ft, with a peak period between 8 and 9 seconds. Using the extreme distribution for seas, the January 2013 wave event has a return period of approximately 8 years.

Nine parameters were tested using the January 2013 storm, however only three changes were made (Table 11). The calibrated model's skill is 0.51 across the profile and 0.61 above MLLW. Model skill, or Brier Skill Score, is the measure of improvement of the model output upon the initial condition toward matching the final measured condition. A score of 1 would be a perfect match, and negative values indicate that the model output is a less accurate than the initial condition. Values qualified as poor for 0-0.3 skill, reasonable-fair for 0.3-0.6 skill, good for 0.6-0.8, and excellent for skill between 0.8 and 1 (Van Rijn et al, 2003). Therefore, the XBeach calibration results are qualified as fair to good. This model skill is on a similar level of accuracy as other published XBeach applications (Vousdoukas et al, 2012).

Table 11: XBeach Parameters

Parameter	Description	Default	Selected
Form	Sediment Transport Formulation	vanthiel_vanrijn	soulsby_vanrijn
Smax	Erosion Limiter	(off)	0.6
Morfac	Morphological Acceleration Factor	1	5

10.3.6. Model Limitations and Assumptions

While the XBeach model is a robust tool with many benefits, the configuration of the model used for this analysis has some limitations:

- The 1D profiles will not capture 2D features such as beach cusps, erosional hot spots, and rip current embayment. The three profile sections are assumed to be representative of the entire Project area.
- The porosity is fixed, and does not update. Thus, runup for the gravel alternatives may be overestimated. An adequate amount of sand is assumed to be present either mixed-in or buried, that a varying porosity would have negligible effects.
- Roughness is not spatially varying and not affected by cobble. It is likely that erosion and runup results for the gravel berm alternatives are conservative.

Many of these limitations are shared with other models and equations that seek to quantify runup and erosion on mixed sand and gravel beaches. Nevertheless, the model results provide significant insight into the proposed Project alternatives and beach response to extreme wave events.

An XBeach model branch, XBeach-G, is currently being developed to simulate storm impacts on a gravel beach. Although promising, this experimental model is not suited for Cardiff Beach, which contains large amounts of sand in its system.

10.4. Model Results

The results of the site-specific modeling effort are summarized in this section. A summary table of all modeled outcomes is provided as Attachment A. Note that only Alternatives 1 and 2 were modeled for this analysis. These alternatives bracket the range of expected results for the concepts being considered. Since Alternative 3 is essentially a hybrid of these two alternatives, results would be expected to fall between the results from Alternatives 1 and 2.

10.4.1. Shoreline Erosion

The shoreline erosion analysis focuses on the least protected, northern profile and the middle profile. The middle and south profiles exhibited similar amounts of erosion. Therefore, the southern profile is largely excluded from this discussion.

The modeled results for the 2050 High SLR in addition to a 43-Year Swell event for all profiles is shown in Figure 30. The initial 2015 profile and the 2050 beach profiles are provided for context. The No Project storm profile erodes back to the rip rap / HWY 101 for all profiles. Alternative 2 performs better than Alternative 1 during this 43 year swell event. For both alternatives, the seaward dune slope steepens and a portion of the proposed dune habitat area would be lost. Although more of the cobble berm is lost, a significant portion of the cobble is deposited on the foreshore beach face. This would likely provide additional protection to the dune feature though would deposit cobble on the beach.

The effect of various extreme wave events on the existing beach and proposed Project under existing sea levels are compared in Figure 31. Three wave events (i.e. 43-year Seas, 43-year Swell, and 100-Year Swell) are compared at the northern transect. The results are summarized below:

- 43-year Seas event (top) - The proposed dune is unaffected. However, the foreshore of the existing beach (initial profile) is significantly flattened from its pre-storm condition.
- 43-year swell event (mid) - The proposed dune is eroded mostly in the form of steeping of the seaward dune face. The dune crest area is largely maintained; thus, no significant impacts to the created habitat area would be anticipated. The No Project beach is eroded back to the revetment / HWY 101. Undermining and overtopping of the roadway were likely during this event.
- 100-year swell (bottom) – The results are similar to the 43-year swell event in terms of erosion. However, significant wave overtopping associated with this event “rounds” the berm feature in Alternative 2. This is less notable for Alternative 1. The dune habitat area would be affected by this overtopping though possibly not significantly. The dune feature would be modified by this event.

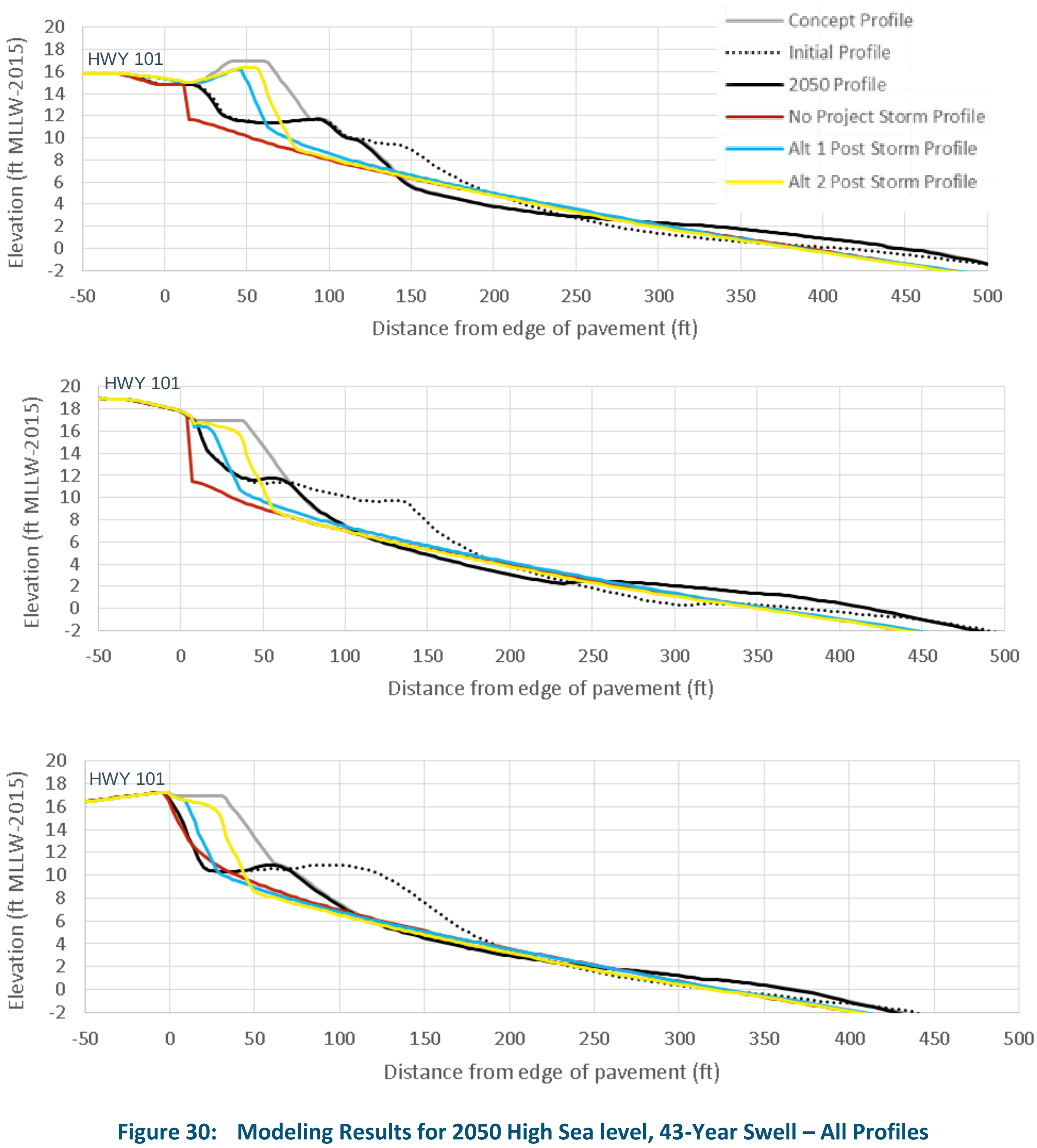


Figure 30: Modeling Results for 2050 High Sea level, 43-Year Swell – All Profiles
(Top: North Profile, Middle: Mid Profile, Bottom: South Profile).

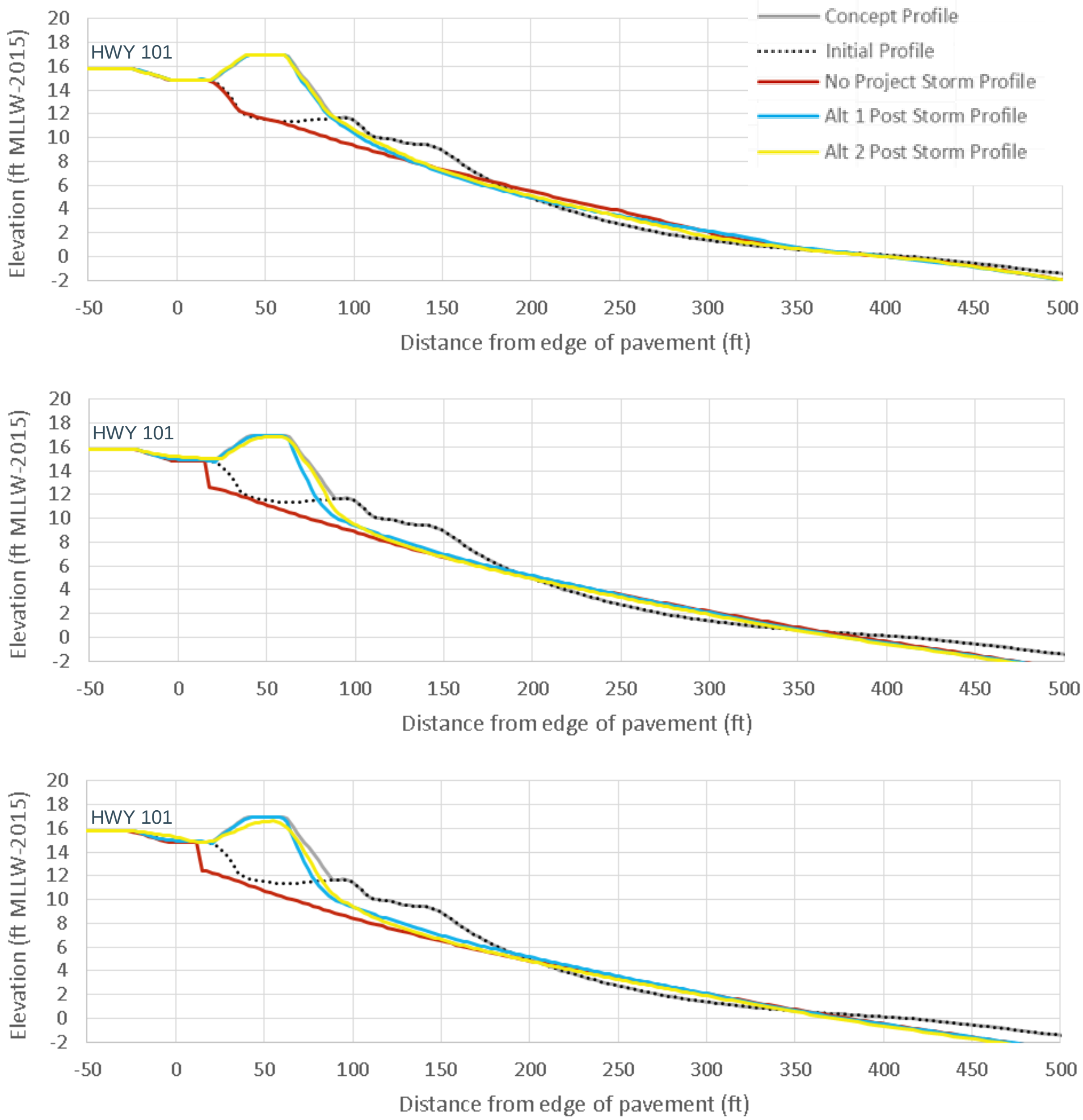


Figure 31: Modeling Results for North Profile, Existing Sea Level
(Top: 43-year Seas, Mid: 43-year Swell, Bottom: 100-Year Swell)

(Alt 1 obscured by Alt 2 in top frame)

Beach berm loss was a metric used to quantify the amount of short-term and long-term beach erosion associated with the modeled extreme storm events and SLR. Berm width represents the level of protection for Highway 101 that is provided by the beach and also the amount of dry beach or towel space available for beachgoers.

An elevation of 9.4 feet MLLW was used to define the beach berm, based on existing conditions. Berm widths were measured from this elevation on the beach profile to the edge of pavement (EOP) along HWY 101. Long-term and short-term erosion were quantified in this analysis. The mid profile was used to summarize the results of this analysis, as the other profiles exhibited similar outcomes. The beach berm analysis was conducted on 43- and 100-year return period seas and swell events under three water levels (i.e. existing, 2050 low SLR and 2050 high SLR). The results are summarized below:

- 43-year Seas (Figure 32) – The Project alternatives provides a benefit to berm widths under all three modeled water levels. The Project provides approximately 10 to 20 feet of additional width, as compared to the No Project condition. Remaining berm width for the 2050 high SLR is 56 feet for both alternatives. It can be seen that the majority of the berm width loss in this scenario is due to long-term erosion as opposed to short-term erosion. Alternatives 1 (Gravel Berm) and 2 (Sand Berm) perform substantially the same.
- 43-year Swell (Figure 33) – The Project alternatives provides a benefit to berm widths under all three modeled water levels. The Project provides approximately 10 to almost 40 feet of additional width, as compared to the No Project condition. Alternative 2 (Sand Berm) significantly out performs Alternative 1 in the 2050 high SLR scenario. A total of 50' of berm width remains for Alternative 2 in this scenario.
- 100-year Seas (Figure 34) – The Project alternatives provides a benefit to berm widths under all modeled water levels. The Project provides approximately 15 to 30 feet of additional width, as compared to the No Project condition. Alternative 2 (Sand Berm) outperforms Alternative 1 in the 2050 high SLR scenario slightly (8 feet).
- 100-year Swell (Figure 35) – The Project alternatives provides a benefit to berm widths under all modeled water levels. The Project provides approximately 20 to 34 feet of additional width, as compared to the No Project condition. Alternative 2 (Sand Berm) outperforms Alternative 1 in the 2050 high SLR scenario significantly.
- 2100 High SLR Scenario – The project alternative is not effective in preventing damage to the highway. The additional 5.5 feet of SLR brings sustained wave action up to the project toe and both the cobble berm and sand berm become completely eroded, exposing HWY 101 subgrade.

In summary, the majority of berm erosion is attributed to long-term erosion or SLR. It was also found that the Project alternatives are effective at reducing berm erosion compared to the No Project condition. For the seas wave events, the protection provided by the sand and gravel berms are similar, however for the swell events, the gravel berm suffers more berm loss than the sand alternative. This difference may be attributed to the fact that the swell events have stronger wave uprush and the larger particles of the gravel are more susceptible to bedload transport or rolling.

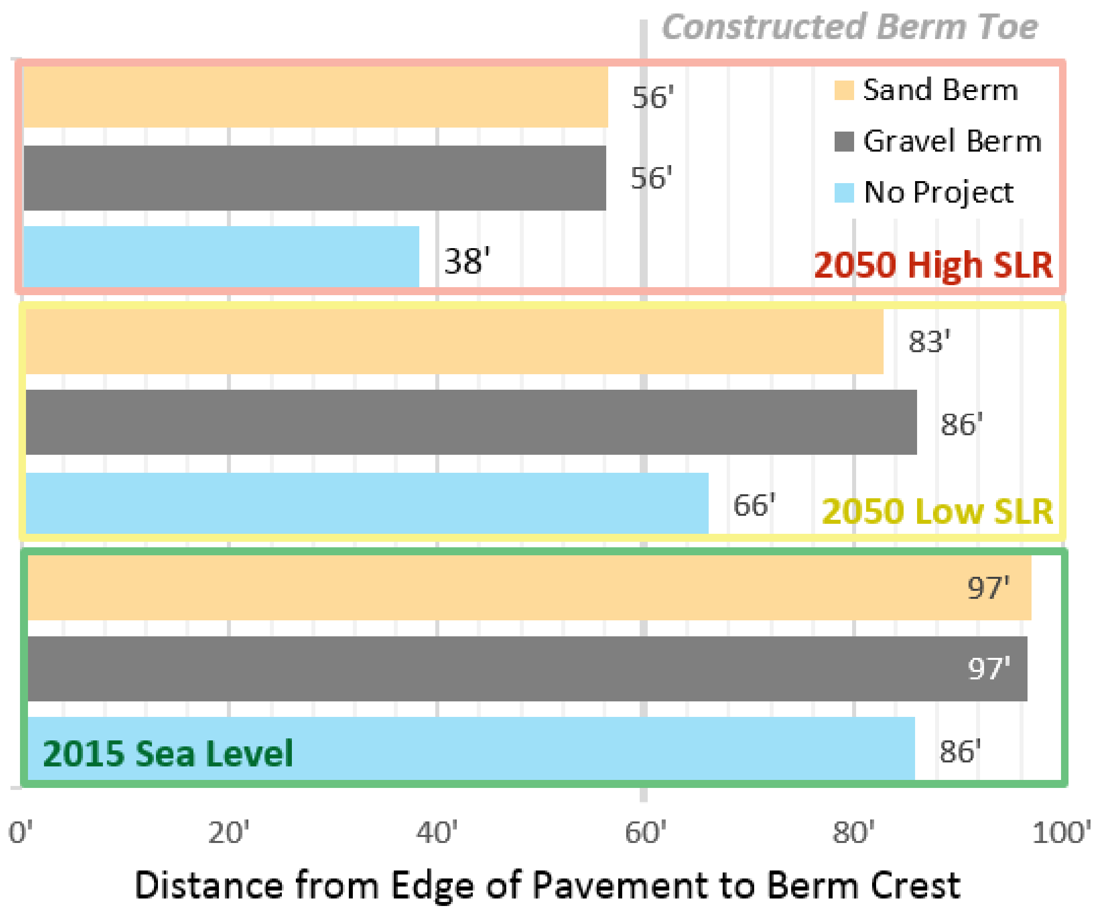


Figure 32: Remaining Berm Width, Mid Profile, 43-year Seas

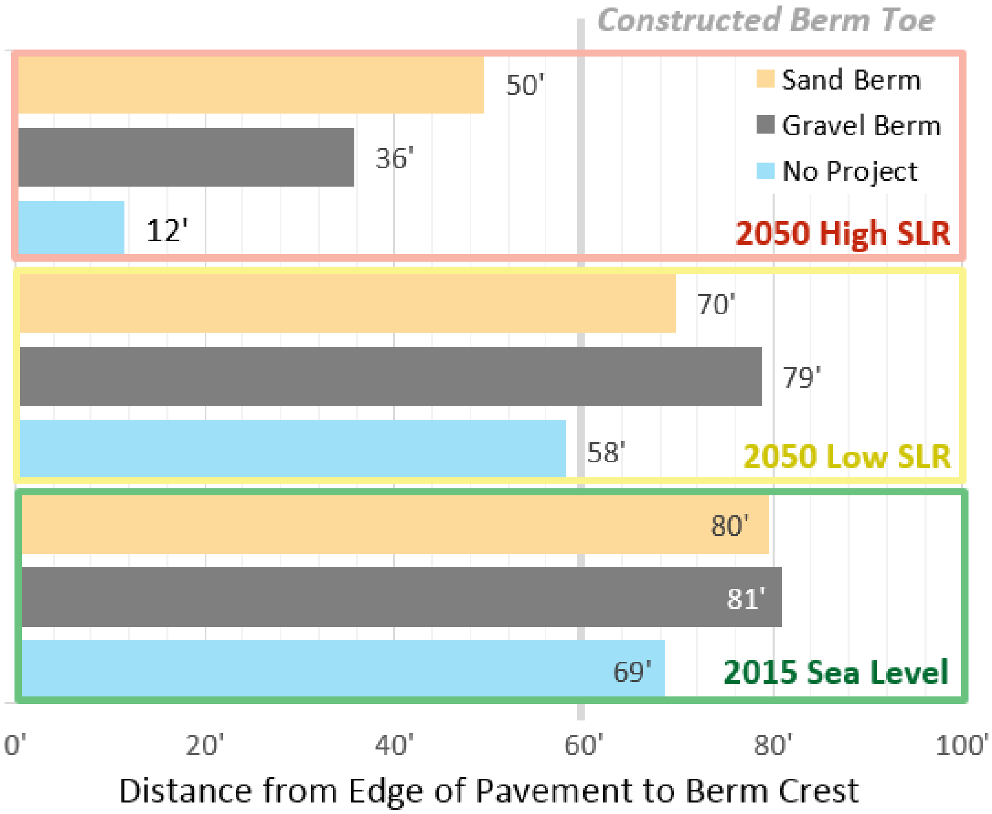


Figure 33: Remaining Berm width, Mid Profile, 43-year Swell

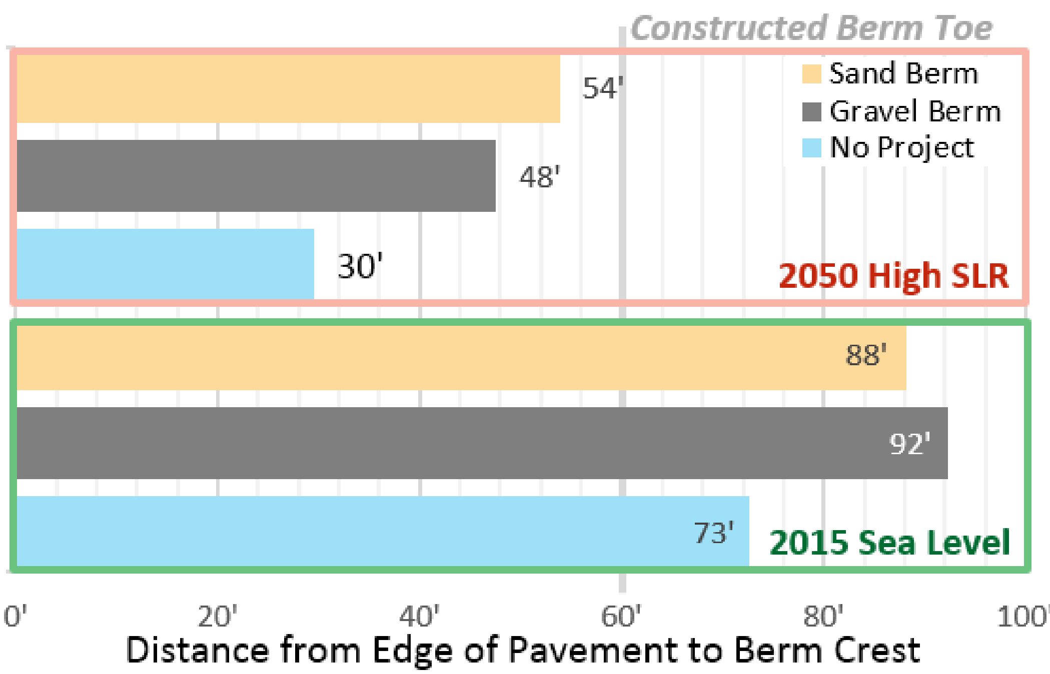


Figure 34: Berm Loss, Mid Profile, 100-year Seas

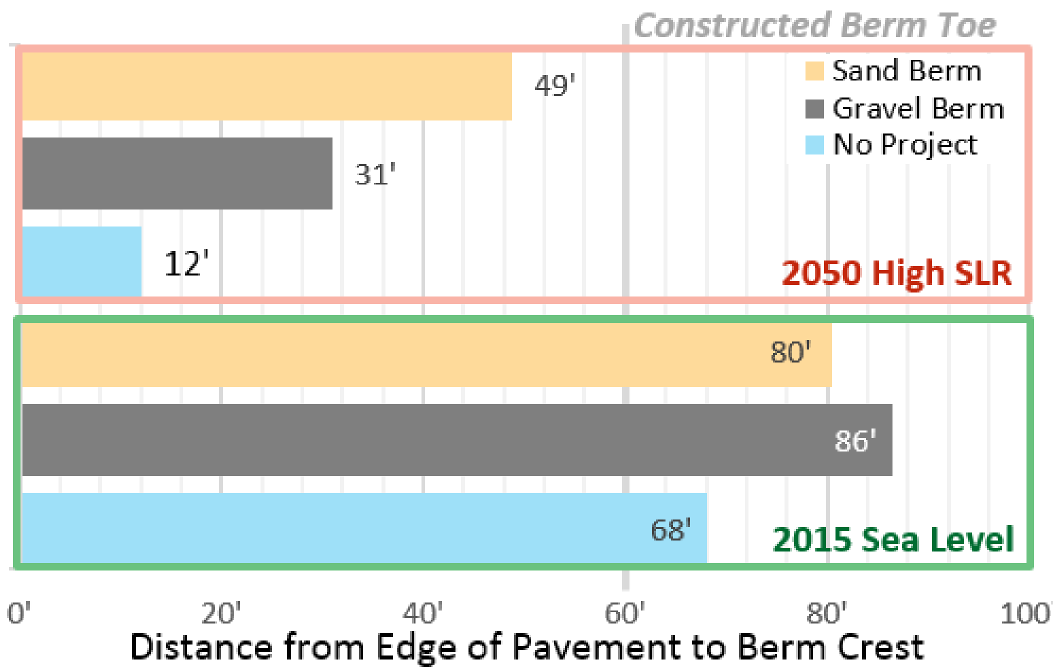


Figure 35: Berm Loss, Mid Profile, 100-yr Swell

10.4.2. Wave Runup

A common measurement used to represent the limit of wave runup is the elevation that is exceeded by only 2% of the waves during a measurement period of approximately 100 to 200 waves, or about one hour. The 2% runup location can also be described by a horizontal distance from a fixed position. This study defines runup in terms of elevation (relative to MLLW) and horizontal distance from the seaward edge of pavement on HWY 101. Since wave runup results are given in terms of elevation, elevations of various points of interest along the Project area are provided in Table 12.

Table 12: Edge of Pavement (EOP) Elevations for various Points of Interest

Point of interest	EOP Elevation (ft MLLW)
Cardiff State Beach parking lot	+12
North end of Project (just south of Chart House parking lot)	+14
Las Olas Traffic signal	+15
North Profile	+15
End of shoulder parking	+17
Mid Profile	+18
Existing repair location (undermining spot)	+17
South Profile	+18

At the north profile, the maximum elevation of HWY 101 is approximately +16 feet MLLW with the seaward edge of pavement (EOP) at about +15 feet. Further north of the modeled profile, the road and EOP is lower (about +14 feet MLLW). The back beach and road at the middle profile is most built up with the highway EOP at or above +18 feet MLLW. For the majority of XBeach runs at the north profile, water overtops the road at least once during the simulation. This often means that the 2% runup elevation cannot be calculated, but only stated as being greater than the berm or road crest. The mid profile is used for much of the runup analysis since the back beach and road is most built up and runup can be calculated up to an elevation of +18 ft. Since the runup values did not vary much more than a foot between the profiles, the mid profile can be assumed to be representative throughout the project site. Furthermore, the runup estimates for the alternatives are similar and are not analyzed separately.

Wave runup results at the Project site under existing, No Project condition with SLR is summarized in Table 13. HWY 101 starts to be overtopped in the 2050 high SLR scenarios.

Table 13: Existing (No Project) Runup with Sea-Level Rise (Mid Profile, 43-year Seas)

SLR SCENARIO	2% Runup Distance (feet, from Edge of Pavement)	2% Runup Elevation (feet, MLLW)
2100 High	< 0 - HWY 101 Overtopped	>19 - HWY 101 Overtopped
2050 High	< 0 - HWY 101 Overtopped	>19 - HWY 101 Overtopped
2050 Low	10	15.4
2015 (existing)	30	12.5

Wave runup results for the proposed Project condition in addition to SLR is summarized in Table 14. HWY 101 starts to be overtopped under the 2100 high SLR scenario, which is a significant improvement over the No Project condition.

Table 14: Runup (with Project) and Sea-Level Rise (Mid Profile, 43-year Seas)

SLR SCENARIO	2% Runup Distance (feet, from Edge of Pavement)	2% Runup Elevation (feet, MLLW)
2100 High	< 0 - HWY 101 Overtopped	>19 - HWY 101 Overtopped
2050 High	45	14.3
2050 Low	54	13.7
2015 (existing)	59	12.9

Wave runup results for existing beach conditions under a variety of wave conditions and existing sea levels is provided in Table 15. HWY 101 is first overtopped by a 43-year swell without the project. HWY 101 is protected from overtopping by the Project during this same 43-year event. The Project would be overtopped by a 100-year swell at existing sea levels.

Table 15: Wave Runup Results With and Without Project (Mid Profile)

Wave Return Period (Year)	Wave Event Type (Sea / Swell)	With Project (Y/N)	SLR SCENARIO	2% Runup Distance (Feet from Edge of Pavement)	2% Runup Elevation (Feet MLLW)
43	Sea	Y	2015	59	12.9
43		N	2015	30	12.5
100		Y	2015	44	15.1
100		N	2015	2.5	17.6
43	Swell	Y	2015	15	17.0
43		N	2015	< 0 - HWY 101 Overtopped	>19 - HWY 101 Overtopped
100		Y	2015	< 0 - HWY 101 Overtopped	>19 - HWY 101 Overtopped
100		N	2015	< 0 - HWY 101 Overtopped	>19 - HWY 101 Overtopped

10.4.3. Successive Wave Event

In order to explore the effect of an extreme winter wave season, a second, less powerful storm was run after the 43-year and 100-year post storm beach profiles. The second wave event used for modeling was an 8-year return period seas event (i.e., January 2013) that was also used for calibration. This event was used so that combined probability of a second storm occurring in the same season as a 43-year event is reasonable. Furthermore, the model configuration had been calibrated and tested using this event.

The successive storm event showed little change in the profile as compared to the previous, larger storm event. This suggests that for a fully developed storm profile, a second, less powerful storm will not lead to further adjustment of profile. The beach profile had become fully adjusted and reconfigured in such a way to effectively dissipate large amounts of wave's energy and reduce erosion.

However, there are scenarios where a second less powerful storm can be expected to lead to further damage. If a protective feature is eliminated or badly damaged by the first storm and vulnerable slopes or structures becomes exposed, further damage can be expected.

11. PREFERRED ALTERNATIVE

Based on the modeling results, coordination with the Project Team and stakeholder outreach, a preferred alternative was developed. The alternative is a hybrid that varies spatially between Alternatives 2 and 3. The alternative would create "lumps and bumps" along the project reach to serve as a heterogeneous habitat improvement over a more continuous linear dune feature. Key components of the Preferred Alternative are described below.

- Rip Rap Reconfiguration/Repair – The existing un-engineered rock riprap will be repaired along the Project area. Repair would consist of reconfiguring/consolidating the existing rock into a more robust form. New 2-ton rock (to match existing) would be imported in areas where the existing rock is not adequate to form the rock template. The amount of rock to be imported would not exceed 10,000 cy. The existing rock footprint would be reduced in many locations.

- Cobble Berm – No new cobble will be imported for the project. Existing cobble that is to be removed in sections of the revetment that require repair will be reconfigured seaward of the revetment in a berm form similar to that shown in Alternative 2.

- Dune Feature – A sand dune would be constructed with approximately 30,000 cy of imported sand. The sand dune would cover the reconfigured riprap and would occupy a maximum width of 60 feet (starting from the edge of pavement at HWY 101). The crest of the sand dune would range from 4 feet above the crown elevation of HWY 101 along the northern end to 2 feet above the crown elevation in the middle and southern reaches. The dune feature would have a crest elevation no greater than 2 feet above the edge of pavement of the highway at any given location to minimize visual impacts from the roadway.

- Dune Habitat Establishment – The dune is proposed to be seeded with a native plant pallet, as provided in Table 16. The seeding may incorporate a rice straw feature that was used at the Surfer's Point project to promote plant establishment by reducing seed blowing and providing nutrients. The dunes would not be seeded until the soils have been adequately leached of salt. Irrigation is not proposed, instead natural rainfall will leach the sand and eventually establish plantings.

Table 16: Proposed Planting Pallet

Common Name	Scientific Name	Form
beach sun cup	*Camissoniopsis cheiranthifolia* subsp. *suffruticosa*	subshrub
Nuttall's acmispon	*Acmispon prostratus*	annual herb
beach sand verbena	*Abronia umbellata*	annual herb
Orcutt's pincushion	*Chaenactis glabriuscula* var. *orcuttiana*	annual herb
coast woolly-heads	*Nemacaulis denudata* var. *denudata*	annual herb
beach bur-sage	*Ambrosia chamissonis*	perennial herb
beach morning-glory	*Calystegia soldanella*	perennial herb
red sand verbena	*Abronia maritima*	perennial herb

- Sand Fence – The parapet wall was removed from the design and replaced with a sand fence. The permanent nature and cost of the wall feature were reasons it was rejected from the preferred alternative. The sand fence would meet many of the wall's goals in that it would act to capture blowing sand and restrict access to intentional points.
- Pedestrian Improvements – A pedestrian "foot trail" was added adjacent to the HWY 101 bicycle lane and street parking to improve public access along the Project site. The foot trail would be 4 feet in width and would be finished with compacted sand or decomposed granite surface.

Based on modeling results, the Project would significantly reduce the vulnerability of HWY 101 to current and future coastal hazards by providing protection from undermining and wave overtopping. The proposed dune was found to erode, but not significantly, in the 2050 high SLR scenario in combination with an extreme wave event. This was in stark contrast to the No Project condition in which the highway is shown to be undermined or overtopped during existing conditions. Thus, the Project would meet the Project's goals and objectives in the short-term by reducing the vulnerability of HWY 101 and a creating dune habitat to possibly year 2050 (assuming periodic maintenance and a relatively benign wave climate).

As sea levels rise, as most projections suggest, the Project and the highway may be overwhelmed by coastal damage or periodic nuisance flooding at some point in the future. For example, all Project alternatives were found to be vulnerable to the year 2100 high SLR scenario in combination with an extreme wave event. To address these longer-term vulnerabilities, a second feasibility study is being recommended. This subsequent and supplemental study would analyze longer-term solutions for the area such as a elevating HWY 101 on piles or removing lanes of HWY 101 (i.e., managed retreat). These alternatives would be to protect the highway as well as the beach, dune, and adjacent lagoon habitats from longer-range projections of sea-level rise and storms.

11.1. 30% Design

The 30% design drawings are included as Attachment B. The drawings are currently draft in nature, therefore, a concept of the hummock dune profile is shown in Figure 36 and Figure 37. The dune crests would be staggered along the reach in order to provide adequate protection of the highway and provide enhanced dune habitat over a more homogenous feature. Dune crest maximums and dune trough minimum elevations would be established in the plans. These elevations would vary along the Project reach in response to the changing highway elevations. Dune plantings would be concentrated within higher elevations within the dune. Lateral beach access points would be positioned within the dune trough features.

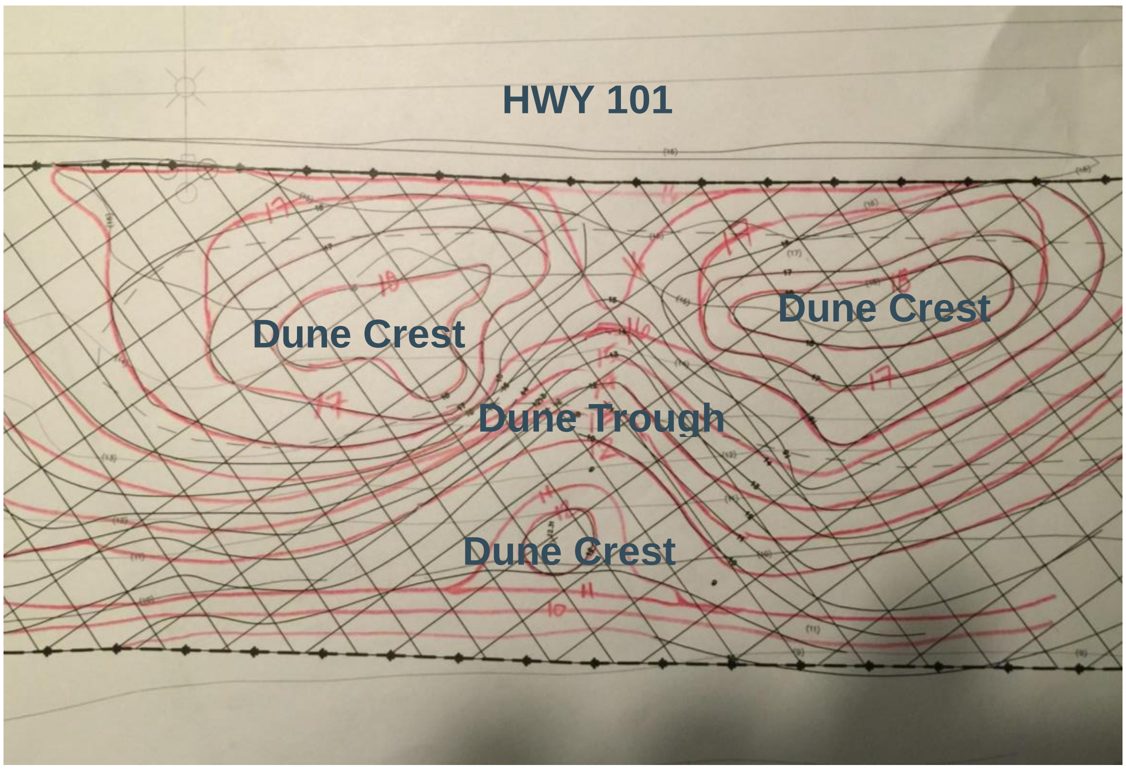


Figure 36: Preferred Alternative – Typical Planform showing "Lumps and Bumps"

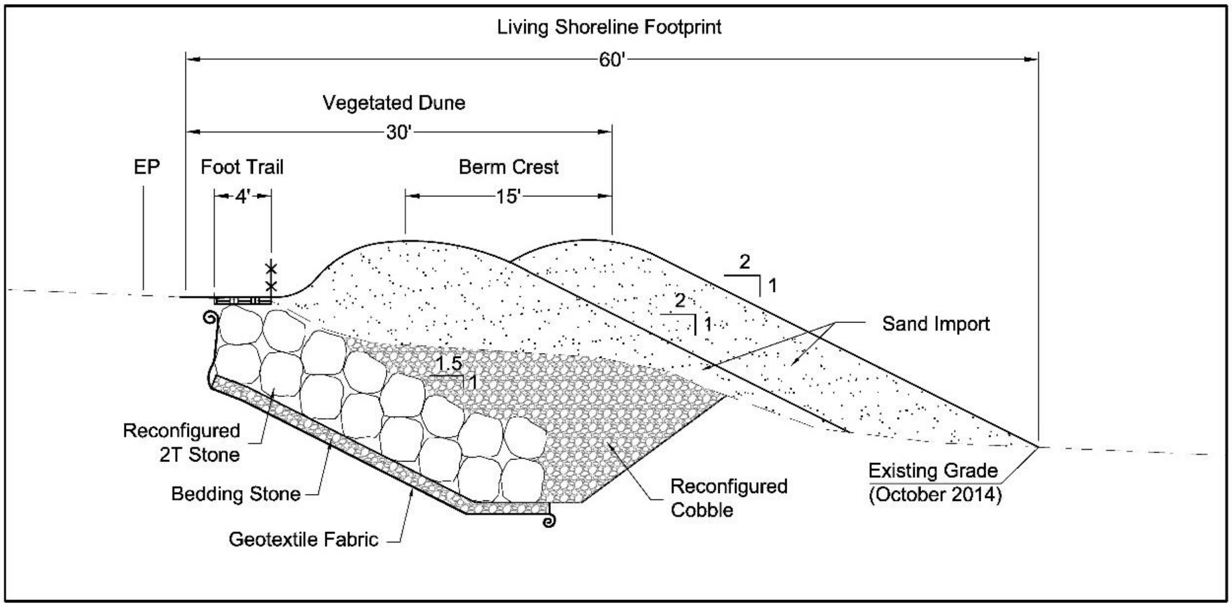


Figure 37: Preferred Alternative – Typical Cross Section

11.2. Cost Estimate

The 30% construction cost estimate is included as Attachment C. The estimate assumes a free source of sand from the SELRP construction. However, a line item is included to rework the sand into the preferred hummock profile. K-Rail will be used during construction along HWY 101 to control traffic around the construction area. It is anticipated that one lane of the highway (southbound, number 1 lane) would need to be closed during construction. Quantities of sand and rock are estimates based on a topographic survey completed in 2012. Construction of the Preferred Alternative is estimated to cost $2,018,000. A 25% contingency of $403,503 is assumed at this time.

12. POTENTIAL PROJECT IMPACTS

The proposed Project was identified as potentially resulting in visual, blowing sand, and beach access and recreation impacts. These impacts and the Project's approach to minimizing these affects are discussed in this section.

12.1. Visual Impacts

HWY 101 within the Project area is considered a scenic highway by the City. Thus, potential Project impacts to the visual corridor were carefully considered. Based on coordination with City staff, a significant visual impact would result if the Project were to be more than 3 feet above the highways' edge of pavement elevation (EOP) between South Cardiff State Beach and the southern end of the street-side parking. The Project was designed to be no more than 2 feet above EOP in this section. Since the highway elevation varies along this reach, dune crest elevations will be specified at adequate resolution in the engineering plans and specifications to clarify this requirement to the construction contractor.

Photo simulations were prepared to compare the existing versus proposed conditions for a number of proposed project features and alternatives from key vantage points. Site photographs for the simulations were taken on September 2, 2015. A simulation of Alternative 1 from a temporary lifeguard tower in the vicinity of the Las Olas Restaurant intersection looking south is shown in Figure 38. The exposed cobble is the most prominent feature in this alternative. A simulation of Alternatives 2 and 3 from the same location is shown in Figure 39.

A second simulation was performed from southbound HWY 101 from the number 2 (inside lane) in the approximate middle of the Project area. A simulation showing the parapet wall compared to the existing conditions is shown in Figure 40. The wall façade was mirrored after the City of Carlsbad seawall in the vicinity of Tamarack Beach. A simulation from the same vantage point showing a sand fence is shown in Figure 41. A simulation showing the sand fence with the addition of a pedestrian foot-trail and lateral beach access way is shown in Figure 42. This simulation represents the Preferred Alternative.

Figure 38: Photo Simulation of Alternative 1 (Exposed Cobble Berm)
View looking south (existing – left, proposed – right)

Figure 39: Photo Simulation of Alternatives 2 & 3

View looking south (existing – left, proposed – right)

Figure 40: Photo Simulation of Parapet Wall
View from HWY 101 southbound (#2 lane) (existing – left, proposed – right)

Figure 41: Photo Simulation of Sand Fence

View from HWY 101 southbound (#2 lane) (existing – left, proposed – right)

Figure 42: Photo Simulation of Sand Fence with Foot Trail and Lateral Beach Access Way
View from HWY 101 southbound (#2 lane) (existing – left, proposed – right)

12.2. Windblown Sand

The potential for wind to blow sand from the created dune features onto the highway was identified as a maintenance concern for the City. While the Project may result in some increased blowing sand on the highway, the following measures were included in the project to reduce this impact:

- Rice Straw – Rice straw was used to successfully stabilize seed and promote plant establishment for the Surfer's Point Project. These features are proposed to serve a similar function.
- Sand Fence – Sand fences are a low-cost method of controlling blowing sand. The Project includes a sand fence that parallels the bike lane/foot trail. Additional sand fences could be added later if determined to be necessary.
- Roadway Buffer – The crest of the dune features are proposed to be set at a buffer distance of approximately 20 feet seaward of the road to allow some blowing sand to settle prior to reaching the road.

Source sand gradation is a factor that may impact blowing sand. Coarser gradation source materials are less likely to become mobilized by aeolian transport.

12.3. Beach Access and Recreation

Existing beach access is continuous along the Project site though it requires traversing loose rock and cobble. The proposed Project would limit beach access to six locations along this reach in order to allow dune habitat to establish in designated areas. Four of the six beach access points along this reach will be in the vicinity of the existing street-side parking on the northern end of the Project area. The two other access points will be within the reach from the end of the existing street-side parking to South Cardiff State Beach Parking lot. This area is not often used in the existing condition due to limited parking and steep rock slopes in this area. All beach access points will be clearly identified by fencing and signage.

Existing pedestrian access along the Project area is unimproved and occurs along the shoulder of the roadway or in the bike lane. This access would be improved by the proposed Project through construction of a 4-foot wide, foot-trail. The trail would provide increased connectivity between the City and the neighboring City of Solana Beach and would also provide access along the Project site during periods of narrow beach widths or high surf.

The proposed Project would designate a portion of recreational beach as a protected habitat area with restricted pubic access. The portion of the beach width within the Project area generally consists of riprap, cobble and sandy beach (from east to west). The total portion of recreational, sandy beach impacted by the Project varies along the reach, but is about 30 feet on average. Assuming this average width, the Project is estimated to convert 2 acres of sandy beach to dune habitat over the Project length. Given the existing beach condition (i.e., approximately 100 feet in width), a total of 40 feet in width (or approximately 2.7 acres) of dry beach would still exist for recreation along this reach. Additionally, the proposed Project is to planned to be constructed at a similar time to the proposed placement of 300,000 cy of beach sand at Cardiff State Beach as a component of the SELRP. The SELRP would benefit the Project by providing wider beach widths, which would reduce impacts to recreation.

13. Conclusions and Recommendations

A summary of the site-specific modeling results are as follows:

- Beach erosion
  - Without the Project, HWY 101 is vulnerable to undermining during a 43-year swell event and possibly weaker swell events. Due to its low elevation, the north end of the Project area is most vulnerable to wave runup and overtopping. The Project protects the highway from extreme wave events in the existing condition.
  - Under 2050 high SLR scenario, a portion of the Project erodes and forms a steeper seaward face. However, most of the proposed dune habitat is retained and the highway is protected from undermining. All No Project profiles show undermining of the highway in this scenario.
- Wave runup and overtopping
  - Wave overtopping of HWY 101 begins with 43-year Swell event at existing sea levels and without the proposed Project. The Project was found to protect the highway from overtopping during this event. Wave overtopping of the Project would only occur during a 100-year (or greater) swell wave event with existing water levels.
  - HWY 101 is overtopped during a 43-year Seas event in 2050 high SLR scenario under the No Project condition. Under the same wave event, the highway is not overtopped until the 2100 high SLR scenario in the with Project condition.
  - None of the proposed Project alternatives would withstand the 2100 high SLR in addition to extreme wave condition scenario.
- The need for a cobble berm feature was not validated by the modeling effort. Based on studies and empirical evidence of the stability of these features, this is believed to be a limitation in the numerical model to predict the morphodynamic response of these mixed substrate beaches.
- Based on a successive event analysis, a weaker 8-year return period storm behind a larger storm does not generate a significant amount of additional erosion.

Based on coordination with the Project Team, a Preferred Alternative was developed. The alternative is a hybrid of Alternatives 2 and 3, with the following features:

- **Sandy dune** constructed from import sand from the SELRP or another opportunistic source. The dune feature would be non-uniform and varying in geometry along the Project reach to form “lumps and bumps” serving as a benefit for habitat. It was estimated that no more than 30,000 CY of sand fill is needed to create the dune feature.
- Reconfigured and imported 2 ton rock would be used to consolidate the existing rip rap footprint into a **revetment** section. The revetment would serve as last line of defense for

HWY 101 to protect it from undermining. It was estimated that no more than 10,000 CY of rock import is needed to form the proposed revetment section.

- A total of six **beach access points** would be included in the dune design to provide public access to the beach along the Project area. Access points would be concentrated along the northern portion of the Project reach where beach usage is highest. The vehicular beach access point in the vicinity of the Las Olas signaled intersection would be retained for State Parks usage.
- A pedestrian **foot trail** would be constructed along HWY 101 to provide improved access along the Project site. The foot trail would increase pedestrian connectivity and provide access along the beach during periods of narrow beach widths or large surf.
- **Sand fences** would be installed adjacent to the foot trail and public access points. The fence would capture blowing sand and focus beach access to intentional points along the reach to protect the proposed habitat areas.
- **Rice straw** would be installed on the constructed sand dune to stabilize seed and promote plant establishment.

The following potential data needs were identified during the 30% design of the Preferred Alternative:

- A mean high tide line (MHTL) survey is only available for a portion of the proposed Project area. A MHTL survey may be required during the permitting process. Coordination with the State Lands Commission and the SELRP is recommended.
- The quantity of existing rock along the Project area is unknown at this time. A potholing survey could inform the design by better defining the available existing quantities of cobble and stone.

14. REFERENCES

California Coastal Commission (CCC). 2015. Sea Level Rise Policy Guidance, Public Review Draft. May 27, 2015.

City of San Buenaventura, Public Works Department (Buenaventura). 2003. Surfers Point Managed Shoreline Retreat – Final Environmental Impact Report. Prepared with the assistance of Rincon Consultants. March 2003.

Coastal Frontiers Corporation (CFC). 2013. 2013 Regional Beach Monitoring Program, Annual Report. April 2014

Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT). 2013. State of California Sea-Level Rise Guidance Document, March 2013 Update.

Dare, J. 2003. Alternative Shore Protection Strategies: Innovative Options and Management Issues. Marine Resources Management Program, College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR. July 2003.

Everts, C.H., and C.D. Eldon. 2002. Performance of Cobble Berms in Southern California. Shore & Beach 5-14.

Gōda, Yoshimi. 2010. Random Seas and Design of Maritime Structures. World Scientific.

Komar, P.D., and J.C. Allan. 2010. "Design with Nature" strategies for shore protection—The construction of a cobble berm and artificial dune in an Oregon State Park, in Shipman, H., Dethier, M.N., Gelfenbaum, G., Fresh, K.L., and Dinicola, R.S., eds., 2010, Puget Sound Shorelines and the Impacts of Armoring. Proceedings of a State of the Science Workshop, May 2009: U.S. Geological Survey Scientific Investigations Report 2010-5254, p. 117-126.

Kuhn, G. and F. Shepard. 1985. Sea Cliffs, Beaches, and Coastal Valleys of San Diego County, Some Amazing Histories and Some Horrifying Implications. University of California Press. 1984

Moffatt, Nichol & Ferver Engineers (M&N). 1998. Protection of Highway 101 Study, Encinitas, California. Prepared for the City of Encinitas. December 1998

National Oceanic and Atmospheric Administration (NOAA). 2015. "Monthly Mean Sea Level Anomalies." http://tidesandcurrents.noaa.gov/.

National Research Council of the National Academies (NRC). 2012. Sea Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future.

Roelvink, D., A. van Dongeren, R. McCall, B. Hoonhout, A. van Rooijen, P. van Geer, L. de Vet, and K. Nederhoof. 2015. "XBeach Manual". Deltares. 27 April 2015.

She, K., D. Horn, and P. Canning. Influence of permeability on the performance of shingle and mixed beaches. Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme, Research Scoping Study. R&D Technical Report FD1923/TR, 2007.

U.S. Army Corps of Engineers (USACE). 2013. Hurricane Sandy Coastal Projects Performance Evaluation Study, Disaster Relief Appropriations Act, 2013. November 6, 2013.

Ventura River Ecosystem. Surfer's Point Case Study. Jenkin, P. 2015. 2007-2014. http://www.venturariver.org/. Accessed 2015.

Vousdoukas, Michalis I., Óscar Ferreira, Luís P. Almeida, and André Pacheco. 2012. "Toward Reliable Storm-Hazard Forecasts: XBeach Calibration and Its Potential Application in an Operational Early-Warning System." Ocean Dynamics 62 (7): 1001–15. doi:10.1007/s10236-012-0544-6.

Van Rijn, L. C, D. J. R Walstra, B Grasmeijer, J Sutherland, S Pan, and J. P Sierra. 2003. "The Predictability of Cross-Shore Bed Evolution of Sandy Beaches at the Time Scale of Storms and Seasons Using Process-Based Profile Models." Coastal Engineering 47 (3): 295–327. doi:10.1016/S0378-3839(02)00120-5.

ATTACHMENT A. SITE SPECIFIC MODEL – ALL RESULTS

Wave Return Period (yr)	Wave Conditions (Sea/Swell)	SLR Scenario (Existing, Low, High)	Profile (North, Mid, South)	Alternative No.	2% Runup Distance (ft From EOP)	2% Runup Elevation (ft, MLLW)
043	SEA	E	N	0	31.3	12.9
043	SEA	E	N	2	84.3	12.3
043	SEA	E	N	1	73.7	14.2
043	SEA	E	M	0	29.8	12.5
043	SEA	E	M	2	59.1	12.9
043	SEA	E	M	1	59.3	12.9
043	SEA	E	S	0	7.4	14.7
043	SEA	E	S	2	48.4	13.4
043	SEA	L	N	0	15.4	14.6
043	SEA	L	N	2	72.9	14.4
043	SEA	L	M	0	10.2	15.4
043	SEA	L	M	2	55.1	13.6
043	SEA	L	M	1	52.7	13.7
043	SEA	H	N	0	-	15.8
043	SEA	H	N	2	79.6	12.2
043	SEA	H	N	1	60.4	16.0
043	SEA	H	M	0	15.4	14.6
043	SEA	H	M	2	49.0	13.1
043	SEA	H	M	1	40.7	15.5
043	SEA	H	S	0	-	17.3
043	SEA	H	S	2	-	17.3
100	SEA	E	N	0	-	15.3
100	SEA	E	N	2	70.6	14.8
100	SEA	E	M	0	2.5	17.6
100	SEA	E	M	2	44.7	15.5
100	SEA	E	M	1	44.0	14.7
100	SEA	H	N	0	-	15.8
100	SEA	H	N	2	9.9	17.0
100	SEA	H	N	1	-	17.0
100	SEA	H	M	0	-	18.9
100	SEA	H	M	2	-	18.9
100	SEA	H	M	1	-	18.9
043	SWELL	E	N	0	-	15.8
043	SWELL	E	N	2	24.0	15.0
043	SWELL	E	N	1	61.5	16.8
043	SWELL	E	M	0	7.2	15.8
043	SWELL	E	M	2	12.5	17.1
043	SWELL	E	M	1	16.8	17.0
043	SWELL	E	S	0	-	17.2
043	SWELL	E	S	2	-	16.9

Wave Return Period (yr)	Wave Conditions (Sea/Swell)	SLR Scenario (Existing, Low, High)	Profile (North, Mid, South)	Alternative No.	2% Runup Distance (ft From EOP)	2% Runup Elevation (ft, MLLW)
043	SWELL	L	N	0	-	15.8
043	SWELL	L	N	2	-	17.0
043	SWELL	L	N	1	12.0	17.0
043	SWELL	L	M	0	-	18.9
043	SWELL	L	M	2	-	18.9
043	SWELL	L	M	1	-	18.9
043	SWELL	H	N	0	-	15.8
043	SWELL	H	N	2	-	17.0
043	SWELL	H	N	1	-	17.0
043	SWELL	H	M	0	-	18.9
043	SWELL	H	M	2	-	18.9
043	SWELL	H	M	1	-	18.9
043	SWELL	H	S	0	-	17.1
043	SWELL	H	S	2	-	17.1
100	SWELL	E	N	0	-	15.8
100	SWELL	E	N	2	-	17.0
100	SWELL	E	M	0	-	18.9
100	SWELL	E	M	2	-	18.9
100	SWELL	E	M	1	-	18.9
100	SWELL	H	N	0	-	15.8
100	SWELL	H	N	2	-	17.0
100	SWELL	H	N	1	-	17.0
100	SWELL	H	M	0	-	18.9
100	SWELL	H	M	2	-	18.9

ATTACHMENT B. 30% DESIGN

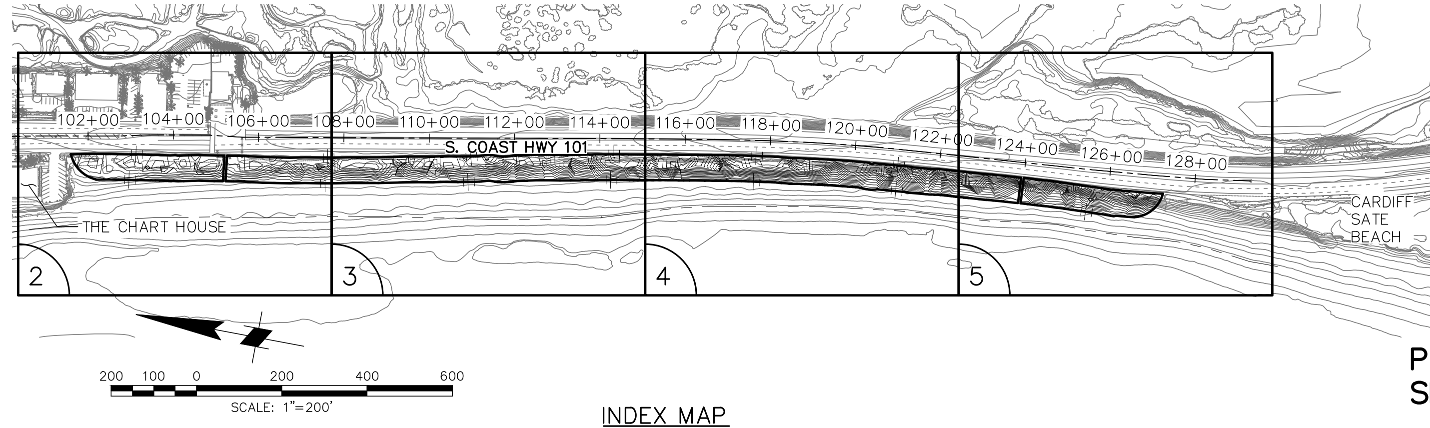
CARDIFF BEACH LIVING SHORELINE PROJECT

REFERENCE DRAWINGS

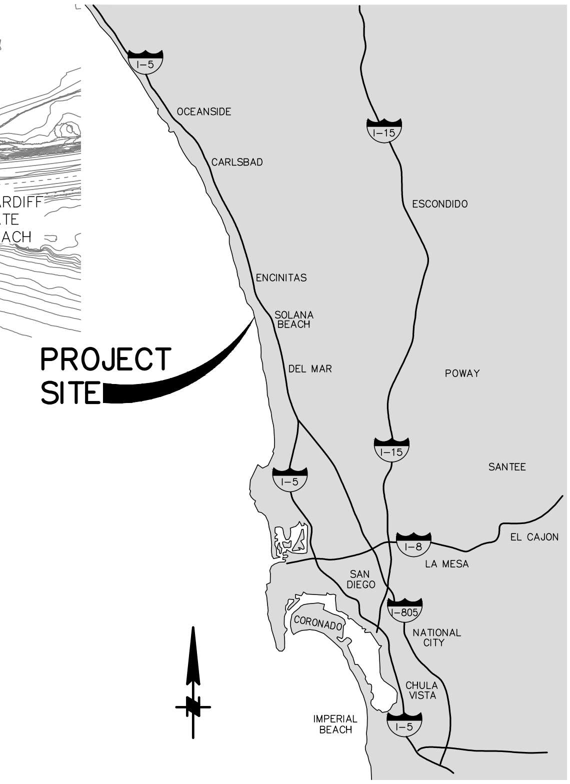
1. EXISTING 30" RCP SAN ELIJO OCEAN OUTFALL PER "OCEAN OUTFALL" AS-BUILT PLANS (9 SHEETS, ENGINEERING W.O. 2943, FILE NO. 7-3 SE, DATED OCT. 1964) - (SEE APPENDIX IN SPECIFICATIONS).
2. EXISTING 48" RCP SAN ELIJO OCEAN OUTFALL PER "SAN ELIJO OCEAN OUTFALL EXTENSION" AS-BUILT PLANS (5 SHEETS, DRAWING NO. P-1, DATED APRIL 1974) - (SEE APPENDIX IN SPECIFICATIONS).

GENERAL NOTES

1. THE INFORMATION DEPICTED ON THESE DRAWINGS REPRESENTS THE RESULTS OF CURRENT AND PREVIOUS SURVEYS AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME.
2. HORIZONTAL DATUM IS STATE PLANE, ZONE 6, N.A.D. 83 (US SURVEY FEET).
3. VERTICAL DATUM IS NAVD-88.
4. NAVY RESOURCE SURVEYS SHOWN ON THE PLANS ARE LIMITED IN AREA AND OUTLINED AS POLYGONS.
5. DRAWINGS NOT TO BE USED FOR NAVIGATION.
6. CONTOUR INTERVAL IS 5 FT, UNLESS OTHERWISE NOTED.
7. ARCHEOLOGICAL SITES: A 500 FOOT SEPARATION DISTANCE SHALL BE MAINTAINED AROUND ARCHEOLOGICAL SITES AT ALL TIMES FOR ALL TYPES OF OPERATION.
8. OUTFALL PIPE: NO PHYSICAL CONTACT TO BE MADE WITH SUBMERGED OUTFALL PIPE. NO ANCHORING WITHIN 500 FEET OF OUTFALL PIPE.
9. CONTRACTOR SHALL INDICATE EGRESS/ACCESS ROUTES FOR TRAFFIC ALONG SHORELINE. SEE SPECIFICATIONS FOR ADDITIONAL REQUIREMENTS.
10. FEATURES SUCH AS PRIVATE STAIRS, LIFEGUARD STATIONS, GARBAGE CANS, VOLLEYBALL COURT POLES, AND STORM DRAIN LINES THAT ARE NOT IDENTIFIED ON THE PLANS SHALL BE FIELD VERIFIED BY THE CONTRACTOR AND NOT DAMAGED OR BURIED. ITEMS THAT MAY BE TEMPORARILY RELOCATED DURING BEACH FILL OPERATIONS SHALL BE RELOCATED WITH THE ENGINEER'S APPROVAL. FEATURES THAT ARE IDENTIFIED ON THE PLANS MAY NOT BE ACCURATELY LOCATED AND SHALL BE FIELD VERIFIED BY THE CONTRACTOR. LIFEGUARD STATIONS SHALL BE TEMPORARILY RELOCATED AS REQUIRED AND DIRECTED UPON APPROVAL BY THE ENGINEER.



INDEX MAP
NOT TO SCALE



PROJECT LOCATION MAP
NOT TO SCALE

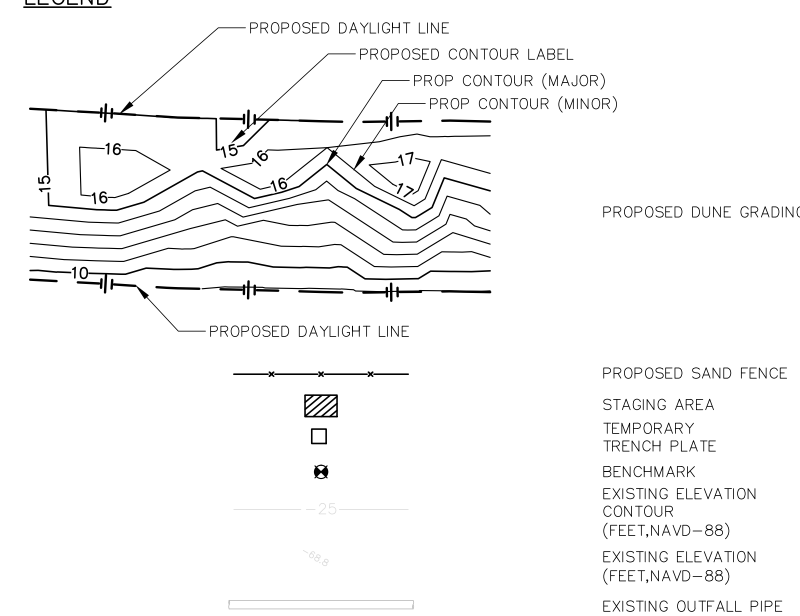
RECORDED WATER LEVELS AT LA JOLLA (1983-2001 TIDAL EPOCH)

DESCRIPTION	ELEVATION (FEET, MLLW)	ELEVATION (FEET, NGVD)
EXTREME HIGH WATER (11/13/1997)	7.65	5.35
MEAN HIGHER HIGH WATER (MHHW)	5.33	3.03
MEAN HIGH WATER (MHW)	4.60	2.30
MEAN TIDAL LEVEL (MTL)	2.75	0.46
MEAN SEA LEVEL (MSL)	2.73	0.44
NATIONAL GEODETIC VERTICAL DATUM 1929 (NGVD)	2.30	0.00
MEAN LOW WATER (MLW)	0.91	-1.39
NORTH AMERICA VERTICAL DATUM 1988 (NAVD)	0.19	-2.11
MEAN LOWER LOW WATER (MLLW)	0.00	-2.30
EXTREME LOW WATER (12/17/33)	-2.87	-5.16

CONSTRUCTION NOTES

1	PROPOSED DAYLIGHT LINE
2	PROPOSED DUNE GRADING
3	PROPOSED TOE OF SLOPE
4	PROPOSED 5:1 SLOPE (HORIZONTAL:VERTICAL)
5	APPROXIMATE LOCATION OF PROPOSED 75' X 50' STAGING AREA IN CARDIFF STATE BEACH SOUTH PARKING LOT. (TO BE CONFIRMED)
6	PROPOSED TEMPORARY TRENCH PLATE. LIMIT CROSSING EXISTING OUTFALL PIPE TO ONE LOCATION. PLACE TRENCH PLATES AND 2' OF SAND OVER OUTFALL LINE AT CROSSING LOCATION
7	PROPOSED CONSTRUCTION ACCESS. SHORE EQUIPMENT ACCESS SITE FROM STAGING AREA IN SOUTH PARKING LOT OF CARDIFF STATE BEACH.
8	PROPOSED 3' WIDE FOOT PATH
9	PROPOSED SAND FENCE
10	PROPOSED SAND FENCH ACCESS PATH(INGRESS AND EGRESS TO BEACH.)
11	PROPOSED 1/2 TON ROCK.
12	PROPOSED 2 TON ROCK REVETMENT
20	SEE SHEET 6 FOR GRADING CROSS-SECTIONS
21	SEE SHEET 9 FOR TYPICAL ROCK REVETMENT SECTION
22	SEE SHEET 9 FOR TYPICAL FOOT PATH & SAND FENCE SECTION
101	APPROXIMATE LOCATION OF EXISTING EDGE OF PAVEMENT. CONTRACTOR TO VERIFY.
102	APPROXIMATE LOCATION OF EXISTING RETAINING WALL. CONTRACTOR TO VERIFY.
103	APPROXIMATE LOCATION OF CENTERLINE OF SOUTH COAST HIGHWAY (REFERENCE ONLY)
104	EXISTING REVETMENT (CONTRACTOR TO VERIFY)
105	MEAN HIGH TIDE LINE (MHTL) (KDM SURVEY MARCH 15, 2011)
201	EXISTING 30" RCP SAN ELIJO OCEAN OUTFALL PER "OCEAN OUTFALL" AS-BUILT PLANS (9 SHEETS, ENGINEERING W.O. 2943, FILE NO. 7-3 SE, DATED OCT. 1964). CONTRACTOR TO VERIFY. (PROTECT IN PLACE).
202	EXISTING UTILITY WATER LINE (LOCATION UNKNOWN & SIZE UNKNOWN). CONTRACTOR TO VERIFY IN THE FIELD. (PROTECT IN PLACE)
203	EXISTING UTILITY SEWER LINE (LOCATION UNKNOWN & SIZE UNKNOWN). CONTRACTOR TO VERIFY IN THE FIELD. (PROTECT IN PLACE)

LEGEND



REFERENCE BENCMARKS (SEE CONSTRUCTION BENCMARKS)

THE BASIS OF BEARINGS/SURVEY INFORMATION SHOWN BELOW ARE SHOWN ON EACH RESPECTIVE SHEET (SEE APPENDIX TO SPECIFICATIONS).

SITE	TYPE OF MARK	STAMPING ON MARK	NORTHING	EASTING	ELEVATION
CARDIFF STATE BEACH (ENCINITAS)	NONE	NONE	1,949,477.29	6,246,038.21	14.40 (MLLW) (FROM RBSP II)

SHEET LIST TABLE

Sheet Number	Sheet Title
1	TITLE SHEET, PROJECT MAPS, & GENERAL NOTES
2	CARDIFF BEACH - STA 101+00.00 THRU STA 107+71.55
3	CARDIFF BEACH - STA 107+71.55 THRU STA 115+06.44
4	CARDIFF BEACH - STA 115+06.44 THRU STA 122+46.61
5	CARDIFF BEACH - STA 122+46.61 THRU STA 129+00.00
6	CARDIFF BEACH SECTIONS (1 OF 3)
7	CARDIFF BEACH SECTIONS (2 OF 3)
8	CARDIFF BEACH SECTIONS (3 OF 3)
9	CARDIFF BEACH DETAILS (1 OF 1)

ABBREVIATIONS

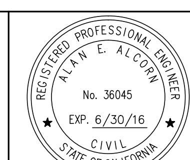
EL, ELEV	ELEVATION
IE	INVERT ELEVATION
H	HORIZONTAL
V	VERTICAL
MLLW	MEAN LOWER LOW WATER
N	NORTHING, NORTH
E	EASTING, EAST
S	SOUTH
W	WEST
NGVD	NATIONAL GEODETIC VERTICAL DATUM
NOS	NATIONAL OCEAN SERVICE
NO	NUMBER

30% SUBMITTAL

DATE: 10/28/15

NO.	DATE	REVISIONS	BY	CHK	APRV

MOFFATT & NICHOL
1660 HOTEL CIRCLE NORTH
SUITE 500
SAN DIEGO, CALIFORNIA
92108
(619) 220-6050



DESIGNED BY:	DATE
A.ALCORN, P.E.	10/28/15
DRAWN BY: A.CRUZ, P.E.	10/28/15
CHECKED BY: -	-
SANDAG PRJ. ENG. -	-

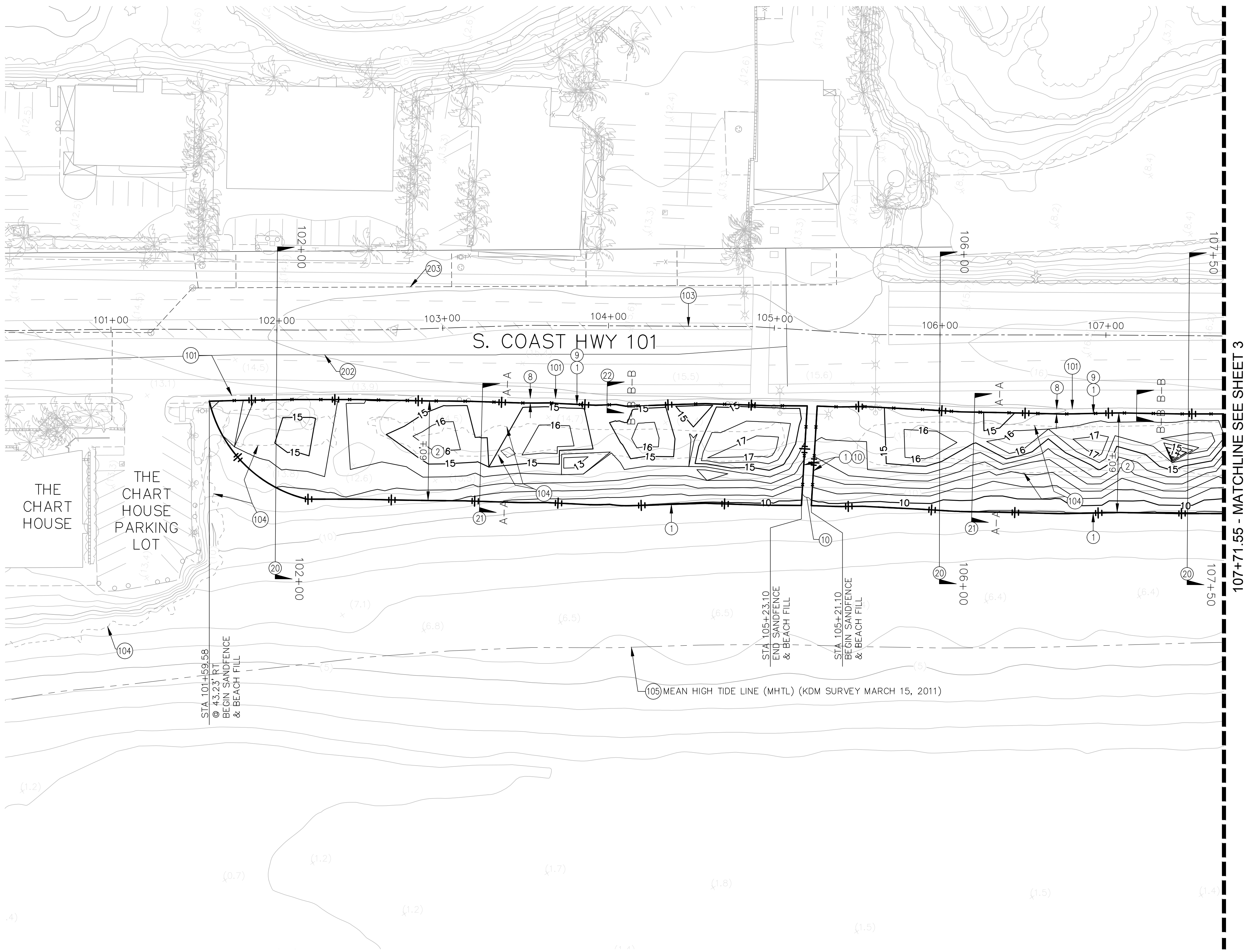
CALIFORNIA STATE COASTAL CONSERVANCY

CITY OF ENCINITAS

CARDIFF BEACH LIVING SHORELINE PROJECT

TITLE SHEET, PROJECT MAPS, & GENERAL NOTES

SCALE: AS SHOWN
DRAWING NO. XXX-XXXXXX
SHEET NO. 1
SHEET 1 OF 9



CONSTRUCTION NOTES

1	PROPOSED DAYLIGHT LINE
2	PROPOSED DUNE GRADING
8	PROPOSED 3' WIDE FOOT PATH
9	PROPOSED SAND FENCE
10	PROPOSED SAND FENCH ACCESS PATH(INGRESS AND EGRESS TO BEACH.)
20	SEE SHEET 6 FOR GRADING CROSS–SECTIONS
21	SEE SHEET 9 FOR TYPICAL ROCK REVETMENT SECTION
22	SEE SHEET 9 FOR TYPICAL FOOT PATH & SAND FENCE SECTION
101	APPROXIMATE LOCATION OF EXISTING EDGE OF PAVEMENT. CONTRACTOR TO VERIFY.
103	APPROXIMATE LOCATION OF CENTERLINE OF SOUTH COAST HIGHWAY (REFERENCE ONLY)
104	EXISTING REVETMENT (CONTRACTOR TO VERIFY)
105	MEAN HIGH TIDE LINE (MHTL) (KDM SURVEY MARCH 15, 2011)
202	EXISTING UTILITY WATER LINE (LOCATION UNKNOWN & SIZE UNKNOWN). CONTRACTOR TO VERIFY IN THE FIELD. (PROTECT IN PLACE)
203	EXISTING UTILITY SEWER LINE (LOCATION UNKNOWN & SIZE UNKNOWN). CONTRACTOR TO VERIFY IN THE FIELD. (PROTECT IN PLACE)

30 15 0 30 60 90
SCALE: 1"=30'

30% SUBMITTAL

DATE: 10/28/15

DRAWING NAME: P:\8909_CB_LivingShore\7 Design\CADD\Sheets\CARDIFF BEACH – STA 101+00.00 THRU STA 107+71.55.dwg
PLOT DATE: Oct 28, 2015 – 3:23pm PLOTTED BY: acruz

NO.	DATE	REVISIONS	BY	CHK	APRV

MOFFATT & NICHOL
1660 HOTEL CIRCLE NORTH
SUITE 500
SAN DIEGO, CALIFORNIA 92108
(619) 220-6050

REGISTERED PROFESSIONAL ENGINEER
ALAN E. ALCORN
No. 36045
EXP. 6/30/16
CIVIL
STATE OF CALIFORNIA

	DATE
DESIGNED BY: A.ALCORN, P.E.	10/28/15
DRAWN BY: A.CRUZ, P.E.	10/28/15
CHECKED BY: –	–
SANDAG PRJ. ENG. –	–

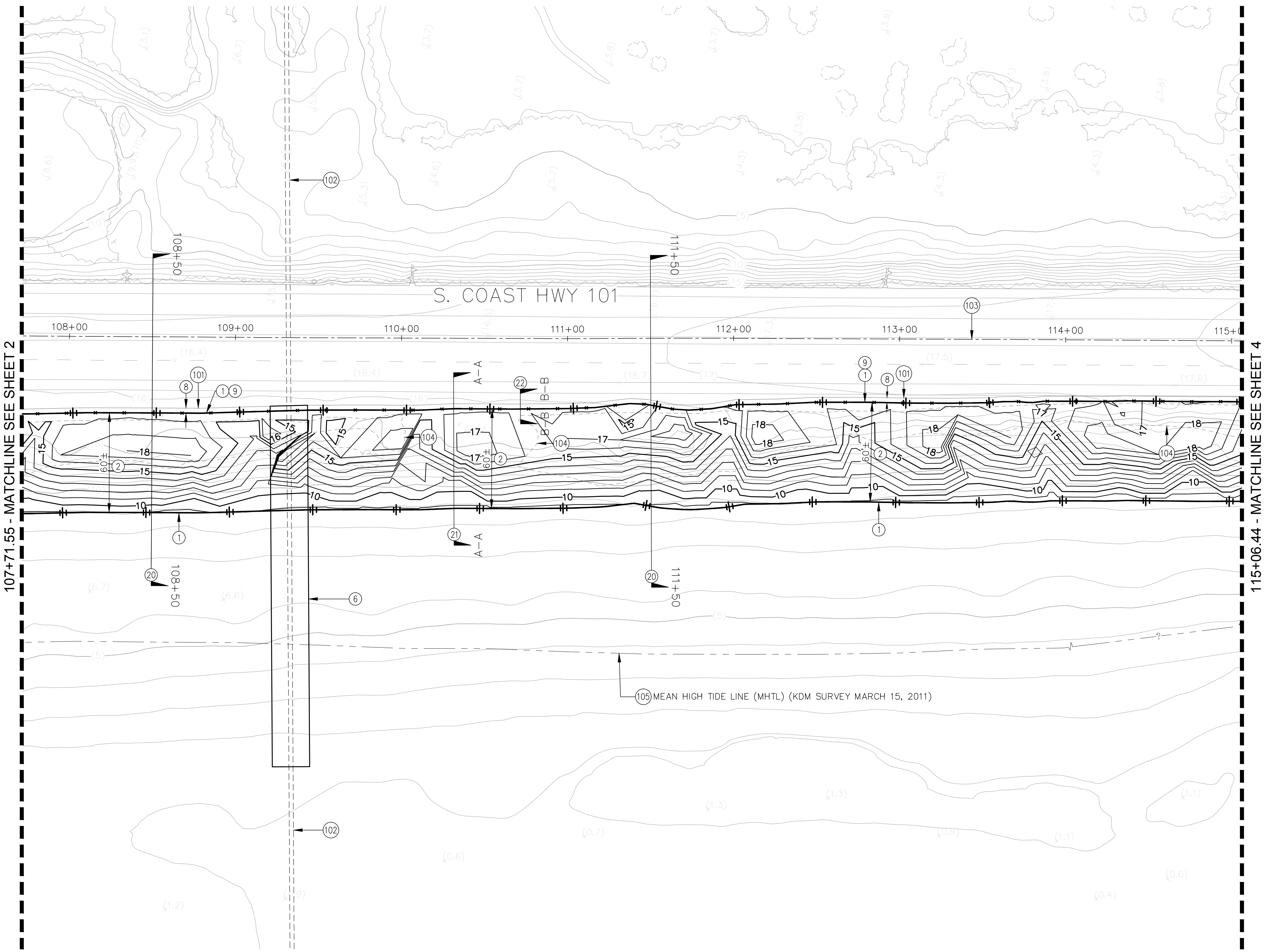
Coastal Conservancy
CALIFORNIA STATE COASTAL CONSERVANCY

Encinitas
CITY OF ENCINITAS

CARDIFF BEACH LIVING SHORELINE PROJECT

CARDIFF BEACH – STA 101+00.00 THRU STA 107+71.55

SCALE: AS SHOWN
DRAWING NO. XXX–XXXXXX
SHEET NO. 2



CONSTRUCTION NOTES	
1	PROPOSED DAYLIGHT LINE
2	PROPOSED DUNE GRADING
6	PROPOSED TEMPORARY TRENCH PLATE. LIMIT CROSSING EXISTING OUTFALL PIPE TO ONE LOCATION. PLACE TRENCH PLATES AND 2' OF SAND OVER OUTFALL LINE AT CROSSING LOCATION
8	PROPOSED 3' WIDE FOOT PATH
9	PROPOSED SAND FENCE
20	SEE SHEET 6 FOR GRADING CROSS-SECTIONS
21	SEE SHEET 9 FOR TYPICAL ROCK REVETMENT SECTION
22	SEE SHEET 9 FOR TYPICAL FOOT PATH & SAND FENCE SECTION
101	APPROXIMATE LOCATION OF EXISTING EDGE OF PAVEMENT. CONTRACTOR TO VERIFY.
102	APPROXIMATE LOCATION OF EXISTING RETAINING WALL. CONTRACTOR TO VERIFY.
103	APPROXIMATE LOCATION OF CENTERLINE OF SOUTH COAST HIGHWAY (REFERENCE ONLY)
104	EXISTING REVETMENT (CONTRACTOR TO VERIFY)
105	MEAN HIGH TIDE LINE (MHTL) (KDM SURVEY MARCH 15, 2011)

SCALE: 1"=30'

30% SUBMITTAL

DATE: 10/28/15

NO.	DATE	REVISIONS	BY	CHK	APRV

MOFFATT & NICHOL
1660 HOTEL CIRCLE NORTH
SUITE 500
SAN DIEGO, CALIFORNIA
92108
(619) 220-6050

REGISTERED PROFESSIONAL ENGINEER ALAN E. ALCORN No. 36045 EXP. 6/30/16 CIVIL STATE OF CALIFORNIA

		DATE
DESIGNED BY:	A.ALCORN, P.E.	10/28/15
DRAWN BY:	A.CRUZ, P.E.	10/28/15
CHECKED BY:	–	–
SANDAG PRJ. ENG.	–	–

CALIFORNIA STATE COASTAL CONSERVANCY

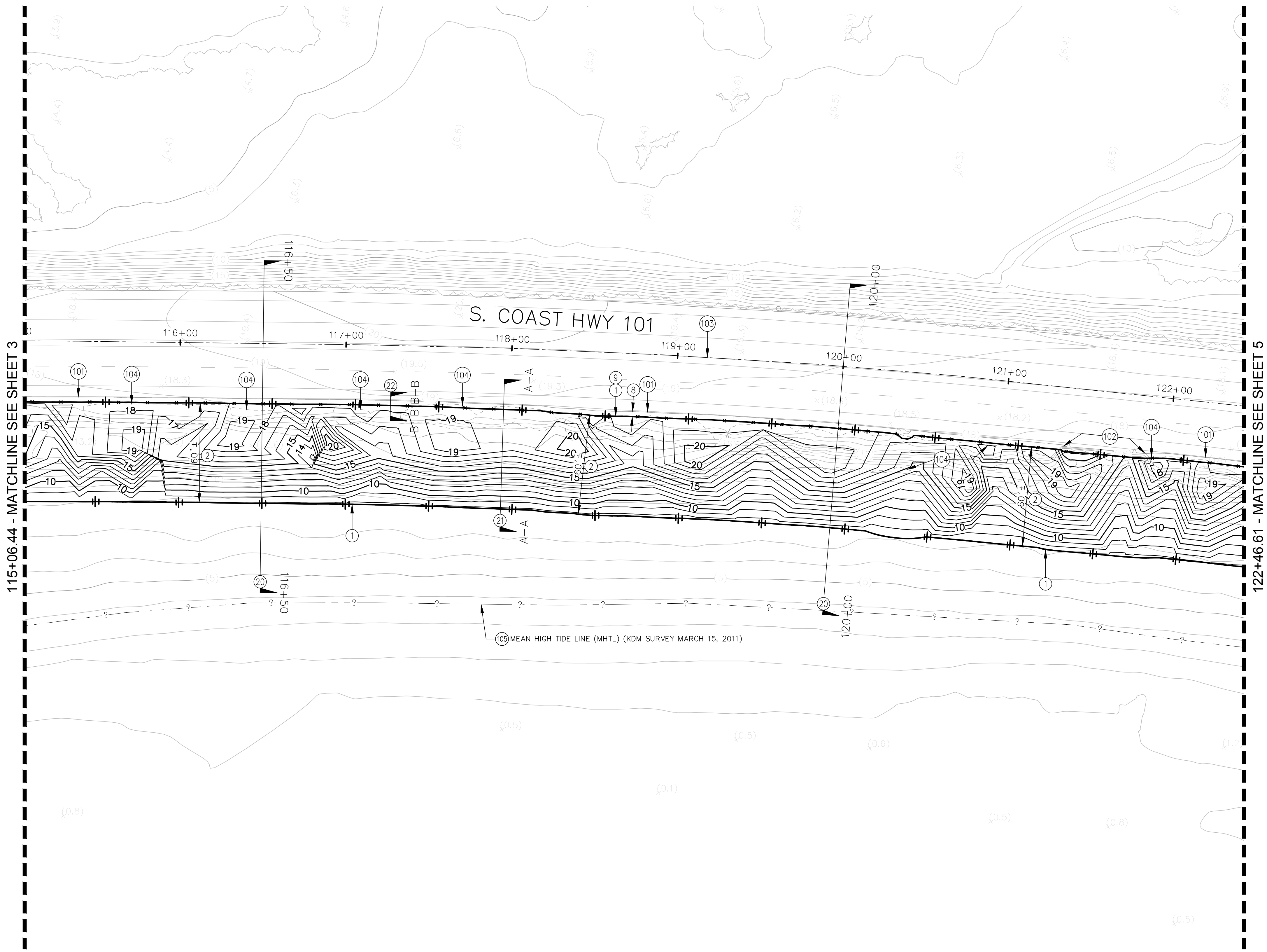
CITY OF ENCINITAS

CARDIFF BEACH LIVING SHORELINE PROJECT

CARDIFF BEACH – STA 107+71.55 THRU STA 115+06.44

SCALE: AS SHOWN
DRAWING NO. XXX–XXXXXX
SHEET NO. 3

DRAWING NAME: P:\8909_CB_LivingShore\7 Design\CADD\Sheets\CARDIFF BEACH – STA 107+71.55 THRU STA 115+06.44.dwg
PLOT DATE: Oct 28, 2015 – 3:24pm PLOTTED BY: acruz



CONSTRUCTION NOTES	
1	PROPOSED DAYLIGHT LINE
2	PROPOSED DUNE GRADING
8	PROPOSED 3' WIDE FOOT PATH
9	PROPOSED SAND FENCE
20	SEE SHEET 6 FOR GRADING CROSS-SECTIONS
21	SEE SHEET 9 FOR TYPICAL ROCK REVETMENT SECTION
22	SEE SHEET 9 FOR TYPICAL FOOT PATH & SAND FENCE SECTION
101	APPROXIMATE LOCATION OF EXISTING EDGE OF PAVEMENT. CONTRACTOR TO VERIFY.
102	APPROXIMATE LOCATION OF EXISTING RETAINING WALL. CONTRACTOR TO VERIFY.
103	APPROXIMATE LOCATION OF CENTERLINE OF SOUTH COAST HIGHWAY (REFERENCE ONLY)
104	EXISTING REVETMENT (CONTRACTOR TO VERIFY)
105	MEAN HIGH TIDE LINE (MHTL) (KDM SURVEY MARCH 15, 2011)

SCALE: 1"=30'

30% SUBMITTAL

DATE: 10/28/15

NO.	DATE	REVISIONS	BY	CHK	APRV

MOFFATT & NICHOL
1660 HOTEL CIRCLE NORTH
SUITE 500
SAN DIEGO, CALIFORNIA
92108
(619) 220-6050

REGISTERED PROFESSIONAL ENGINEER — ALAN E. ALCORN — No. 36045 — EXP. 6/30/16 — CIVIL — STATE OF CALIFORNIA

		DATE
DESIGNED BY:	A.ALCORN, P.E.	10/28/15
DRAWN BY:	A.CRUZ, P.E.	10/28/15
CHECKED BY:	–	–
SANDAG PRJ. ENG.	–	–

CALIFORNIA STATE COASTAL CONSERVANCY

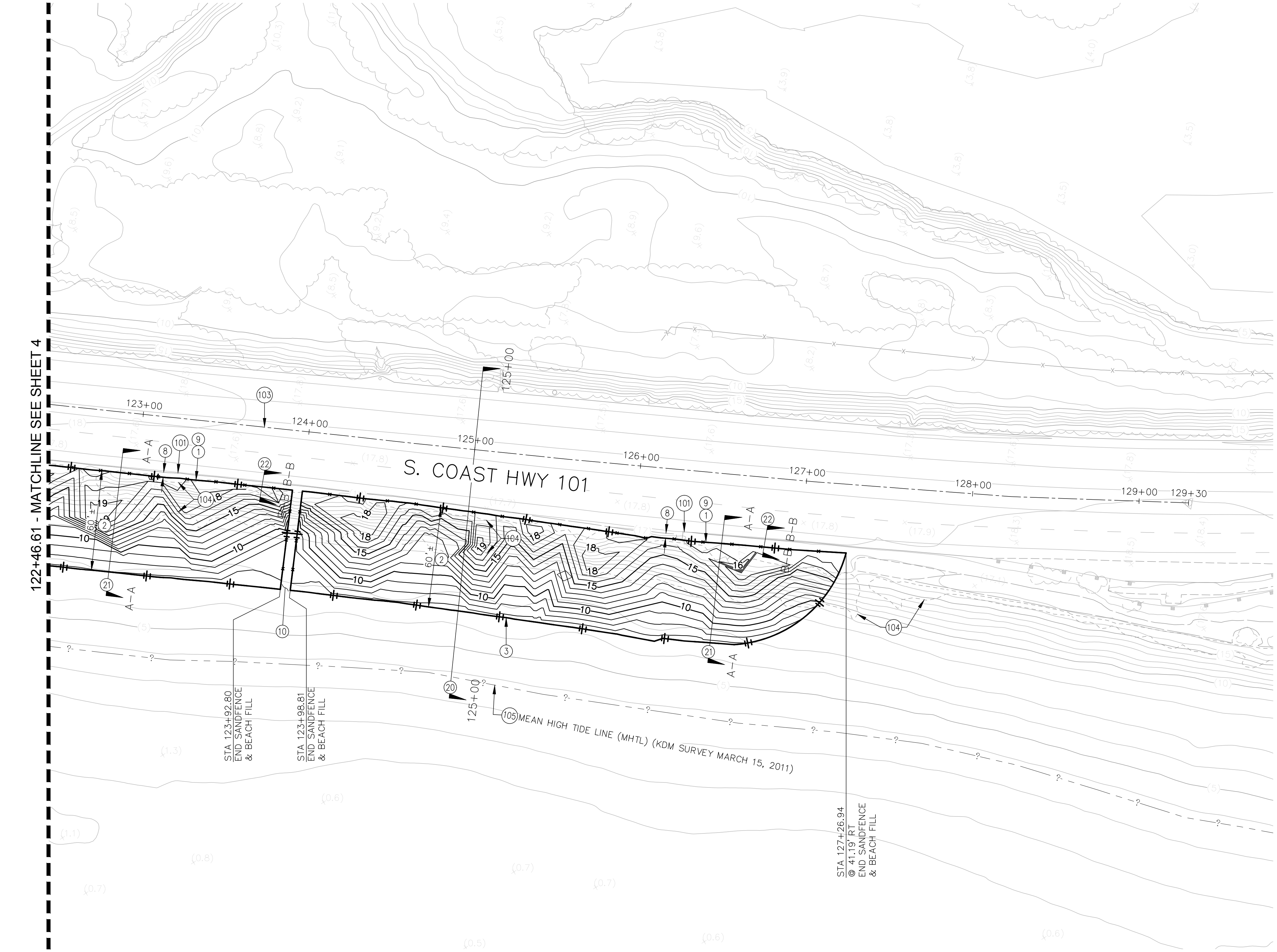
CITY OF ENCINITAS

CARDIFF BEACH LIVING SHORELINE PROJECT

CARDIFF BEACH – STA 115+06.44 THRU STA 122+46.61

SCALE: AS SHOWN
DRAWING NO. XXX-XXXXXX
SHEET NO. 4

DRAWING NAME: P:\8909_CB_LivingShore\7 Design\CADD\Sheets\CARDIFF BEACH – STA 115+06.44 THRU STA 122+46.61.dwg
PLOT DATE: Oct 28, 2015 – 3:25pm PLOTTED BY: acruz



CONSTRUCTION NOTES	
1	PROPOSED DAYLIGHT LINE
2	PROPOSED DUNE GRADING
3	PROPOSED TOE OF SLOPE
8	PROPOSED 3' WIDE FOOT PATH
9	PROPOSED SAND FENCE
10	PROPOSED SAND FENCH ACCESS PATH(INGRESS AND EGRESS TO BEACH.)
20	SEE SHEET 6 FOR GRADING CROSS-SECTIONS
21	SEE SHEET 9 FOR TYPICAL ROCK REVETMENT SECTION
22	SEE SHEET 9 FOR TYPICAL FOOT PATH & SAND FENCE SECTION
101	APPROXIMATE LOCATION OF EXISTING EDGE OF PAVEMENT. CONTRACTOR TO VERIFY.
103	APPROXIMATE LOCATION OF CENTERLINE OF SOUTH COAST HIGHWAY (REFERENCE ONLY)
104	EXISTING REVETMENT (CONTRACTOR TO VERIFY)
105	MEAN HIGH TIDE LINE (MHTL) (KDM SURVEY MARCH 15, 2011)

30 15 0 30 60 90
SCALE: 1"=30'

30% SUBMITTAL

DATE: 10/28/15

NO.	DATE	REVISIONS	BY	CHK	APRV

MOFFATT & NICHOL
1660 HOTEL CIRCLE NORTH
SUITE 500
SAN DIEGO, CALIFORNIA
92108
(619) 220-6050

REGISTERED PROFESSIONAL ENGINEER
ALAN E. ALCORN
No. 36045
EXP. 6/30/16
CIVIL
STATE OF CALIFORNIA

		DATE
DESIGNED BY:	A.ALCORN, P.E.	10/28/15
DRAWN BY:	A.CRUZ, P.E.	10/28/15
CHECKED BY:	-	-
SANDAG PRJ. ENG.	-	-

Coastal Conservancy
CALIFORNIA STATE COASTAL CONSERVANCY

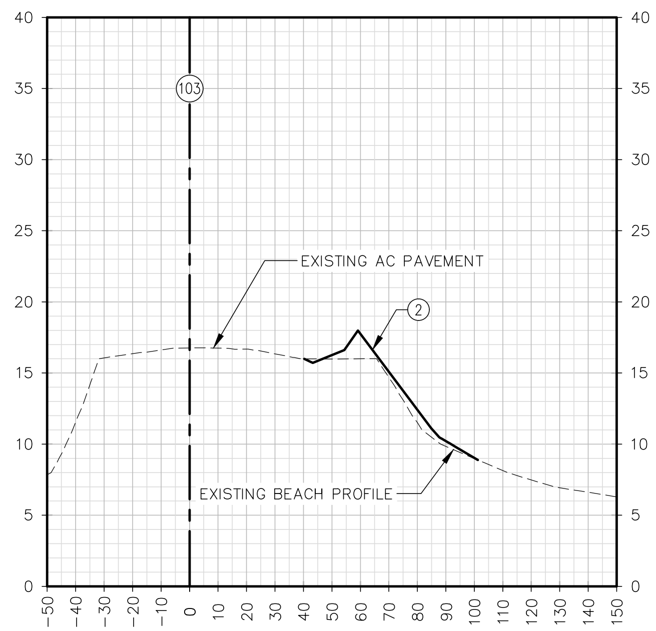
Encinitas
CITY OF ENCINITAS

CARDIFF BEACH LIVING SHORELINE PROJECT

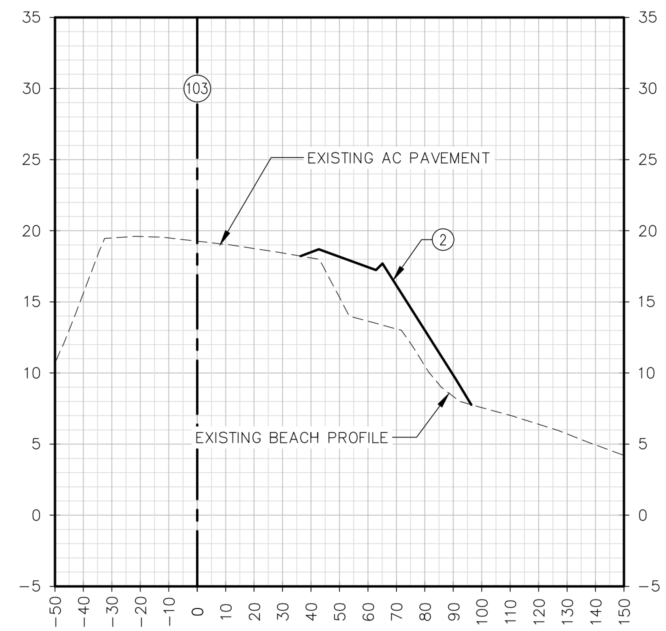
CARDIFF BEACH – STA 122+46.61 THRU STA 129+00.00

SCALE: AS SHOWN
DRAWING NO. XXX-XXXXXX
SHEET NO. 5
SHEET 5 OF 9

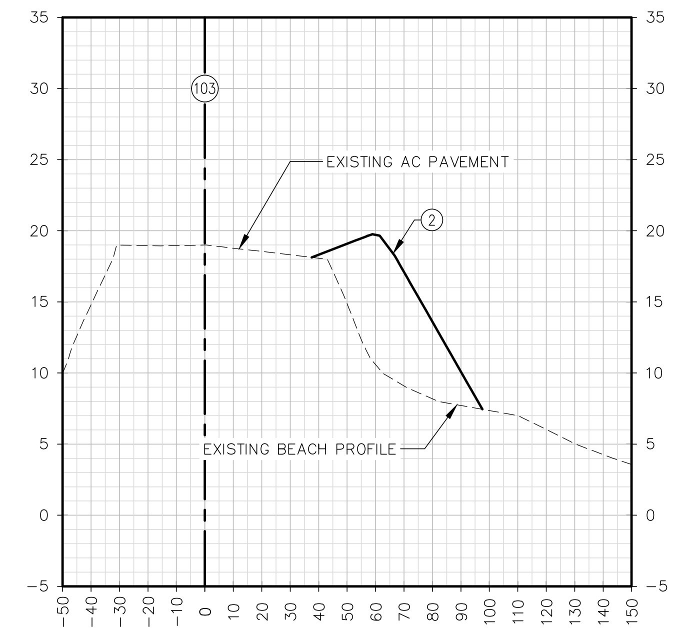
DRAWING NAME: P:\8909_CB_LivingShore\7 Design\CADD\Sheets\CARDIFF BEACH – STA 122+46.61 THRU STA 129+00.00.dwg
PLOT DATE: Oct 28, 2015 – 3:25pm PLOTTED BY: acruz



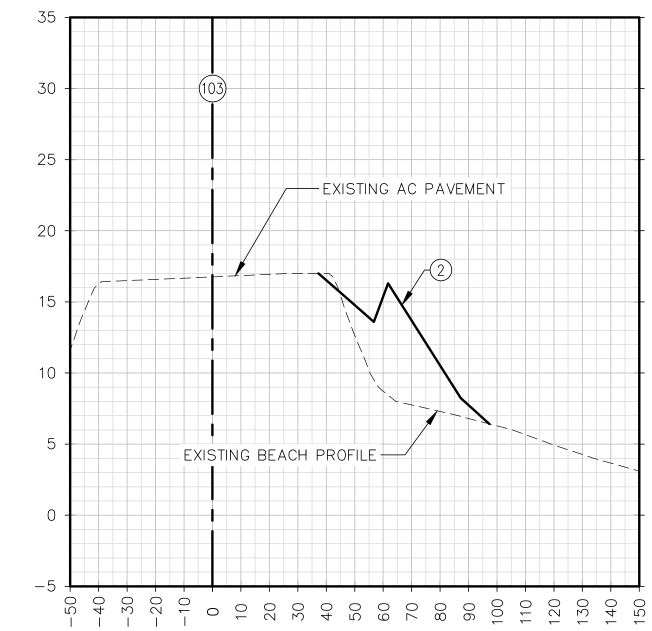
SECTION: 111+50.00
HORIZONTAL: 1"=30'
VERICAL: 1"=6'



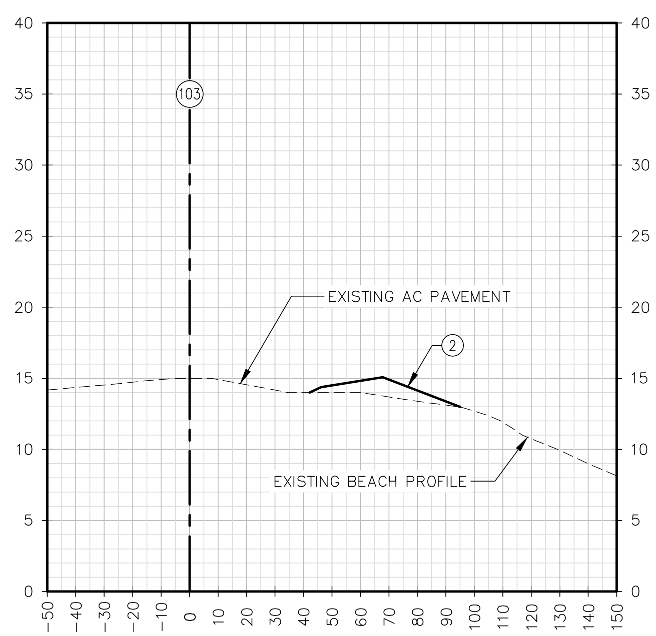
SECTION: 116+50.00
HORIZONTAL: 1"=30'
VERICAL: 1"=6'



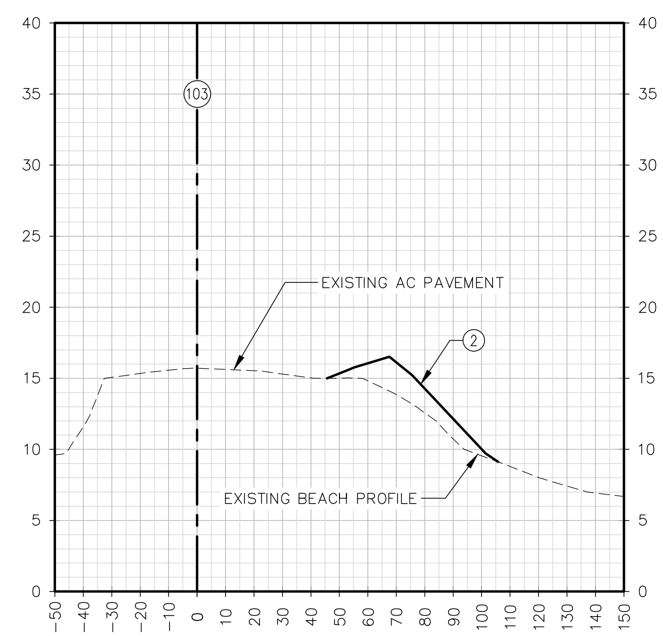
SECTION: 120+00.00
HORIZONTAL: 1"=30'
VERICAL: 1"=6'



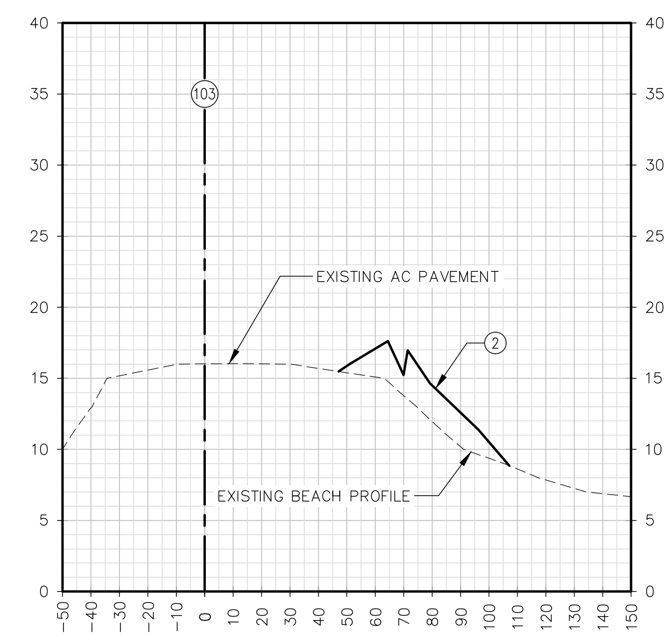
SECTION: 125+00.00
HORIZONTAL: 1"=30'
VERICAL: 1"=6'



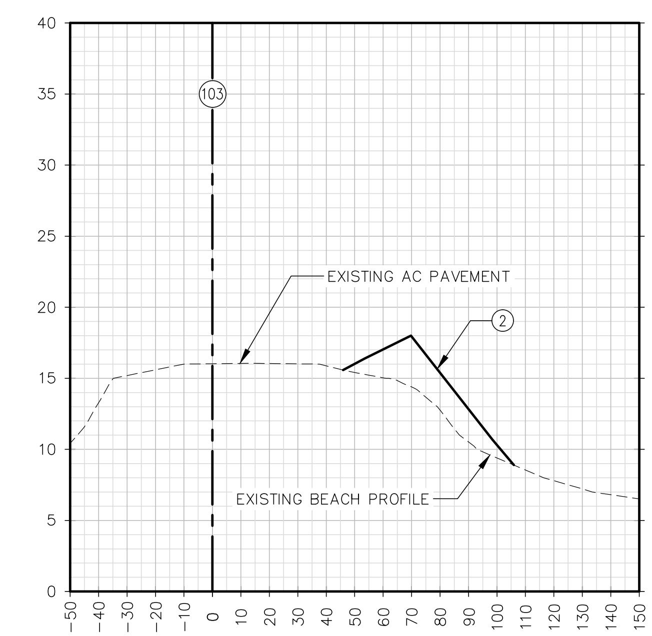
SECTION: 102+00.00
HORIZONTAL: 1"=30'
VERICAL: 1"=6'



SECTION: 106+00.00
HORIZONTAL: 1"=30'
VERICAL: 1"=6'



SECTION: 107+50.00
HORIZONTAL: 1"=30'
VERICAL: 1"=6'



SECTION: 108+50.00
HORIZONTAL: 1"=30'
VERICAL: 1"=6'

CONSTRUCTION NOTES

2	PROPOSED DUNE GRADING
103	APPROXIMATE LOCATION OF CENTERLINE OF SOUTH COAST HIGHWAY (REFERENCE ONLY)

VERTICAL SCALE: 1"=6' (6 3 0 6 12 18)
HORIZONTAL SCALE: 1"=30' (30 15 0 30 60 90)

30% SUBMITTAL

DATE: 10/28/15

NO.	DATE	REVISIONS	BY	CHK	APRV

MOFFATT & NICHOL
1660 HOTEL CIRCLE NORTH
SUITE 500
SAN DIEGO, CALIFORNIA
92108
(619) 220-6050

REGISTERED PROFESSIONAL ENGINEER
ALAN E. ALCORN
No. 36045
EXP. 6/30/16
CIVIL
STATE OF CALIFORNIA

	DATE
DESIGNED BY: A.ALCORN, P.E.	10/28/15
DRAWN BY: A.CRUZ, P.E.	10/28/15
CHECKED BY: –	–
SANDAG PRJ. ENG. –	–

Coastal Conservancy
CALIFORNIA STATE COASTAL CONSERVANCY

CITY OF ENCINITAS

CARDIFF BEACH LIVING SHORELINE PROJECT

CARDIFF BEACH SECTIONS (1 OF 3)

SCALE: AS SHOWN
DRAWING NO. XXX–XXXXXX
SHEET NO. 6
SHEET 6 OF 9

DRAWING NAME: P:\8909_CB_LivingShore\7 Design\CADD\Sheets\CARDIFF BEACH SECTIONS (1 OF 3).dwg
PLOT DATE: Oct 28, 2015 – 3:26pm PLOTTED BY: dcruz

THIS SHEET IS A PLACE HOLDER FOR FUTURE PLAN SUBMITTALS

30% SUBMITTAL

DATE: 10/28/15

NO.	DATE	REVISIONS	BY	CHK	APRV

MOFFATT & NICHOL
1660 HOTEL CIRCLE NORTH
SUITE 500
SAN DIEGO, CALIFORNIA
92108
(619) 220-6050

REGISTERED PROFESSIONAL ENGINEER
ALAN E. ALCORN
No. 36045
EXP. 6/30/16
CIVIL
STATE OF CALIFORNIA

	DATE
DESIGNED BY: A.ALCORN, P.E.	10/28/15
DRAWN BY: A.CRUZ, P.E.	10/28/15
CHECKED BY: –	–
SANDAG PRJ. ENG. –	–

CALIFORNIA STATE
COASTAL CONSERVANCY

CITY OF ENCINITAS

CARDIFF BEACH LIVING SHORELINE PROJECT

CARDIFF BEACH SECTIONS (2 OF 3)

SCALE: AS SHOWN

DRAWING NO. XXX-XXXXXX

SHEET NO. 7

SHEET 7 OF 9

DRAWING NAME: P:\8909_CB_LivingShore\7 Design\CADD\Sheets\CARDIFF BEACH SECTIONS (2 OF 3).dwg
PLOT DATE: Oct 28, 2015 – 3:26pm PLOTTED BY: acruz

THIS SHEET IS A PLACE HOLDER FOR FUTURE PLAN SUBMITTALS

30% SUBMITTAL

DATE: 10/28/15

NO.	DATE	REVISIONS	BY	CHK	APRV

MOFFATT & NICHOL

1660 HOTEL CIRCLE NORTH
SUITE 500
SAN DIEGO, CALIFORNIA
92108
(619) 220-6050

REGISTERED PROFESSIONAL ENGINEER
ALAN E. ALCORN
No. 36045
EXP. 6/30/16
CIVIL
STATE OF CALIFORNIA

	DATE
DESIGNED BY: A.ALCORN, P.E.	10/28/15
DRAWN BY: A.CRUZ, P.E.	10/28/15
CHECKED BY: –	–
SANDAG PRJ. ENG. –	–

Coastal Conservancy

CALIFORNIA STATE
COASTAL CONSERVANCY

Encinitas

CITY OF ENCINITAS

CARDIFF BEACH LIVING SHORELINE PROJECT

CARDIFF BEACH SECTIONS (3 OF 3)

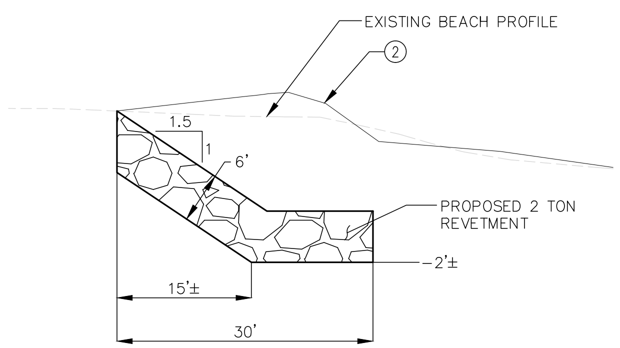
SCALE: AS SHOWN

DRAWING NO. XXX–XXXXXX

SHEET NO. 8

DRAWING NAME: P:\8909_CB_LivingShore\7 Design\CADD\Sheets\CARDIFF BEACH SECTIONS (3 OF 3).dwg
PLOT DATE: Oct 28, 2015 – 3:26pm PLOTTED BY: acruz

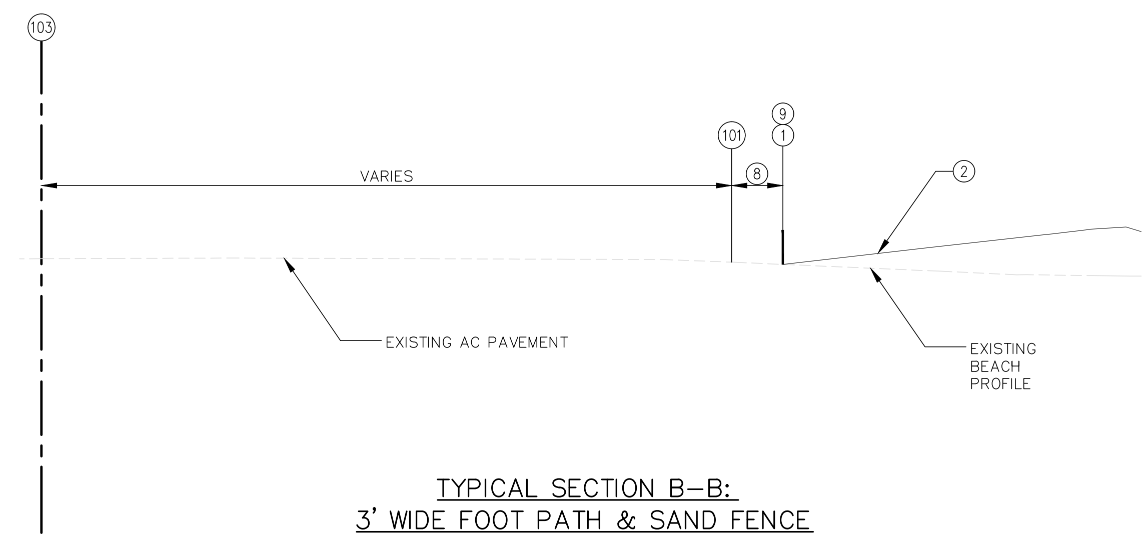
CONSTRUCTION NOTES	
1	PROPOSED DAYLIGHT LINE
2	PROPOSED DUNE GRADING
8	PROPOSED 3' WIDE FOOT PATH
9	PROPOSED SAND FENCE
101	APPROXIMATE LOCATION OF EXISTING EDGE OF PAVEMENT. CONTRACTOR TO VERIFY.
103	APPROXIMATE LOCATION OF CENTERLINE OF SOUTH COAST HIGHWAY (REFERENCE ONLY)



TYPICAL SECTION A–A: ROCK REVETMENT

HORIZONTAL: 1"=10'
VERTICAL: 1"=10'

SCALE: 1"=10'



TYPICAL SECTION B–B: 3' WIDE FOOT PATH & SAND FENCE

HORIZONTAL: 1"=5'
VERTICAL: 1"=5'

SCALE: 1"=5'

30% SUBMITTAL

DATE: 10/28/15

NO.	DATE	REVISIONS	BY	CHK	APRV

MOFFATT & NICHOL
1660 HOTEL CIRCLE NORTH
SUITE 500
SAN DIEGO, CALIFORNIA
92108
(619) 220-6050

REGISTERED PROFESSIONAL ENGINEER
ALAN E. ALCORN
No. 36045
EXP. 6/30/16
CIVIL
STATE OF CALIFORNIA

	DATE
DESIGNED BY: A.ALCORN, P.E.	10/28/15
DRAWN BY: A.CRUZ, P.E.	10/28/15
CHECKED BY: –	–
SANDAG PRJ. ENG. –	–

Coastal Conservancy
CALIFORNIA STATE COASTAL CONSERVANCY

CITY OF ENCINITAS

CARDIFF BEACH LIVING SHORELINE PROJECT

CARDIFF BEACH DETAILS (1 OF 1)

SCALE: AS SHOWN
DRAWING NO. XXX–XXXXXX
SHEET NO. 9
SHEET 9 OF 9

DRAWING NAME: P:\8909_CB_LivingShore\7 Design\CAD\Sheets\CARDIFF BEACH DETAILS (1 OF 1).dwg
PLOT DATE: Oct 28, 2015 – 3:26pm PLOTTED BY: dcruz

ATTACHMENT C. PROBABLE ESTIMATE OF CONSTRUCTION COST

Owner: City of Encinitas / California State Coastal Conservancy **A-E Firm Name**

Location: Cardiff State Beach, California **Date** **10/28/15**

Project Title: Living Shoreline Project

Estimated By Firm: **M&N**

Est Name: **MOD**

Checked By: **BPL**

Status of Design: **30%**

Estimate Summary

				LABOR COST		EQUIPMENT COST		MATERIAL COST		SUB QUOTE COST		TOTAL COST	
ITEM NO.	ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT
	Purchase,Set and Remove K-Rail	LF	2,500	$3.00	$7,500	$2.00	$5,000	$10.00	$25,000		$0	$15.00	$37,500
	Excavate/Re-Arrange Existing Rock	CY	10,000	$14.00	$140,000	$20.00	$200,000		$0		$0	$34.00	$340,000
	Purchase and Place New Rock	CY	10,000	$8.00	$80,000	$12.00	$120,000	$40.00	$400,000		$0	$60.00	$600,000
	Grade Sand from Project	CY	20,000	$4.00	$80,000	$6.00	$120,000		$0		$0	$10.00	$200,000
	Purchase and Install New Wood Fence	LF	3,000	$10.00	$30,000	$5.00	$15,000	$15.00	$45,000		$0	$30.00	$90,000
	Construct DG Walkway (W=3', D=6")	CY	140	$15.00	$2,100	$15.00	$2,100	$30.00	$4,200		$0	$60.00	$8,400
	SUBTOTAL	LF	2,500		$339,600		$462,100		$474,200		$0		$1,275,900
									10%	Mobilization/Demob/Field OH			$127,590
									15%	Contractor Profit/Central Office OH			$210,524
									25%	Contingency			$403,503
										TOTAL			$2,018,000

Notes:

Prepared on 10/28/2015