APPENDIX 10.6.1

Preliminary Geotechnical Study with Ninyo and Moore 2015

Ninyo & Moore
Geotechnical and Environmental Sciences Consultants

PRELIMINARY GEOTECHNICAL STUDY
DOHENY DESALINATION PROJECT BEACH FACILITIES
SOUTH COAST WATER DISTRICT
DANA POINT, CALIFORNIA

PREPARED FOR:
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February 5, 2015
Project No. 201029014

February 5, 2015
Project No. 201029014

Mr. Andrew D. Wiesner
Carollo Engineers
3150 Bristol Street, Suite 500
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Subject: Preliminary Geotechnical Study
Doheny Desalination Project Beach Facilities
South Coast Water District
Dana Point, California

Dear Mr. Wiesner:

In accordance with your request and authorization, Ninyo & Moore has performed a preliminary geotechnical study for the proposed beach facilities associated with the Doheny Desalination Project in Dana Point, California. This study presents data regarding site geotechnical conditions, potential geologic hazards and ocean processes that may affect the beach facilities for planning purposes. Our evaluation was conducted in general accordance with the scope of services presented in our proposal dated April 29, 2014. This report presents our findings and preliminary conclusions along with discussions regarding risk management of potential hazards.

We appreciate the opportunity to provide our services for this project.

Sincerely,
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EXECUTIVE SUMMARY

Ninyo & Moore performed a preliminary geotechnical study for the Doheny Desalination Project in Dana Point, California. The project will be located at the mouth of San Juan Creek in Dana Point and includes three primary elements: 1) production wells, 2) feedwater conveyance pipelines and 3) the desalination plant. This study addresses the beach facilities, which include the production wells and the conveyance pipelines.

The project has been in the planning and feasibility study phase since approximately 2002. An engineering feasibility report and hydrogeologic studies have been prepared for the project. Detailed design for the project has not been performed. This preliminary geotechnical study presents data regarding site geotechnical conditions, potential geologic and seismic hazards, and ocean processes that may affect the beach facilities for planning purposes. This study also includes preliminary evaluation of design protection measures that may be implemented to protect the beach facilities against potential geologic/seismic hazards and coastal impacts.

As currently planned the production wells will consist of cluster slant wells constructed along Doheny State Beach and extending outward below the seafloor into the marine alluvium. The feedwater conveyance pipelines will deliver the source water to the desalination facility using collector pipes and pipelines that trend northerly along the east and/or west sides of the San Juan Creek to the proposed desalination plant site. A combination of open cut and cover trenching and trenchless pipeline installation is anticipated. Trenchless construction options in the preliminary project plans include tunneling with a Micro Tunnel Boring Machine (MTBM) or Horizontal Directional Drilling (HDD).

The beach facilities project area is underlain primarily by beach sediments and unconsolidated alluvial deposits. Relatively shallow fills are also present in the area. The beach sediments and alluvial deposits are comprised predominantly of sandy soils with interbeds of gravel and cobbles. Scattered interbedded fine-grained (clay and silt) alluvial layers are also present beneath the project site. Shallow groundwater conditions are present. Groundwater elevations are anticipated several feet above sea level and subject to tidal and storm water fluctuations.

The results of this study indicate that the beach facilities project is feasible from a geotechnical perspective. Significant findings include the following:

- The project site is subject to strong seismic ground shaking and the alluvial sediments and beach sands are potentially liquefiable during a large earthquake event.
- The beach areas are relatively stable, but subject to erosion during dry periods and are replenished during wet winter storms. Significant beach erosion is anticipated due to predicted sea level rise.
- Excavations in the sandy soils and shallow groundwater conditions will be unstable; construction dewatering and shoring will be involved.
- Tunneling below groundwater will encounter flowing sand conditions and interbedded cobble zones. Tunneling design should consider these conditions to evaluate appropriate equipment and procedures to reduce risk of ground settlement and obstructions.

A brief summary of the significant conditions and potential impacts is presented below. Detailed information is included in this report.

The project site is not crossed by known active faults, however, the site is located in a seismically active area and the potential for strong ground motion in the project area is considered significant during the design life of the proposed facilities. The project site is mapped in a State of California Seismic Hazard Zone as potentially liquefiable. Previous geotechnical studies in the project area indicate that sandy alluvial deposits are potentially liquefiable during design earthquake events. Previous analyses in these studies indicate dynamic settlement due to liquefaction ranging from 2 to 14 inches and also indicate that some areas along the San Juan Creek and the sloping beach are susceptible to lateral spread hazards.

Mitigation of liquefaction hazards may involve supporting structures on deep pile foundations extending through liquefiable zones, various types of in-situ ground improvement methods to densify or otherwise stabilize the soil, design of improvements to tolerate anticipated ground movement, or avoiding liquefiable zones. The need for mitigation and the type of mitigation will depend on the severity of the liquefaction hazard based on a detailed geotechnical study.

Our coastal processes study indicates that Doheny Beach is a relatively stable beach area subject to cyclic variations in beach width under historic and current conditions. Doheny Beach is

subject to relatively slow retreat (erosion) during dry weather periods and relatively rapid accretion (sedimentation) during wet weather flooding events along the San Juan Creek. Predictions of sea level rise (SLR) due to global climate change, however, suggest a potential for significant erosional impacts to the beach.

Protection of the beach facilities from the long-term beach erosion associated with SLR would involve locating the well head vaults and associated pipe systems further inland beyond projected erosion areas or considering alternate well head vault design at the planned locations. The beach areas west of the San Juan Creek are wider due to the protective effects of the Dana Point Harbor and the existing river jetty, and locating the beach facilities at the back edges of the existing beach should provide adequate protection. The beach areas east of the San Juan Creek are less protected and are not as wide during extended dry periods of erosion. Therefore, protection of the beach facilities from potential beach erosion due to SLR would involve locating the beach facilities inside the existing over-night campground areas of the Doheny State Beach or considering alternate well head vault design at the planned locations. Additional measures that could be considered include long-term maintenance with periodic beach sand replenishment. Protective beach barriers, such as offshore breakwater jetties or beach groin jetties could also be considered for beach protection. The feasibility of these alternatives would involve significant coastal processes and environmental studies and goes beyond the scope of this study.

The presence of sandy soils, oversize materials (cobbles and boulders) and shallow groundwater presents potential constraints for construction of the beach facilities for the project. Excavations for trenches or pits below the water table will be unstable. Construction dewatering and temporary shoring will be involved. Gravel and cobble layers should be evaluated with regard to installation of shoring.

Tunneling risks include possible ground settlement and encountering obstructions. HDD tunneling also includes risk of “frac-outs” (inadvertent loss of drilling fluid) to the ground surface (creek channel), into highly permeable (gravel/cobble) zones, or into other voids such as utility crossings). Flowing soil conditions may be anticipated in the sandy soils below groundwater. If tunneling operations are not carefully monitored or obstructions are encountered,

ground settlement can occur from excessive soil removal during tunneling compared to casing advancement. Oversize materials obstructions (cobbles, boulders, concrete, foundations, debris) can cause tunneling refusal, which can result in major disruptions and project changes to recover the tunneling machine and complete the tunnel. Detailed geotechnical exploration, selection of appropriate tunneling equipment and careful tunneling procedures can mitigate these risks. MTBM's with earth pressure balance systems and HDD drilling systems should be suitable tunneling methodologies for these conditions.

1. INTRODUCTION

In accordance with your request, we have performed a preliminary geotechnical study for the beach facilities of the proposed Doheny Desalination Project in Dana Point, California. The desalination project has been in the planning and feasibility study phase since approximately 2002. Several reports have been prepared for the project, including an Engineering Feasibilty Report (Boyle, 2007). More recent studies have included hydrogeologic evaluations, including exploratory borings and groundwater pumping wells (Geoscience, 2005). Detailed design engineering has not been performed to date.

The desalination facility, as currently planned, will be located along lower San Juan Creek in Dana Point. The project includes three primary elements: 1) production wells, 2) feedwater conveyance pipelines and 3) the desalination plant. This study addresses the beach facilities, which include the production wells and the conveyance pipelines.

The production wells will provide the source water for desalination. As currently planned the production wells will consist of cluster slant wells constructed along Doheny State Beach and extending outward below the seafloor into the marine alluvium. Three slant wells will be constructed at each of three locations: two locations westerly of the San Juan Creek and one location to the east. The well clusters will be constructed below grade with well head vaults that will not be visible on the beach.

The feedwater conveyance pipelines will deliver the source water to the desalination facility. Several optional alignments for the feedwater conveyance pipelines were evaluated in the feasibility report (Boyle, 2007) and three were recommended for further study. Each of the recommended alignments include a collector pipe from the cluster wells and pipelines that trend northerly along the east and/or west sides of the San Juan Creek to the desalination plant site. A combination of open cut and cover trenching and trenchless pipeline installation is anticipated.

The desalination plant will be situated on a 30-acre property owned by the South Coast Water District (SCWD) along the east side of San Juan Creek. Concentrate water from the desalination process is proposed to be discharged via the existing South Orange County Wastewater Agency

(SOCWA) ocean outfall pipeline that exits the J.B. Latham Wastewater Treatment Plant and follows the east side of the San Juan Creek to a discharge point approximately 6,000 feet offshore from the beach. The desalination plant and the outfall pipeline are excluded from this preliminary study.

The purpose of this Preliminary Geotechnical Study was to evaluate potential geologic and seismic hazards that may impact the production wells and feedwater conveyance pipelines of the desalination project. This Preliminary Geotechnical Study also addresses coastal processes, including beach erosion and wave impacts, sea level rise, wave run-up and tsunami hazards. The coastal processes study was performed by our subconsultant, Coastal Environments. The report by Coastal Environments is included in Appendix B. This Preliminary Geotechnical Study includes preliminary evaluation of design protection measures that may be implemented to protect the project facilities against potential geologic hazards and coastal impacts.

2. SCOPE OF SERVICES

Our scope of services was performed in general conformance with our proposal dated April 29, 2014, and included the following:

- Research and review of readily available geologic, seismic and tsunami background data, including but not limited to published geologic maps, geologic literature, fault and seismic hazard maps and data, groundwater data, topographic maps, and aerial photographs.

- Research and review of available pertinent geotechnical reports, soil boring logs, foundation plans and other project area specific data, including preliminary reports and hydrogeologic borehole data prepared for the Doheny Desalination Project, geotechnical and environmental reports for the SCWD 30-acre site, State Parks Lifeguard Building geotechnical report, Pacific Coast Highway (PCH) bridge foundation reports, plans and boring logs for the SOCWA treatment plant and outfall pipeline, County of Orange plans for the San Juan Creek Channel and other soil and geologic data for nearby properties from the City of Dana Point.

- Review existing information about the San Juan Creek watershed area, including hydrology studies, available data, and flow statistics.

- A field geologic reconnaissance was performed to evaluate the current site conditions, including surficial geologic exposures, topographic features, and man-made features.

- The background research and field reconnaissance was compiled and analyzed to address the following geotechnical site conditions and hazards and to prepare preliminary mitigation alternatives:
    - Geologic conditions, including regional geologic setting, soil types and sediment characteristics.
    - Tectonic setting, including locations of fault traces that may impact the project site and the potential for surface fault rupture hazards impacting the project.
    - Evaluation of potential seismic ground shaking including a probabilistic analysis to evaluate the anticipated ground accelerations associated with a 2 percent probability in 50 years. A deterministic analysis was performed to evaluate potential ground accelerations associated with a Maximum Considered Earthquake event on the major active faults in the region.
    - Evaluation of secondary seismic hazards that could potentially impact the project, including soil liquefaction, dynamic settlement, lateral spread, landsliding and ground lurching.
    - Landslide and mudflow hazard potential.
    - Soil erosion or loss of topsoil.
    - Land subsidence.
    - Compressible/collapsible soil.
    - Expansive soil.
- A coastal processes and hydraulic/hydrology study for Doheny State Beach by Coastal Environments included the following:
    - Evaluation of the existing shoreline conditions, including existing protective structures.
    - Review of available oceanographic and coastal processes data for Doheny State Beach.
    - Beach profile surveys.
    - Review of historic aerial photographs.
    - Evaluation of sediment sources for the beach.
    - Evaluation of seasonal and annual beach cycles.
    - Analysis of design wave height for various return periods (5, 10, 25, 50 and 100 years).

- Evaluate wave run-up and potential for overtopping for various design return period waves.
- Evaluation of ocean tides and estimates of maximum water level elevations for various return periods (5, 10, 25, 50 and 100 years).
- Address the long-term stability of the beach.
- Analysis of beach and creek channel erosion/scouring effects.
- Impacts such as a beach retreat analysis due to anticipated sea level rise.
- Tsunami hazards.

3. SITE DESCRIPTION

The Doheny Desalination Project is situated at the mouth of the San Juan Creek in the City of Dana Point, California (Figure 1). As mentioned above the desalination facilities will include a system of three cluster slant wells along Doheny State Beach and feedwater conveyance pipelines that extend northerly and generally parallel to the San Juan Creek to the planned desalination plant site. The desalination plant site is proposed for a parcel within the SCWD owned 30-acre property, which is located adjacent to the east side of the San Juan Creek (Figure 2). The actual plant location on the 30-acre property has not been decided.

The San Juan Creek drains the western slopes of the Santa Ana Mountains and includes a watershed of over 110,000 acres. Major tributaries include the Horno, Trabuco and Oso Creeks. As it approaches the ocean, the San Juan Creek flows along a relatively narrow, south-trending, alluvial valley situated between the San Joaquin hills to the west and the San Clemente hills to the east. The lower approximately 2.6 miles San Juan Creek has been improved with concrete lined levees. The creek bottom is generally about 150 feet wide with levee embankments on the order of 18 feet high. The creek widens to over 400 feet across as it approaches the beach. The creek is crossed by two pile-supported bridges near the ocean for Pacific Coast Highway and East Coast Highway. The creek is bordered by a below grade concrete groin wall on the west side south of the bridges (Boyle, 2007). The groin wall reportedly extends to an elevation of 18 feet below mean sea level (MSL). On the beach the groin wall alignment is extended with a rock

jetty, referred to as Thor's Hammer. A timber pile bulkhead wall is present along the west side of the creek south of the bridges and reportedly extends to an elevation of 24 feet below MSL (Lowry and Associates, 1977).

The beach area of the project is part of the Doheny State Beach, which is operated and maintained by the California State Parks. The western end of the beach terminates at the Dana Point Harbor. The harbor area is bordered by a protective rock jetty along the east side and an ocean breakwater jetty, which combine to form the harbor entry (Figure 1). A day use park area is present between the beach and Pacific Coast Highway west of the San Juan Creek. The day use park includes lawn and picnic areas, snack bar, paved parking areas and the entry drive for the park. A lifeguard headquarters building and tower is located at the southeast corner of the day use park adjacent to the San Juan Creek. The beach park includes overnight camping areas east of the San Juan Creek on the inland side of the beach. The topography along the beach park areas is relatively flat and has elevations ranging from about 12 to 14 feet above MSL.

The land areas north of Pacific Coast Highway near the San Juan Creek, include a variety of residential, commercial, and public works developments. A retail center with a gas station is present on the north side of the highway west of the creek. The retail center is bordered on the west, north and east sides by an abandoned and vacant trailer park. The SOCWA J.B. Latham Treatment Plant occupies the land adjacent to the creek and just north of the trailer park. The treatment plant is a fully developed wastewater treatment facility with numerous tanks, processing facilities and pipelines. The 57-inch ocean outfall pipeline exits the southeast corner of the treatment plant, crosses beneath the San Juan Creek and then follows below the east levee continuing offshore. A hotel is present on the east side of the creek occupying the parcel of land between Pacific Coast Highway and East Coast Highway. The property bordering the east side of the San Juan Creek north of Pacific Coast Highway is the SCWD 30-acre parcel and planned site of the desalination plant. The majority of this property is currently leased to a variety of small tenants for equipment storage and small business operations. The former Victoria Wastewater Treatment Plant was located in the southern half of this property. The treatment plant was abandoned and some of the structures remain, buried in place. The SCWD Groundwater

Recovery Facility is located at the north end of the 30-acre parcel. The SCWD 30-acre site is bordered along the east side by an AT&SF railway line. In general, the land areas adjacent to the San Juan Creek north of Pacific Coast Highway are relatively flat lying and rise gently to the north and away from the creek. Ground surface elevations generally range from approximately 15 to 30 feet above MSL near the creek.

Aerial photographs showing the existing site conditions as discussed above are presented in Figures 2, 3A and 3B. Aerial photographs showing the site conditions in 1972 and 1979 are presented on Figures 4 and 5, respectively (California Coastline.org).

4. PROJECT DESCRIPTION

The project includes three primary elements: 1) production wells, 2) feedwater conveyance pipelines and 3) the desalination plant. This section describes the beach facilities, which include the production wells and the conveyance pipelines.

The production wells will provide the source water for desalination. As currently planned (Boyle, 2007) the production wells will consist of a cluster array of slant wells along Doheny State Beach and extending outward below the seafloor into the marine alluvium. Three slant wells will be constructed at each of three locations: two locations westerly of the San Juan Creek and one location to the east (Figure 6). The locations of the wells are based on previous hydrogeologic studies and are intended to penetrate alluvial sediments within the ancestral canyon of the San Juan Creek that extends offshore. The preliminary design (Boyle, 2007) indicated that three slant wells at each cluster location will be drilled at a shallow angle in a radial pattern approximately 500 feet in length (Figure 6). We understand that more current studies by Geoscience include wells up to approximately 1,000 feet in length. The wells will be approximately 30 inches in diameter and will be installed with submersible pumps. Each cluster well head will be enclosed in a below grade concrete vault that will not be visible on the beach (Figure 7).

The desalination source water that is pumped from the slant wells will be delivered to the desalination plant through a system of feedwater conveyance pipelines. Several alternative

pipeline layouts have been studied (Boyle, 2007). Each of the conveyance pipeline layouts that were evaluated involve multiple challenges, including shallow groundwater, potential environmental impacts, access limitations, existing structures, temporary easements and pipeline easements through public and private properties. Based on their evaluation, Boyle recommended three potential pipeline layouts for further consideration which were labeled Option 1, Option 1A and Option 4. Each pipeline layout involves a combination of trenching and tunneling construction methods. Options 1 and 1A involve trenching and tunneling with a Micro Tunnel Boring Machine (MTBM). Option 4 would involve trenching and tunneling using Horizontal Directional Drilling (HDD). Launching and reception shafts (pits) for tunneling sections were selected based on accessibility and space limitations. Pipe materials suggested include high density polyethylene (HDPE) for the conveyance pipelines. Double walled pipes would be involved to meet Caltrans crossing criteria and may include an outer steel jacking pipe and inner HDPE conveyance pipe.

The Option 1 alignment is shown on Figure 8A and includes:

- A 20-inch collector pipe extends from the west cluster to the central cluster where it joins a 36-inch intake pipeline (trenching).
- The 36-inch intake pipeline extends inland to Launch Shaft 1 in the parking lot of the day use park area (trenching).
- From Launch Shaft 1, the 36-inch intake pipeline crosses under PCH to Reception Shaft 1 located in the yard area of the SOCWA wastewater treatment plant (MTBM tunneling).
- From Reception Shaft 1, the 36-inch intake pipeline crosses under the San Juan Creek at a relatively shallow depth to Launch Shaft 2 (MTBM tunneling).
- A 20-inch intake pipeline from the east cluster extends inland to Reception Shaft 2 located in the Doheny Beach State Park campground (trenching).
- From Launch Shaft 2, the 20-inch intake pipeline crosses under PCH and extends to Reception Shaft 2 (MTBM tunneling).
- From Launch Shaft 2, the 36-inch and 20-inch collector pipes join a 42-inch diameter intake pipeline that leads to the desalination plant (trenching).

The Option 1A alignment is shown on Figure 8B and includes:

- A 20-inch collector pipe extends from the west cluster to the central cluster where it joins a 36-inch intake pipeline (trenching).
- The 36-inch intake pipeline extends inland from the central cluster to Launch Shaft 1 in the day use parking lot (trenching).
- A 20-inch collector pipe from the east cluster extends inland to Reception Shaft 1 in the Doheny Beach State campground (trenching).
- At Launch Shaft 1, the 36-inch intake pipe crosses under the San Juan Creek at a relatively deep grade to Reception Shaft 1 (the deeper MTBM tunnel involves crossing below the existing groin wall and timber bulkhead on each side of the creek). At Reception Shaft 1 the pipeline 20-inch and 36-inch pipes join a 42-inch intake pipe.
- From Launch Shaft 2 located north of PCH, the 42-inch intake pipeline crosses under the PCH to Reception Shaft 1 located in the Doheny Beach State campground (MTBM tunneling).
- From Launch Shaft 2, the 42-inch intake pipeline leads to the desalination plant (trenching).

The Option 4 alignment is shown on Figure 8C and includes:

- A 20-inch collector pipe extends from the west cluster to the central cluster where it joins a 36-inch intake pipe (trenching).
- The 36-inch intake pipe extends inland from the central cluster to the day use area parking lot and the starting point of an HDD pipeline (trenching).
- The HDD 36-inch pipeline crosses under PCH and San Juan Creek to a connection point on the east bank of the creek.
- A 20-inch intake pipeline from the east cluster extends inland to the Doheny Beach State Park campground and the starting point of an HDD pipeline (trenching).
- The HDD 20-inch collector pipe crosses under PCH to a connection point on the east bank of San Juan Creek.
- The 36-inch and 20-inch pipes join to a 42-inch diameter intake pipeline that leads to the desalination plant (trenching).

5. GEOLOGY

5.1. Geomorphic Setting

The State of California is divided into geomorphic provinces defined by geographic location, large-scale bedrock types, and tectonic structure. The project site is situated at the northwest end of the Peninsular Ranges geomorphic province of southern California. This geomorphic province encompasses an area that extends approximately 125 miles from the Transverse Ranges province and the Los Angeles Basin south to the Mexican border, and beyond another approximately 775 miles to the tip of Baja California. The Peninsular Ranges province varies in width from approximately 30 to 100 miles and is characterized by northwest-trending mountain range blocks separated by similarly northwest-trending faults (Norris and Webb, 1990).

The predominant rock type that underlies the Peninsular Ranges province is a Cretaceous-age igneous rock (granitic rock) referred to as the Southern California batholith. Older Jurassic-age metavolcanic and metasedimentary rocks and older Paleozoic limestone, altered schist, and gneiss are present within the province. Cretaceous period marine sedimentary rocks, and younger Tertiary period rocks comprised of volcanic, marine, and non-marine sediments overlie the older rocks (Norris and Webb, 1990). More recent Quaternary period sediments, primarily of alluvial origin, comprise the low-lying valley and drainage areas within the region, while Quaternary marine terrace deposits and beach deposits are present along the coastal areas.

5.2. Regional Geology

The Doheny Desalination Project is located within the alluvial valley of the San Juan Creek between the San Joaquin Hills to the west and San Clemente Hills to the east. The project study area ranges in elevation from approximately Mean Sea Level (MSL) at the coastline to approximately 30 above MSL along the top of the creek channels in the upstream portions of the creek. Regional geologic maps show that the San Juan Creek valley, including the beach facilities area, is underlain by Holocene age flood plain deposits comprised of sandy silt and

clay. Fill soils of varying thickness and material type related to previous developments are present in portions of the project area. The San Juan Creek channel is underlain by active wash deposits comprised of sand, silt and gravel. The beach is underlain by active sandy beach sediments (Tan, 1999). A regional geologic map of the site vicinity showing the distribution of geologic units is presented on Figure 9.

The adjacent hills and deeper subsurface areas beneath the project site are underlain by Tertiary age marine sedimentary formations, predominantly Capistrano Formation comprised of siltstone, claystone and sandstone. Younger Tertiary age Niguel formation comprised of sandstone and siltstone overlies the Capistrano Formation in scattered outcrops in the adjacent hills. Older Tertiary age San Onofre Breccia underlies the Capistrano Formation to the west of the site (Tan, 1999). Studies by others (Schaeff, Dylan and Lowery) conducted in the 1970s as part of the SOCWA ocean outfall design suggest that the San Onofre Breccia dips down coast from the west toward the west side of the San Juan Creek channel below the shoreline (Boyle, 2007).

During the Pleistocene epoch (2.7 million to 11,700 years ago), periods of glaciation caused sea level fluctuations, which created a series of terraces cut into the coastal sedimentary rock by wave erosion. Shallow marine sediments were deposited on the wave-cut platforms while they were submerged beneath the ocean. Regional uplift and declining sea levels during the Pleistocene resulted in emergence of the marine terraces of varying ages, which are mapped along the elevated coastal terraces and hills in the site region.

Near the end of the Pleistocene epoch (end of the last ice age circa 11,700 years ago), ocean levels were more than 300 feet lower than present time and the ancestral canyon (paleocanyon) of San Juan Creek extended further offshore. The continental shelf offshore of Dana Point extends over seven miles before dropping off into deeper water (Boyle, 2007). The ancient creek incised the continental shelf and filled the paleocanyon with sediment. During the transgression (sea level rise) that occurred from 11,000 years ago to present, the San Juan Creek channel was progressively filled with alluvial sediments. The alluvial sediments within the present creek channel and paleocanyon are comprised of

unconsolidated and interbedded deposits of silt, sand, clay, gravel and cobbles that were deposited within stream channels and river terraces and vary from approximately 65 to 200 feet thick (Boyle, 2007). The intake wells for the proposed project located at the mouth of San Juan Creek are intended to penetrate the water-bearing alluvial sediments of the offshore paleocanyon.

5.3. Site Geology

A review of subsurface conditions in the project area was performed for this study utilizing previous exploratory boring logs in the project area by Ninyo & Moore and others. The purpose of the review was to evaluate the subsurface conditions that will possibly impact the design and construction of the proposed beach facilities (wells and conveyance pipelines). Thus, our review addresses the subsurface conditions within the upper approximately 50 to 100 feet of the project area. The following consultant data were reviewed:

- Ninyo & Moore exploratory borings and cone penetration tests (CPTs) performed for previous studies at the SCWD 30-acre site (1997, 2001), State Parks Lifeguard Building (2004) and SOCWA J.B. Latham Treatment Plant (2004, 2007b, 2012b, 2014b).
- Geoscience (2005) exploratory borings performed on the beach area for the Phase I Hydrogeology Investigation for the Doheny Desalination Project.
- Converse, Davis, Dixon and Associates (1976a) exploratory borings performed on the beach and creek bank areas on the west side of San Juan Creek and at the SOCWA treatment plant for the SERRA Ocean Outfall project.
- State of California Department of Transportation (Caltrans, 1976) exploratory borings for the PCH San Juan Creek Bridge.
- GMU Geotechnical (2014) exploratory borings and CPTs performed (and referenced from others) for the property at 34202 Del Obispo Street and PCH (Del Obispo Development).
- County of Orange Environmental Management Agency (1981) exploratory borings for the San Juan Creek Channel Levee Study.

A plan showing the locations of existing exploratory borings and CPT soundings utilized in our study is shown on Figure 10. Geologic sections depicting the interpreted subsurface

geology in the project area are presented in Figures 11A through 11D. Logs of the exploratory borings and CPT soundings utilized in our study are included in Appendix A.

In general, our review of the referenced subsurface data indicate the area of the planned beach facilities is underlain predominantly by coarse-grained alluvial and beach sediments generally comprised of sand and silty sand with varying amounts of gravel and cobbles. Near surface deposits include fill materials of variable composition in the developed areas of the beach facilities. Fine-grained (silt and clay) alluvial overbank deposits are interbedded at various depths within the sandy alluvium regime. Coarser alluvial deposits containing high concentrations of gravel and cobbles with few boulders are also present at various depths in the project area.

The following sections present a summary of the subsurface geologic data in four separate areas of the project site: 1) the beach and day use area on the west side of the mouth of San Juan Creek, 2) the beach and campground area on the east side of the mouth of San Juan Creek, 3) the Del Obispo Development and J.B. Latham Treatment plant on the west side of San Juan Creek, and 4) the and 30-acre site on the east side San Juan Creek (Figures 2 and 10). Detailed information is contained on the logs in the referenced reports.

5.3.1. Beach and Day Use Area – West Side of San Juan Creek Mouth

The borings conducted by Ninyo & Moore (Lifeguard Building) and Geoscience (Hydrogeology Study) in the vicinity of the beach and Doheny State Park day use area on the west side of the San Juan Creek mouth indicate that this area is underlain by fill soils, beach sediments and alluvial deposits. Fill soils up to approximately 5 feet thick comprised of medium dense silty sand were encountered at elevations ranging from approximately 14 to 9 feet above MSL in exploratory borings by Ninyo & Moore in the vicinity of the Lifeguard Building. The alluvial deposits at the boring locations generally consist of granular sediments comprised of sand and silty sand with varying amounts of gravel and cobbles. An approximately 6-foot-thick gravel layer was encountered in Lifeguard Building Boring B-4 at elevations ranging from

approximately zero to minus 6 feet below MSL. An approximately 10 to 14-foot-thick layer of clay and clayey sand was encountered in Hydrogeology Study Borings B-2, B-3 and B-4 at elevations ranging from approximately minus 19 to minus 33 feet below MSL.

5.3.2. Beach and Campground Area – East Side of San Juan Creek Mouth

The borings conducted by Converse, Davis, Dixon and Associates (CDD) in 1976 for the SERRA Ocean Outfall in the vicinity of the beach and Doheny State Park campground area on the east side of the San Juan Creek indicate that this area is underlain by minor fill soils and alluvial deposits. The alluvial deposits at the boring locations generally consist of granular sediments comprised of sand with varying amounts of gravel and cobbles. Some interbedded layers encountered in this area reportedly contain up to 40 percent gravel and cobbles. Some of the gravel and cobble layers reported on the logs are up to approximately 10 feet thick. An approximately 12-foot-thick layer of fine-grained sediments comprised of silty clay, sandy silt and silt was reported in SERRA Outfall Boring B-4 at elevations ranging from approximately 15 to 3 feet above MSL. An approximately 8-foot-thick layer of fine-grained sediments comprised of silty clay, sandy silt and silt was reported in SERRA Outfall Borings B-5 and B-6 on the beach area at elevations ranging from approximately minus 22 to minus 30 feet below MSL (similar to the elevations of the 14-foot-thick layer of fine-grained material reported in Hydrogeology Study Boring B-2 on the west side of the creek).

5.3.3. Del Obispo Development and SOCWA Treatment Plant – West Side of San Juan Creek

Borings and CPTs conducted by Caltrans, the County of Orange, GMU Geotechnical, Ninyo & Moore and CDD on the west side of the San Juan Creek from the PCH bridge inland (Figures 8A and 8C) indicate that this area is underlain by fill soils and alluvial deposits. Fill soils up to approximately 5 feet thick comprised of loose to medium dense sand and silty sand were encountered at elevations ranging from approximately 10 to 5 feet above MSL in exploratory borings by Ninyo & Moore at the SOCWA treatment

plant near the west side of the San Juan Creek channel. The alluvial deposits underlying this part of the project area at the boring locations generally consist of granular sediments comprised of sand with varying amounts of gravel and cobbles. An approximately 6 to 16-foot-thick layer of fine-grained silt and clay sediments was encountered in the CPTs performed by GMU at the Del Obispo Development in the upper part of the explorations at elevations varying from approximately 16 to zero feet above MSL. An approximately 17-foot-thick layer of fine-grained clayey sediments was encountered in the 2004 J.B. Latham Treatment Plant Boring B-1 by Ninyo & Moore at an elevation of approximately minus 10 to minus 27 feet below MSL.

5.3.4. 30-Acre-Site – East Side of San Juan Creek

The borings conducted by Caltrans, the County of Orange, CDD, and Ninyo & Moore along the east side of San Juan Creek from the PCH bridge inland (Figures 8A, 8B and 8C) indicate that this area is underlain by fill soils and alluvial deposits. Fill soils up to approximately 10 feet thick comprised of medium dense silty sand with gravel and cobbles were encountered at elevations ranging from approximately 15 to 5 feet above MSL in SERRA Outfall Borings B-2 and B-3 located on the east creek bank. Fine-grained clayey and silty fill soils up to approximately 13 feet thick were encountered in Ninyo & Moore borings at elevations ranging from approximately 22 to 9 feet above MSL at the SCWD 30-acre site along the east bank of San Juan Creek. These fill soils were observed to contain gravel, cobbles and concrete debris. The alluvial deposits at the boring locations in this area generally consist of granular sediments comprised of sand and silty sand with varying amounts of gravel and cobbles. Some interbedded layers encountered in CDD SERRA Outfall Boring B-2 reportedly contain up to 40 percent gravel and cobbles. Interlayered fine-grained (silt and clay) sediments were reported on the SERRA Outfall Boring B-2 log at elevations ranging from approximately minus 8 to minus 22 feet below MSL. Boulders were reported on the Caltrans PCH Bridge Boring B-4 log in the upper few feet of the boring at elevations ranging from approximately 14 to 10 feet above MSL.

5.4. Groundwater

The project study area extends from the beach inland along relatively low-lying terrain and groundwater is anticipated near sea level. Groundwater was observed in the Ninyo & Moore exploratory borings performed at the SCWD 30-acre site, State Parks Lifeguard Building and J.B. Latham treatment plant. Groundwater has also been reported on boring logs by others performed for the PCH bridge foundation, SERRA outfall pipeline, County of Orange logs for the San Juan Creek channel levee, and geotechnical reports (GMU, 2014) for nearby properties. The various boring logs in the vicinity of the project site indicate that the groundwater elevations in the project area range from approximately 3 to 16 feet above MSL. In general, the reported groundwater elevations are lower near the coastline, on the order of 3 to 7 feet above MSL at the beach, day use area, campground and PCH bridge. The reported groundwater levels are generally higher at the Del Obispo Development, J.B. Latham treatment plant and SCWD 30-acre site, on the order of 7 to 16 feet above MSL. General groundwater flow within the alluvial sediments underlying San Juan Creek is southerly under the ocean floor (Boyle, 2007).

The California Geologic Survey (CGS) Seismic Hazard Zone report for the project area indicates that the historic high groundwater in the vicinity of the site is approximately 5 feet below the ground surface (CDMG, 2001a). Fluctuations in the depth to groundwater will occur due to tidal variations, flood events along the San Juan Creek, seasonal precipitation, variations in ground elevations, groundwater pumping, projected sea level rise and other factors.

6. FAULTING AND SEISMICITY

6.1. Regional Seismicity

California is situated along the boundary between the Pacific crustal plate and the North American crustal plate. The San Andreas fault zone and related fault systems in California are the surface expressions of this plate boundary. The predominant tectonic movement along the San Andreas fault zone and other major fault systems in southern California, is

right-lateral, strike-slip movement (Norris and Webb, 1990). Strike-slip movement along faults generally involves horizontal displacement of the ground across the trace of the fault. Other active northwest-trending strike-slip fault systems in the site region include the Newport-Inglewood-Rose Canyon fault system, Palos Verdes-Coronado Bank fault system, Elsinore fault zone, and the San Jacinto fault zone.

California's tectonic framework is complex and also includes thrust faults, which are low angle faults with a relative oblique-vertical sense of motion. Active faults in the region also include blind thrust faults. Blind thrust faults do not have a surface trace because the rupture surface is buried.

The project site is not located within a State of California Earthquake Fault Zone (formerly known as Alquist-Priolo Special Studies Zone) (Hart and Bryant, 1997). However, the site is located in a seismically active area, as is the majority of southern California, and the potential for strong ground motion in the project area is considered significant during the design life of the proposed facilities. The approximate locations of major faults in the region and their geographic relationship to the site are shown on Figure 12.

Table 1 lists selected principal known active faults that may affect the subject site and the maximum moment magnitude (M_{max}) as published by the United States Geological Survey (USGS, 2014a). The approximate distances to the principal faults as measured from the beach at the mouth of San Juan Creek were calculated using the USGS fault parameters web-based design tool (USGS, 2014a).

Based on our document review, the Offshore Zone of Deformation associated with the active Newport-Inglewood–Rose Canyon Fault Zone is located approximately 3 miles southwest of the beach site (Figure 12). Other known principal active faults within approximately 25 miles of the project site include the San Joaquin Hills Blind Thrust, Palos Verdes, Coronado Bank and Elsinore Fault Zone (Table 1). Based on the proximity and number of known active and potentially active faults within the general region, it is reasonable to expect a

strong ground motion seismic event during the lifetime of structures for the proposed desalination project.

Since they are buried at depth and do not have a mapped surface trace, the San Joaquin Hills, Puente Hills and Upper Elysian Park blind thrust faults are not shown on official State fault zone maps and are, therefore, not shown on Figure 12. These faults are, however, included in the State database of active faults to be considered during seismic evaluations. They can be capable of generating damaging earthquakes and are included in Table 1.

As defined by the California Geological Survey (CGS), an active fault is one that has had surface displacement within Holocene time (roughly the last 11,700 years). Potentially active faults are those that show evidence of surface displacement during the last 1.6 million years of Quaternary time but for which evidence of Holocene movement has not been established. A fault is considered inactive if it has not shown evidence of surface displacement during the last 1.6 million years. The major faults shown on Figure 10 and listed on Table 1 include the active and potentially active faults in the site region categorized by the CGS and USGS as depicted on the Fault Activity Map of California (Jennings and Bryant, 2010).

The site region also includes numerous ancient faults that have become inactive as a result of changes in tectonic activity. Figure 10 also shows inactive faults in the site region that are mapped on various geologic references reviewed for our study. These inactive faults include the Cristianitos, Mission Viejo, Temple Hill, Laguna Canyon, Pelican Hills, and Shady Canyon faults.

Table 1 – Principal Regional Active Faults

Fault	Approximate Fault to Site Distance miles (km)[1]	Maximum Moment Magnitude (M_{max})[2]
Newport-Inglewood (Offshore)	3.0 (4.8)	7.1
San Joaquin Hills (Blind Thrust)	9.3 (15.0)	6.6
Newport-Inglewood (L.A. Basin)	17.8 (28.6)	7.1
Palos Verdes	18.0 (29.0)	7.3
Coronado Bank	18.5 (29.8)	7.6

Table 1 – Principal Regional Active Faults

Fault	Approximate Fault to Site Distance miles (km)[1]	Maximum Moment Magnitude (M_{max})[2]
Elsinore	22.0 (35.4)	6.8
Whittier	25.8 (41.5)	6.8
Chino-Central Avenue	25.9 (41.7)	6.7
Rose Canyon	27.8 (44.7)	7.2
Puente Hills (Blind Thrust)	31.4 (50.5)	7.1
San Jose	41.3 (66.5)	6.4
San Jacinto	44.4 (71.4)	6.7
Sierra Madre	45.7 (73.5)	7.2
Cucamonga	45.8 (73.7)	6.9
Upper Elysian Park (Blind Thrust)	48.2 (77.6)	6.4
Raymond	51.3 (82.5)	6.5
Clamshell – Sawpit Canyon	52.6 (84.6)	6.5
Verdugo	53.5 (86.1)	6.9
San Andreas	54.3 (87.4)	7.4
Hollywood	55.1 (88.7)	6.4

Notes:
[1] United States Geological Survey, 2013a.
[2] Cao, et al., 2003.

6.2. Principal Regional Faults

The following sections include discussion of selected principal active fault systems in the region of the project site based on the proximity to the site and relative fault activity, as shown on Figure 12.

6.2.1. Newport-Inglewood Fault Zone – Rose Canyon Fault Zone

The Newport-Inglewood Fault Zone (NIFZ) extends approximately 45 miles from the southern edge of the Santa Monica Mountains, through Long Beach and Torrance, southeast to Newport Bay, to offshore from the Dana Point area where it merges with the Rose Canyon fault (Grant and Shearer, 2004). The total length of the Newport-Inglewood-Rose Canyon fault system is approximately 130 miles (Treiman and Lundberg, 1999).

The active NIFZ is a significant tectonic structure in the Los Angeles Basin area and consists of a series of northwest-trending, right-lateral, strike-slip fault segments, with the Pacific Ocean side moving northwestward relative to Los Angeles (Harding, 1973). The NIFZ was the source of the 1933 Long Beach earthquake with a measured magnitude (M) 6.4. The Newport-Inglewood fault is considered capable of generating about a M_{max} 7.1 earthquake. The fault has an estimated slip rate of approximately 1 millimeter (mm) per year. The project site is located approximately 3.0 miles from the offshore portion of the NIFZ (the Offshore Zone of Deformation).

The Rose Canyon fault is a right-lateral, strike-slip fault that is located southeast of the project site and extends offshore approximately 19 miles north from San Diego and La Jolla. The Rose Canyon fault is considered capable of generating a M_{max} 7.2 earthquake and has a slip rate of approximately 1.5 mm per year.

6.2.2. San Joaquin Hills Blind Thrust Fault

Recent studies have reported the presence of the San Joaquin Hills blind thrust fault underlying the San Joaquin Hills, Newport Coast, and Newport Beach area northwest of the project site (Grant, 1999). The San Joaquin Hills blind thrust fault is considered to be located approximately 9.3 miles northwest of the project site and is considered capable of generating a M_{max} 6.6 earthquake (USGS, 2013a; Cao, 2003).

6.2.3. Palos Verdes Fault Zone - Coronado Bank Fault Zone

The active Palos Verdes fault extends approximately 50 miles from the Palos Verdes Peninsula to offshore (west) of the project site. This right-reverse fault has a slip rate of approximately 3 mm per year and is considered capable of generating about a M_{max} 7.3 earthquake. The project site is located approximately 18 miles east of the Palos Verdes fault zone.

The Palos Verdes fault zone continues southward as the Palos Verdes-Coronado Bank Fault Zone, which is located offshore from the project site, and extends a total length of approximately 106 miles. Rupture extending from one named section across to another

is considered possible (SCEC, 2004). The active Coronado Bank fault is characterized as a right-lateral, strike-slip and normal fault, has a slip rate of approximately 2 to 3 mm per year, and is considered capable of generating about a M_{max} 7.6 earthquake. The project site is located approximately 18.5 miles northeast of the Coronado Bank fault zone.

6.2.4. Elsinore Fault Zone (Including Whittier and Chino-Central Avenue Faults)

The active Elsinore fault zone is a significant tectonic feature in southern California and consists of a series of right-lateral, strike-slip fault segments that extend northwest through the communities of Julian, Temecula, Lake Elsinore, and Glen Ivy for a length of approximately 112 miles to Corona. The Elsinore fault zone was the source of a M_w 5 earthquake that occurred on the fault in 1910. The fault zone includes the active Whittier fault and Chino-Central Avenue fault branches which splay from the northwest end of the zone. The Elsinore fault zone is considered capable of generating an approximate M_{max} 6.8 earthquake, and has a slip rate of approximately 5 mm per year. The Glen Ivy segment of the Elsinore fault zone is located approximately 22 miles northeast of the project site.

The Whittier fault is a right-lateral, strike-slip fault that extends approximately 24 miles from the Corona area in the Santa Ana Canyon, where it splays from the Elsinore fault zone, northwest to Whittier Narrows. The Whittier fault is considered capable of generating a M_{max} 6.8 earthquake and has a slip rate of approximately 2.5 mm per year. The Whittier fault is located approximately 25.8 miles north of the project site.

The Chino-Central Avenue fault is a right-reverse fault that extends approximately 13 miles from the Corona area in the Santa Ana Canyon, where it splays from the Elsinore fault zone, northwest through the Chino Valley. The Chino-Central Avenue fault is considered capable of generating a M_{max} 6.7 earthquake and has an estimated

slip rate of 1 mm per year. The Chino-Central Avenue fault is located approximately 25.9 miles north of the project site.

6.2.5. Puente Hills Blind Thrust Fault

The Puente Hills blind thrust fault (PHT) is an active reverse thrust fault that does not reach the surface (blind) and extends for more than 25 miles in the northern Los Angeles Basin from downtown Los Angeles east to northern Orange County (USGS, 2013a; Dolan, et al, 2003). The fault consists of three distinct segments. From west to east, the segments are known as the Los Angeles, Santa Fe Springs, and Coyote Hills segments. Although not presently designated an Earthquake Fault Zone due to the lack of a well-defined surface trace, this fault is considered active and capable of generating moderate (M 6.5-6.6) earthquakes every approximately 400 to 1,320 years for single-segment earthquakes and strong earthquakes (M 7.1) every approximately 780 to 2,600 years for multi-segment earthquakes (Shaw, et al, 2002). The Puente Hills blind thrust fault is considered to be located approximately 31.4 miles northwest of the project site (USGS, 2013a) and the slip rate of the fault is estimated to be 0.7 mm per year (Cao, 2003).

6.2.6. San Jose Fault

The San Jose fault is a left-lateral reverse oblique fault the strikes northeasterly through the communities of Claremont, La Verne and Pomona for a length of approximately 14 miles. The fault is considered capable of generating a M_{max} 6.4 earthquake and has a slip rate of approximately 0.5 mm per year (Cao, 2003). The San Jose fault is considered to be the source of the 1988 M4.7 and 1990 M5.4 Upland earthquakes (SCEC, 2004). The San Jose fault is located approximately 41.3 miles north of the project site (USGS, 2013a).

6.2.7. San Jacinto Fault Zone

The active San Jacinto fault zone is a significant tectonic feature in southern California and consists of a series of right-lateral, strike-slip fault segments that extend northwest

for a length of approximately 130 miles through the communities of Borrego Springs, Anza, Hemet, Loma Linda, and San Bernardino. The project site is located approximately 44.4 miles southwest of the San Jacinto Valley segment of the fault. The Coyote Creek segment of the fault, located at the southeast end of the fault zone, was the source of the 1968 M_{max} 6.5 Borrego Mountain earthquake. The different segments of the San Jacinto fault zone are considered capable of generating earthquakes in the range of M_{max} 6.7 to 7.2, and have an estimated slip rate of approximately 6 mm per year (Cao, 2003).

6.2.8. Sierra Madre Fault Zone

The Sierra Madre fault zone is composed of a series of active reverse faults. The approximately 35-mile-long fault zone is located between the cities of Sunland and Azusa along the foothills of the San Gabriel Mountains, and is considered to be located approximately 45.7 miles northwest of the project site (USGS, 2013a). The Sierra Madre fault is considered capable of generating about a M_{max} 7.2 earthquake, and the slip rate of the fault is estimated to be 2 mm per year (Cao, 2003).

6.2.9. Cucamonga Fault

The active Cucamonga thrust fault dips to the north near the communities of Claremont, Upland, and Cucamonga and is about 17 miles long. The Cucamonga fault is considered capable of generating about a M_{max} 6.9 earthquake, and the slip rate of the fault is estimated to be 5 mm per year (Cao, et. al., 2003). The Cucamonga fault is considered to be located approximately 45.8 miles north of the project site (USGS, 2013a).

6.2.10. Upper Elysian Park Blind Thrust

The Upper Elysian Park blind thrust is a reverse thrust fault that does not reach the surface (blind). Geomorphic evidence of this fault at the surface is the Elysian Park anticline that extends for approximately 12.4 miles from the Hollywood fault on the northeast through the Silver Lake district and the cities of South Pasadena and Alhambra to San Gabriel on the east (Yeats, 2005). Although not presently designated

an Earthquake Fault Zone due to the lack of a well-defined surface trace, this fault is considered active (Oskin, et al., 2000) and capable of producing moderate earthquakes (M 6.2-6.7) every 500 to 1,300 years on average. The fault is considered to be located approximately 48.2 miles northwest of the project site (USGS, 2013a).

6.2.11. San Andreas Fault Zone

The San Andreas fault zone has long been recognized as the dominant seismotectonic feature in California. This right-lateral, strike-slip fault system strikes northwest through the state from the Gulf of California to north of San Francisco. Two of California's three largest historic earthquakes, the 1906 San Francisco earthquake and the 1857 Fort Tejon earthquake, occurred along the San Andreas fault. The project site is located approximately 54.3 miles southwest of the San Bernardino segment of the fault and is located approximately 59 miles southwest of the Mojave segment of the fault which ruptured during the 1857 Fort Tejon earthquake. The slip rate of the fault zone is estimated to be 30 mm per year (Cao, 2003). The San Andreas fault zone is considered capable of producing earthquakes in excess of M_{max} 7.4, and the average frequency of earthquakes along the Mojave segment of the San Andreas fault is approximately 140 years (SCEC, 2004).

7. POTENTIAL SEISMIC AND GEOLOGIC HAZARDS

The principal seismic hazards evaluated at the site are surface ground rupture, ground shaking, seismically induced liquefaction, and various manifestations of liquefaction-related hazards (e.g., dynamic settlement and lateral spreading). A brief description of these hazards and other geologic hazards are discussed in the following sections.

7.1. Surface Fault Rupture

Surface fault rupture is the offset or rupturing of the ground surface by relative displacement across a fault during an earthquake. Based on our review of the referenced geologic and seismic literature and our site reconnaissance, no active faults are known to cross the project

site. The project site is located approximately 3 miles northeast of the NIFZ. Therefore, the probability of damage from surface fault rupture at the site is considered to be low. However, lurching or cracking of the ground surface as a result of nearby seismic events is possible.

7.2. Seismic Ground Shaking

Earthquake events from one of the regional active or potentially active faults near the project area could result in strong ground shaking which could affect the project site and proposed improvements. The level of ground shaking at a given location depends on many factors, including the size and type of earthquake, distance from the earthquake, and subsurface geologic conditions. The type of construction also affects how particular structures and improvements perform during ground shaking.

The 2013 California Building Code (CBC) specifies that the Risk-Targeted, Maximum Considered Earthquake (MCE_R) ground motion response accelerations be used to evaluate seismic loads for design of buildings and other structures. The MCE_R ground motion response accelerations are based on the spectral response accelerations for 5 percent damping in the direction of maximum horizontal response and incorporate a target risk for structural collapse equivalent to 1 percent in 50 years with deterministic limits for near-source effects. The horizontal peak ground acceleration (PGA) that corresponds to the MCE_R for the site was calculated as 0.57g using the USGS (USGS, 2014) seismic design tool (web-based). Spectral response acceleration parameters, consistent with the 2013 CBC, are also provided in Section 12.2 for the evaluation of seismic loads on buildings and other structures.

The 2013 CBC specifies that the potential for liquefaction and soil strength loss be evaluated, where applicable, for the mapped PGA (PGA_M) which is defined as the Maximum Considered Earthquake Geometric Mean (MCE_G) PGA with adjustment for site class effects in accordance with the American Society of Civil Engineers (ASCE) 7-10 Standard. The MCE_G PGA is based on the geometric mean PGA with a 2 percent probability

of exceedance in 50 years. The MCE_G PGA was calculated using the USGS (USGS, 2014) seismic design tool that yielded a mapped MCE_G PGA of 0.57g for the site and a site coefficient (F_{PGA}) of 1.00 for Site Class D.

7.3. Site-Specific Ground Response Analysis

We have performed a site-specific ground response analysis in accordance with Section 1616A.1.3 of the CBC (CBC, 2013) and the ASCE Standard 7-10 (ASCE, 2010). The analysis consisted of a review of available seismologic information for nearby faults and performance of probabilistic and deterministic seismic hazard analyses (DSHA) to develop acceleration response spectrum curves. In accordance with the recommendations of 2013 CBC, the Next Generation Attenuation (NGA) relations were used while evaluating site-specific ground motion. The NGA relations we used for developing the deterministic and probabilistic spectra are by Chiou and Youngs (2008), Campbell and Bozorgnia (2008) and Boore and Atkinson (2008). The Open Seismic Hazard Analysis software developed by USGS (USGS, 2010) was used for performing the probabilistic seismic hazard analyses (PSHA) and DSHA.

In order to develop the response spectra, PSHA was performed for earthquake hazards having a 2 percent chance of being exceeded in 50 years. The spectral accelerations generally correspond to those associated with the MCE_R with 5 percent damping. The maximum rotated components of ground motions were considered in PSHA. A DSHA was then performed considering a M_{max} 7.1 earthquake (USGS, 2013a; Cao, 2003) event on the Newport-Inglewood offshore fault located 3.0 miles away from the site. Corrections were made to the spectral accelerations for the 84th percentile of the maximum rotated component of ground motion with 5 percent damping following the guidelines presented in 2009 National Earthquake Hazards Reduction Program recommended seismic provisions (NEHRP, 2009). The site-specific design spectrum is the lesser of the probabilistic and deterministic ordinates evaluated for the site at each period, but not less than 80% of the mapped PGA_M (ASCE, 2010). The various acceleration response spectra are shown on Figure 13.

7.4. Liquefaction, Dynamic Settlement and Lateral Spreading

Liquefaction is the phenomenon in which loosely deposited granular soils and non-plastic silts located below the water table undergo rapid loss of shear strength when subjected to strong earthquake-induced ground shaking. Ground shaking of sufficient duration results in the loss of grain-to-grain contact due to a rapid rise in pore water pressure, and causes the soil to behave as a fluid for a short period of time. Liquefaction is known generally to occur in saturated or near-saturated cohesionless soils at depths shallower than 50 feet below the ground surface. Factors known to influence liquefaction potential include composition and thickness of soil layers, grain size, relative density, groundwater level, degree of saturation, and both intensity and duration of ground shaking.

The project site is mapped in a State of California Seismic Hazard Zone as potentially liquefiable as shown on Figure 14 (CDMG, 2001b). Based on our review of referenced background data the site is underlain by unconsolidated, predominantly sandy alluvial sediments and shallow groundwater conditions are present. Ninyo & Moore's previous geotechnical studies at the Lifeguard Building, J.B. Latham Treatment Plant and the SCWD 30-acre site and GMU's study at the Del Obispo Development indicate that scattered zones of sandy alluvial deposits are potentially liquefiable during design earthquake events. Our previous analyses of liquefaction potential included the results of CPT soundings, exploratory borings and laboratory test results of representative soil samples. The liquefaction analyses were based on the National Center for Earthquake Engineering Research (NCEER) procedures (Youd, et al., 2001) developed from the methods originally recommended by Seed and Idriss (1982) using the computer modeling programs. Assumptions utilized in the analyses included depth to groundwater and design ground accelerations.

To evaluate the potential impacts from liquefaction, our previous analyses included estimates of dynamic settlement due to liquefaction. In order to estimate the amount of post-earthquake settlement, the method proposed by Tokimatsu and Seed (1987) is generally used in which the seismically induced cyclic stress ratios and corrected blow counts (N-values)

are correlated to the volumetric strain of the soil. The amount of soil settlement during a strong seismic event depends on the thickness of the liquefiable layers and the density and/or consistency of the soils. Previous analyses for projects located in the study area indicate potential dynamic settlement at the ground surface ranging from approximately 2 to 14 inches. Prior to detailed project design, additional subsurface exploration should be performed to evaluate the site-specific liquefaction potential and appropriate mitigation.

Lateral spreading is a liquefaction hazard that results in lateral earth movement. Lateral spreading of the ground surface during an earthquake usually takes place along weak shear zones that have formed within a liquefiable soil layer. Lateral spread has generally been observed to take place in the direction of a free-face (i.e., retaining wall, slope, channel) but has also been observed to a lesser extent on ground surfaces with gentle slopes. An empirical model developed by Youd, et al. (2002) is typically used to predict the amount of horizontal ground displacement within a site. For sites located in proximity to a free-face, the amount of lateral ground displacement is strongly correlated with the distance of the site from the free-face. Other factors such as earthquake magnitude, distance from the earthquake epicenter, thickness of the liquefiable layers, and the fines content and particle sizes of the liquefiable layers also affect the amount of lateral ground displacement.

The project site includes free-face slopes along the San Juan Creek Channel and the sloping beach frontage. Previous analyses by Ninyo & Moore for the SCWD 30-acre site and the J.B. Latham Treatment Plant site indicate some areas along the San Juan Creek are susceptible to lateral spread hazards. The sloping beach area is also considered potentially susceptible to lateral spread hazards.

7.5. Erosion

Erosion is process by which soil or earth material is loosened or dissolved and removed from its original location. Erosion can occur by varying processes and may occur at the project site where bare soil is exposed to wind or moving water (rainfall or surface runoff).

The processes of erosion are generally a function of material type, terrain steepness, rainfall or irrigation levels, surface drainage conditions, and general land uses.

Periodic erosion along the San Juan Creek and beach areas occurs in response to storm flooding and wave action. These areas are addressed in the coastal processes report by Coastal Environments (Appendix A).

The near-surface soils at the project site are comprised predominantly of sandy soils. Sandy soils have low cohesion and have a relatively higher potential for erosion from surface runoff. Surface soils with higher amounts of clay or silt tend to be less erodible as the clay and silt acts as a binder to hold the soil particles together.

Construction of the proposed project would result in ground surface disruption during excavations and trenching that would create the potential for erosion to occur. However, a Storm Water Pollution Prevention Program (SWPPP) incorporating Best Management Practices (BMPs) for erosion protection would be prepared prior to the start of construction. In addition, the topographic gradients at the project site are relatively gentle, which would tend to reduce the potential for off-site runoff and erosion. The subject beach facilities are underground structures and after construction surface improvements are anticipated to be restored to similar conditions without significant alteration of surface runoff or erosion potential. Surface drainage design provisions and site maintenance would mitigate soil erosion at the site. Therefore, the potential impacts due to erosion are considered to be relatively low.

7.6. Slope Stability

Landslides, slope failures, and mudflows of earth materials generally occur where slopes are steep and the earth materials too weak to support themselves. Earthquake-induced landslides may also occur due to seismic ground shaking. The beach facilities project area is relatively flat and there are no significant slopes within the project limits. The San Juan Creek channel embankments in the project area are inclined at 2:1 (horizontal to vertical) and are lined with concrete. The channel embankments not been subject to slope failures, but could be at risk if

significant channel scouring were to occur that undermined the concrete liners. The channel embankments could also be at risk of slope failure during significant seismic shaking, including liquefaction induced failure.

7.7. Subsidence

Subsidence is characterized as a sinking of the ground surface relative to surrounding areas, and can generally occur where deep soil deposits are present. Subsidence in areas of deep soil deposits is typically associated with regional groundwater withdrawal or other fluid withdrawal from the ground such as oil and natural gas. Subsidence can result in the development of ground cracks and damage to foundations, buildings and other improvements. Historic oil and gas withdrawal has resulted in significant ground subsidence in areas of the City of Long Beach and in the Huntington Beach Oil Field area. The project site is not located in an area of known historic subsidence. Therefore, the potential for subsidence is relatively low.

7.8. Compressible/Collapsible Soils

Compressible soils are generally comprised of soils that undergo consolidation when exposed to new loading, such as fill or foundation loads. Soil collapse is a phenomenon where the soils undergo a significant decrease in volume upon increase in moisture content, with or without an increase in external loads. Buildings, structures and other improvements may be subject to excessive settlement-related distress when compressible soils or collapsible soils are present.

Based on our previous subsurface explorations and review of the referenced geotechnical background data, the project site is underlain by minor existing fill soils and alluvial sediments comprised predominantly of sandy materials. The beach facilities will generally involve relatively light, below grade structures (pipes and vaults) and will not involve placement of new fill loads upon the existing soils at the site. Poorly compacted fill soils, if present, could be subject to consolidation under the loads of planned structures, but may be mitigated during construction. Due to the existing shallow groundwater levels at the site, it

is our opinion that the site soils are not susceptible to hydro-collapse. Therefore, the potential impacts of settlement are not considered significant and should not be a constraint for the proposed project improvements. Site-specific geotechnical evaluations should be conducted during detailed project design to evaluate the potential for soils prone to settlement.

7.9. Expansive Soils

Expansive soils include clay minerals that are characterized by their ability to undergo significant volume change (shrink or swell) due to variations in moisture content. Sandy soils are generally not expansive. Changes in soil moisture content can result from rainfall, irrigation, pipeline leakage, surface drainage, perched groundwater, drought, or other factors.

Volumetric change of expansive soil may cause excessive cracking and heaving of structures with shallow foundations, concrete slabs-on-grade, or pavements supported on these materials. The near-surface soils at the project site are predominantly comprised of sandy materials that are typically low in expansion potential. Furthermore, the beach facilities will consist primarily of below grade vaults and pipes that should not be impacted by expansive soils. Therefore, the potential impacts of expansive soils are not considered significant and should not be a constraint for the proposed project improvements. The potential for expansive soils at the locations of the proposed improvements should be evaluated during the detailed design stage of the project in order to provide recommendations to mitigate the potential impacts of expansive soils, as appropriate.

8. COASTAL PROCESSES

A study of the coastal processes at Doheny State Beach was performed to evaluate potential shoreline conditions that could impact the beach facilities portions of the project. The coastal processes study was performed by Coastal Environments (CE). CE performed an evaluation of

coastal processes in 2004 for the Doheny State Beach lifeguard headquarters. Their current study is supplemental to and expands on the 2004 study.

The coastal processes study included a review of beach history and beach physical conditions, analysis of beach profiles and aerial photographs, changes in beach width and beach stability, beach sediment sources, wave exposure and longshore sand transport, sea level rise and impacts to the beach, wave run-up potential, hydrology of the San Juan Creek, and tsunami potential.

The following sections present a brief summary of the findings of the coastal processes study. The full report by CE is presented in Appendix B. The full report includes details regarding supporting technical data, analysis methodologies, assumptions and data uncertainties. The full report should be reviewed in detail when planning for beach facilities.

8.1. Doheny State Beach

Doheny State Beach is a south facing beach that extends west and east of the mouth of the San Juan Creek. The "West Beach" area includes approximately 1,400 feet of beach in front of the day use area of the state campground. The west end of the beach is bordered by the east breakwater of the Dana Point Harbor. A small creek known as North Creek discharges to the beach at the west end. The east end of the West Beach is bordered by a concrete and rock jetty referred to as Thor's Hammer. The beach is roughly 300 to 400 feet wide. The back of the beach is bordered by a 2-foot high retaining wall that reportedly extends up to 15 feet below grade (seawall).

The Thor's Hammer rock jetty borders the San Juan Creek at the beach. The mouth of the San Juan Creek is up to 400 feet wide at the beach. The east side of the creek also includes a timber pile bulkhead wall constructed for erosion protection. The river mouth is commonly blocked by the build-up of a berm across the face of the beach, which is periodically breached and eroded during large storm events.

The "East Beach" area extends east of the creek approximately 4,500 feet in length. The back of the beach is bordered by the over-night camping area of the state beach campground for a distance of approximately 3,200 feet. The East Beach is on the order of 200 feet wide.

Doheny Beach originally extended west of the San Juan Creek to the Dana Point headland. Construction of Dana Point Harbor began about 1966 and was essentially completed by 1970.

8.2. Beach Widths and Stability

Beach profiles and review of aerial photograph data were used to evaluate the beach configurations and beach width changes over time. Beach widths are a fundamental and frequently measured characteristic that are related to sand volume. Fluctuations in beach width are related to beach stability.

Nine beach profiles surveys performed by CE in 2004 and 2 additional historical beach profiles by others were evaluated as part of the study. The beach profiles included 5 profiles along the West Beach, 3 profiles along the mouth of the San Juan Creek and 2 along the East Beach area. The profiles generally extended perpendicular to the beach from the back of the beach heading offshore to approximately 12 feet below sea level. The beach profiles indicate relatively consistent conditions with a near shore slope starting at the beach crest of approximately 15:1 (horizontal to vertical) and an offshore gentle slope of 100:1 beyond a depth of approximately 4 feet below sea level. The 2004 beach profiles indicated the West Beach had an average width of approximately 280 feet and the East Beach had an average width of 186 feet.

Historical beach profiles are limited and aerial photographs were utilized to further evaluate beach widths and historic changes. Aerial photographs from 2004 were compared to beach profile data and indicated good correlation. Aerial photographs prior to the construction of the Dana Beach Harbor indicated a West Beach width of approximately 225 feet. After harbor construction the West Beach area increased to over 300 feet in width. Historical aerial photographs from 1970 to 2012 show variations in the West Beach widths ranging

from approximately 320 to 639 feet. The East Beach area ranged from approximately 143 to 654 feet in width. The data indicates periods of beach retreat and periods of beach replenishment. In particular, significant storm and wave events in 1982-83 and 1988 were associated with beach retreat. Beach replenishment was indicated during wet weather storm events in 1980, 1983, 1993, 1995, and 1998.

The data reviewed indicate that the Doheny State Beach area is relatively stable, but is subject to wave erosion and beach retreat during extended dry periods and storm wave events. Beach replenishment occurs during storm events associated with runoff and high flows along the San Juan Creek. The beach is currently near its minimum width, since the last flood event was in the winter of 1997-1998.

8.3. Beach Sediment Sources

The Doheny State Beach is part of the Oceanside Littoral cell that extends from Dana Point 53 miles south to La Jolla Point and the La Jolla submarine canyon. A littoral cell is defined as the geographic area with a full cycle of littoral sand sources, longshore sediment transport and sinks. Sources of sand in the Oceanside Littoral cell include river discharge, cliff erosion and to a smaller extent artificial beach nourishment. Since the 1930's, the sediment entering the system has decreased due to daming and stabilization of associated rivers.

The sediment budget for the reach of the coast between Dana Point and San Mateo (near San Clemente) shows that during dry periods, there is a deficit (erosion) of approximately 56,000 cubic yards (cy). During wet periods there is a surplus (accretion) of approximately 3,000 cy. Doheny State Beach is located at the end of the littoral cell and is protected from north-northwest waves and the shoreline is likely to lose small amounts of sand during dry periods.

The San Juan Creek receives run-off from a large watershed area of approximately 176 square miles. The sediment contribution to the beach areas from the San Juan Creek has been estimated between 34,000 and 56,000 cy per year.

Some sand replenishment may occur from cliff erosion along the Doheny Point headlands associated with longshore transport. Sand spits have been observed off the east breakwater of the Dana Point Harbor.

Artificial sand replenishment also plays a part in beach nourishment. In 1966 approximately 690,000 cy of sediment were placed at Doheny Beach from excavations at Camp Pendleton. In 1969 approximately 212,000 cy of sand was placed at the beach. In 1970 approximately 125,000 cy of sand from dredging operations were placed at Doheny Beach.

8.4. Wave Run-up and Overtopping

Doheny State Beach is a south facing beach which is sheltered from the majority of north-northwesterly swells by offshore islands, the Dana Point headland and the Dana Point Harbor. The beach is exposed to waves from south swells and tropical storms with a mean direction of 215 degrees at a 33-feet water depth. Wave heights typically range from 4 to 8 feet with an average height of 6 feet. 50 and 100-year storm events can generate wave heights of 12 to 14 feet.

Tidal gauge data was used to estimate water level design parameters for the study area. Design water levels of 3.3 feet and 5.2 feet above sea level were calculated for a 5 percent probability occurence and 100-year return period events, respectively.

Doheny State Beach is subject to southern swells which are characterized by long wave periods that can cause frequent wave run-up and overtopping. The wave run-up and overtopping that typically occurs is of low volume with little damage potential. If large waves were to occur during times of elevated ocean levels, such as spring tides, there could be damage to structures in the vicinity of the beach. However, the probability of large waves occurring at the same time as high tides is low.

8.5. Sea Level Rise

Sea level rise (SLR) can be attributed to two main factors: thermal expansion of the oceans and global ice melt. Greenhouse gas emissions, especially carbon dioxide, are believed by many climatologists to increase ocean and air temperatures, which leads to thermal expansion of the oceans and global ice melt.

Global projections for SLR vary from study to study and range from 0.59-6.6 ft (18-200 cm) by 2100. This is mainly due to uncertainties in the estimation values for some of the model parameters used in emission models, specifically ice cap melting. Additionally, the overall short time period since SLR models have developed does not allow for a long data set to be utilized in model calibrations.

The projected SLR utilized in this study included 1.5 feet by 2050 and 4.6 feet by 2100. The projections utilized were the higher end estimates from Canyan, et al. (2012). Bruun's Rule (1962) was used to estimate changes in beach width associated with SLR. Sea level is likely to increase gradually over the next 30-40 years, giving time for the beach profile to adjust with waves and tides. Based on Bruun's Rule assumptions and limitations, the beach width along the West Beach area would retreat up to approximately 63 feet by 2050. The East Beach area is estimated to retreat up to approximately 55 feet by 2050. By 2100 the West Beach could retreat up to 197 feet and the East Beach may retreat up to 172 feet.

8.6. Tsunami Potential

The project study area is located in a State of California mapped tsunami inundation area (California Emergency Management Agency, 2009). Figure 15 shows the potential inundation area at Doheny Beach. The extent of the propagation of tsunami waves along the beach and into San Juan Creek is defined by the tsunami inundation line shown on Figure 15. This map was prepared based on tsunami modeling efforts performed by the University of Southern California. Several tsunami source events were selected for modeling, representing realistic close and distant earthquakes and hypothetical extreme undersea, near-shore landslides, such as offshore reverse-thrust faults, restraining bends on strike-slip fault

zones and large submarine landslides capable of significant seafloor displacement and tsunami generation. Distant tsunami sources that were considered include subduction zone events that are known to have occurred historically (1960 Chile and 1964 Alaska earthquakes) and others which can occur around the Pacific Ocean "Ring of Fire".

This map does not represent inundation from a single scenario event. It was created by combining inundation results for an ensemble of source events affecting a given region. For this reason, all of the inundation region in a particular area will not likely be inundated during a single tsunami event. The map also does not give the height of the tsunamis at Doheny State Beach.

Recorded tsunami run-up values observed along the California coast range from approximately 1.3 to 3 feet in height. These values are generally recorded in harbors and bays which magnify the heights of tsunamis; accordingly these are conservative values for tsunamis that are generated from distance source areas. Close sources, which are rare, could generate higher tsunamis.

9. PRELIMINARY FINDINGS

Based on the results of our preliminary geotechnical evaluation, construction of the beach facilities for the proposed Doheny Desalination Project is considered feasible from a geotechnical perspective. Our preliminary study indicates that there are potential significant seismic hazards and coastal processes that could impact the project and should be considered during planning and design phases of the project.

The project area is located in a State of California Seismic Hazard Zone for soil liquefaction. Previous geotechnical studies in the project area indicate the presence of soil layers that are susceptible to liquefaction during large earthquake events. The liquefaction potential and severity of hazard is variable with location and depth below the surface. Groundwater depths, material types, and material densities affect the liquefaction potential. Liquefaction may result in ground settlement and lateral spreading. Further discussion of the liquefaction hazards and possible

mitigation methods are presented in the following sections of this report. Detailed assessment of liquefaction and appropriate mitigation should be performed during the design phase of the project.

Our coastal processes study provides information regarding the stability of Doheny Beach and potential coastal impacts to the project. In general, the study indicates that Doheny Beach is subject to relatively slow retreat (erosion) during dry weather periods and relatively rapid accretion (sedimentation) during wet weather flooding events along the San Juan Creek. The coastal processes data and observed changes in beach width, indicate a relatively stable beach area subject to cyclic variations in beach width under historic and current conditions. Predictions of SLR due to global climate change, however, suggest a potential for significant impacts to the beach. Predicted SLR's of 1.5 feet by 2050 and 4.6 feet by 2100 were utilized in this study. SLR impacts to Doheny State Beach could result in losses of beach width ranging from 55 to 63 feet by 2050 and as much as 172 to 197 feet by 2100. It should be noted that there remains large uncertainties regarding the magnitude of SLR that will actually occur. Nevertheless, SLR is anticipated and the impacts to the beach facilities could be significant.

A summary of additional preliminary findings is presented below. Subsequent sections discuss potential mitigation measures and geotechnical constraints.

- The project area is underlain by beach sediments and unconsolidated alluvial deposits. Relatively shallow fills are also present in the area. The beach sediments and alluvial deposits are predominantly comprised of sandy soils with interbeds of gravel and cobbles. Scattered interbedded fine-grained (clay and silt) alluvial layers are also present beneath the project site.

- Shallow groundwater conditions are present in the area. The depth to groundwater will vary, but should be anticipated within approximately 3 to 16 feet above MSL. Construction dewatering and tunneling below groundwater are anticipated.

- Gravel and cobble layers should be anticipated during construction and may involve difficult excavation. Appropriate tunneling equipment should be considered for the variable subsurface conditions. Tunneling by use of a MTBM is considered suitable for the soil and groundwater conditions at the project site. HDD tunneling methods are also considered suitable.

- The sandy alluvium and beach sediments are prone to caving; steep excavations for trenches or pits will involve shoring such as driven sheet piles. Unsupported excavations below groundwater in the sandy soils may exhibit flowing behavior.

- The project site is situated in an area of relatively high seismic activity, similar to most of California. The MCE_G peak ground acceleration with adjustment for site class effects (PGA_M) was calculated as 0.54g using the USGS (USGS, 2014c) seismic design tool for Site Class D.

- The site is not located within a State of California Earthquake Fault Zone (Alquist-Priolo Special Studies Zone). No active faults are known to cross the project site. The project site is located approximately 3 miles northeast of the NIFZ. Therefore, the probability of damage from surface fault rupture at the site is considered to be low.

- Doheny State Beach is exposed to occasional wave run-up and beach over topping. The impacts to proposed below grade structures is not considered a significant hazard.

- The project area is located in a tsunami run-up hazards area. Historical tsunami data indicate wave heights of 2 to 3 feet in the project area. The impacts to the proposed below grade structures is not considered a significant hazard.

10. RISK MANAGEMENT AND GEOTECHNICAL CONSTRAINTS

The following sections present discussion of potential alternatives to reduce the impacts and risk associated with geologic and seismic hazards, coastal processes and geotechnical construction issues. The alternatives are for preliminary planning consideration. Prior to project design a detailed geotechnical evaluation should be performed. The geotechnical evaluation should include subsurface exploration sufficient to evaluate the hazards and the magnitude of risk that may be involved. Future studies should also include a thorough evaluation of underground utilities and structures that could impact pipeline alignments.

The need to mitigate hazards should also include an evaluation of the risk and consequences. Regulatory guidelines may not require mitigation of geologic hazards for the planned beach facilities improvements. Therefore, the owners/stakeholders may evaluate mitigation alternatives and risks to decide if mitigation is appropriate.

10.1. Seismic Ground Shaking

As previously discussed, earthquake events from one of the regional active or potentially active faults near the project area could result in strong ground shaking which could affect the project site and proposed improvements. Strong ground shaking should be anticipated during the lifetime of the project. Mitigation of the potential impacts of seismic ground shaking can be achieved through project design. During the detailed design phase, site-specific seismic design parameters should be developed based on a detailed geotechnical evaluation for use by the project structural engineer. Structural elements of the project can then be designed to resist or accommodate appropriate site-specific ground motions and to conform to the current seismic design standards. In general, structures designed in conformance to current building codes, and with appropriate geotechnical and structural engineering design should provide suitable protection from the impacts related to strong seismic ground shaking.

10.2. Liquefaction Hazards

The site is located in an area susceptible to seismically induced soil liquefaction. Soil liquefaction may result in ground settlement, ground cracking or lateral spreading. The potential for soil liquefaction and the severity of ground deformation within the project area varies. The need for mitigation and the type of mitigation will depend on the liquefaction hazard based on a detailed geotechnical study. Mitigation of liquefaction hazards for various project components may involve the following:

- Supporting structures on deep pile foundations extending through liquefiable zones.
- Various types of in-situ ground improvement methods to densify the soil or otherwise stabilize the soil.
- Design of improvements to tolerate anticipated ground movement.
- Avoiding liquefiable zones.

Deep pile foundations can be used to support structures and mitigate liquefaction hazards. In general, the piles are designed to extend below liquefiable zones and derive support in the

underlying non-liquefiable material. During a liquefaction event, ground settlement may occur, but the pile supported structures are protected. Wellhead vaults could be supported on deep pile foundations. Lateral spread potential should also be evaluated to see whether piles would be effective. Pile foundations can also be used to mitigate the liquefaction hazard for pipelines. The planned conveyance pipeline alignments, however, cross multiple properties with various existing improvements, which will likely preclude installation of piles along the lengths of the pipelines.

In-situ densification of liquefiable soils to mitigate the liquefaction hazard can be achieved using in-situ ground improvement techniques such as vibro-replacement stone columns, rammed aggregate piers, soil-cement mixing, compaction grouting or deep dynamic compaction. Each of these methods involves densifying targeted subsurface liquefiable zones. Typically the ground improvement is performed in a grid pattern beneath planned improvement areas. In-situ ground improvement mitigates the potential for liquefaction and new structures may be supported on shallow foundation systems constructed in the stabilized ground. In general, each of the referenced alternative methods may be feasible from a geotechnical perspective, depending on future geotechnical analyses. Site constraints, such as work areas, access to heavy equipment, existing improvements, potential environmental concerns, etc. would need to be evaluated to decide appropriate methods. Feasible ground improvement methods beneath the pipeline alignments would be limited, due to the existing improvements present.

Mitigation of liquefaction hazards may also involve design of improvements to tolerate some ground deformation. Pipeline materials and flexible couplings may be considered for liquefaction mitigation. HDPE pipes and other pipe materials may be used that can tolerate some movement. This may be a more practical approach for the pipelines crossing various properties with existing improvements. The suitability of this approach depends on the severity of the liquefaction hazard to be assessed during the design phase.

Another consideration for the project would be to avoid liquefaction hazard zones. Based on our experience and review of subsurface data, the density of soil beneath the project area

generally increases with depth. Liquefaction hazards are typically more severe in shallow ground areas where soil is relatively looser. Locating pipelines at deeper depths may be considered to penetrate denser material where the liquefaction hazard may be absent or less severe. The feasibility and benefits of this alternative should be evaluated during the project design phase.

10.3. Beach Stability

Our coastal risks study indicates that under current conditions the beach areas are subject to periodic erosion and replenishment, but are relatively stable. The beach areas west of the San Juan Creek are wider due to the protective effects of the Dana Point Harbor and the existing river jetty. The beach areas east of the San Juan Creek are less protected and are not as wide during extended dry periods of erosion. Under current conditions, it would be reasonable to locate the well head vaults at the back of each beach area to avoid the cyclic erosion hazards.

In the long term, however, projected sea level rise indicates a potential for relatively severe beach erosion. Estimated beach width losses due to SLR of 55 to 63 feet by 2050 and losses of 172 to 197 feet by 2100 may occur. The estimates of SLR and beach impacts include significant uncertainties.

Protection of the beach facilities from the long-term beach erosion associated with SLR would involve locating the well head vaults and associated pipe systems further inland beyond projected erosion areas or considering alternate well head vault design at the planned locations. The West Beach area has maintained a beach width of 320 feet or more since harbor construction in 1970. Therefore assuming 197 feet of potential beach loss due to SLR, locating the beach facilities at the back edges of the existing beach should provide adequate protection.

The East Beach, however, is less protected and not as wide. Since harbor construction the beach has eroded to estimated width of 143 feet. Therefore, protection of the beach facilities from potential beach erosion due to projected SLR by 2100 would involve locating the beach facilities inside the existing over-night campground areas of the Doheny State Beach or considering alternate well head vault design at the planned locations.

Additional measures that could be considered include long-term maintenance with periodic beach sand replenishment. Protective beach barriers, such as offshore breakwater jetties or beach groin jetties could also be considered for beach protection. The feasibility of these alternatives would involve significant coastal processes and environmental studies and goes beyond the scope of this study.

10.4. Geotechnical Construction Constraints

10.4.1. Excavations

Excavations in the predominantly sandy alluvium and beach sands should be feasible with heavy earthmoving equipment. Some difficulty may be encountered when excavating relatively dense gravel and cobble layers.

Sandy soils generally have relatively little cohesion and have a high potential for caving. Steep excavations in these materials will be unstable and temporary construction slopes should be laid-back to stable inclinations. Temporary slopes above the water table should be relatively stable at an inclination of 1½:1 (horizontal to vertical). Some surficial sloughing may occur. Temporary slopes should also be evaluated with regard to proximity to existing structures or other improvements.

Excavations for trenches or pits below the water table will be unstable and temporary shoring such as driven sheet piles will be involved. The appropriate type of shoring system will depend on the subsurface materials and depths of excavations. For example, gravel and cobble layers may impact the ability to drive sheet piles. Other types of shoring systems may be appropriate and should be evaluated based on a detailed geotechnical evaluation.

10.4.2. Groundwater Dewatering

Shallow groundwater is present in the study area and some excavations are anticipated to involve construction dewatering to maintain relatively dry conditions. The relatively sandy soils have relatively high permeabilities and relatively high dewatering rates should be anticipated. Dewatering near beach areas for underground well vaults may encounter particularly high rates due to presence of ocean water recharge. Permits for dewatering will be involved in accordance with the appropriate agencies.

Settlement due to construction dewatering can occur depending on the soil conditions and depths of dewatering. In general, the granular soils in the project area are considered to have a low potential for settlement due to dewatering. Settlement potential should be evaluated during subsequent detailed geotechnical evaluations.

10.4.3. Tunneling

Tunneling risks include ground settlement and encountering obstructions. HDD tunneling also includes risk of “frac-outs” (inadvertent loss of drilling fluid) to the ground surface (creek channel), into highly permeable (gravel/cobble) zones, or into other voids such as utility crossings).

Ground settlement may result from excessive soil removal during tunneling compared to casing advancement. This is a potential risk along the beach facilities tunnel alignments due to the soil and groundwater conditions. Tunneling will occur below groundwater in unconsolidated sands. Flowing soil conditions may be anticipated in this environment. Where tunneling operations encounter cobbly material or other

obstructions casing advancement can stall or slow down. This can result in excess soil removal if the tunneling operator does not adjust the soil removal. Appropriate tunneling equipment and careful tunneling procedures can mitigate these risks. MTBM's with earth pressure balance systems and HDD drilling systems should be suitable tunneling methodologies for these conditions.

Oversize materials obstructions (cobbles, boulders, concrete, foundations, debris) can cause tunneling refusal, which can result in major disruptions and project changes to recover the tunneling machine and complete the tunnel. The risks of encountering obstructions can be reduced by thorough evaluations of subsurface conditions to select tunnel alignments free of possible obstructions. This evaluation should include geotechnical exploration to evaluate the conditions along the tunnel alignments, including stratigraphy, soil types, density of materials, material strength characteristics, clast sizes (sands, gravels, cobbles, boulders) and groundwater conditions. The existing boring logs reviewed during this study indicate that the project area includes interbedded layers of sand, silty sand, sand with gravel, silt and lenses of gravel, cobbles with few boulders. Tunneling experts should evaluate the appropriate tunneling equipment for these conditions. Geophysical surveying and thorough review of plans for existing improvements (i.e., the PCH Bridge, nearby buildings, and the channel levee) should also be performed. Records regarding historic site conditions, such as old structure foundations, pits/dump sites, abandoned pipes/utilities should also be researched.

Frac-out releases are typically caused by the pressurization of the drill hole beyond the containment capability of the near surface geologic materials (soil and/or rock). Therefore the type and depth of these materials, as well as the drilling pressure, are key factors in avoiding frac-outs.

Careful planning, design and implementation of appropriate tunneling methods are ways to reduce the risks associated with tunneling. Thorough evaluations of subsurface soil and groundwater conditions, existing underground utilities, existing foundations

and other possible obstructions along the alignments are important for successful tunneling projects. Where soil conditions are considered highly susceptible to settlement, ground improvement methods, such as grouting may be considered to provide more stable conditions. This may be appropriate where tunneling is close to existing structures. The need for ground improvement should be evaluated during the design phase based on the geotechnical conditions and proposed alignments.

Monitoring during tunneling is also recommended to evaluate tunneling performance and reduce risk. Monitoring may include surface monitoring points, inclinometers, structure monitoring points and/or extensometers. Monitoring may be used to provide real time assessment of tunneling impacts and allow for evaluation and modifications to the tunneling operation before significant distress occurs.

11. ADDITIONAL STUDIES

During the design phase of the project a detailed geotechnical evaluation should be performed. The geotechnical evaluation should include subsurface exploration sufficient to evaluate the potential hazards that may impact the project and the magnitude of risk that may be involved. The geotechnical evaluation should include appropriate mitigation methods for various geologic hazards and detailed design and construction recommendations. Future studies should also include a thorough evaluation of underground utilities and structures that could impact conveyance pipeline alignments.

12. LIMITATIONS

This report is intended for preliminary project planning purposes. It does not provide sufficient data for detailed design or accurate construction cost estimates. During the design phase of the project, a detailed geotechnical evaluation, including subsurface exploration, should be performed. The purpose of additional geotechnical evaluation would be to develop additional subsurface data and prepare detailed design and construction recommendations for the project.

The data evaluation and geotechnical analyses presented in this geotechnical report have been conducted in general accordance with current practice and the standard of care exercised by geotechnical consultants performing similar tasks in the project area. No warranty, expressed or implied, is made regarding the conclusions, recommendations, and opinions presented in this report. Variations may exist and conditions not observed or described in this report may be encountered during future subsurface explorations and project construction. Uncertainties relative to subsurface conditions can be reduced through additional subsurface exploration. Our evaluation was limited to assessment of the geotechnical aspects of the project and did not include evaluation of structural issues, environmental concerns, or the presence of hazardous materials.

This document is intended to be used only in its entirety. No portion of the document, by itself, is designed to completely represent any aspect of the project described herein. Ninyo & Moore should be contacted if the reader requires additional information or has questions regarding the content, interpretations presented, or completeness of this document.

Our preliminary conclusions and recommendations are based on a review of readily available geotechnical literature and referenced geotechnical reports conducted in the project vicinity, and an analysis of the observed conditions. It should be understood that site conditions may change with time as a result of natural processes or the activities of man at the subject site or nearby sites. In addition, changes to the applicable laws, regulations, codes, and standards of practice may occur due to government action or the broadening of knowledge. The findings of this report may, therefore, be invalidated over time, in part or in whole, by changes over which Ninyo & Moore has no control.

This report is intended exclusively for use by the client. Any use or reuse of the findings, conclusions, and/or recommendations of this report by parties other than the client is undertaken at said parties' sole risk.

13. REFERENCES

American Society of Civil Engineers (ASCE), 2010, Minimum Design Loads for Building and other Structures, Standard 7-10.

Association of Engineering Geologists, Southern California Section, 1989, Engineering Geology Along Coastal Orange County, dated September 23.

Boore, D. M., Atkinson, G. M., 2008, Ground-motion prediction equations for the average horizontal component of PGA, PGV, and 5%-damped PSA at spectral periods between 0.01 s and 10.0 s, Earthquake Spectra, Volume 24, Issue 1.

Boyle Engineering Corporation, 2007, Dana Point Ocean Desalination Project – Engineering Feasibility Report, Final Draft, dated March.

California Building Standards Commission, 2013, California Building Code (CBC): California Code of Regulations.

California Climate Change Center, 2009, The Impacts of Sea-Level Rise on The California Coast, dated March.

California Coastal Commission, 2004, Seawater Desalination and the California Coastal Act, dated March.

California Department of Conservation, Division of Mines and Geology (CDMG), 1974, Geology of the Dana Point Quadrangle, Orange County, California, Special Report 109.

California Department of Conservation, Division of Mines and Geology (CDMG), 1976, Environmental Geology of Orange County, California, Open File Report 79-8.

California Department of Conservation, Division of Mines and Geology (CDMG), 1988a, Planning Scenario For a Major Earthquake on the Newport-Inglewood Fault Zone, Special Publication 99.

California Department of Conservation, Division of Mines and Geology (CDMG), 1988b, Recently Active Traces of the Newport-Inglewood Fault Zone, Los Angeles and Orange Counties, California, Open File Report 88-14.

California Department of Conservation, Division of Mines and Geology, 1997a, Guidelines for Evaluating and Mitigating Seismic Hazards in California: Special Publication 117, 74 pp.

California Department of Conservation, Division of Mines and Geology (CDMG), State of California, 2001a, Seismic Hazards Zones Report for the Dana Point 7.5-Minute Quadrangle, Orange County, California: Seismic Hazard Zone Report 049.

California Department of Conservation, Division of Mines and Geology (CDMG), State of California, 2001b, Seismic Hazards Zones Official Map, Dana Point Quadrangle, 7.5-Minute Series: Scale 1:24,000, Seismic Hazard Zone Report 049, dated December 21.

California Emergency Management Agency, 2009, Tsunami Inundation Map for Emergency Planning, Dana Point Quadrangle – San Juan Capistrano Quadrangle: Scale 1:24,000, dated March 15.

Campbell, K.W., and Bozorgnia, Y., 2008, NGA Ground Motion Model for the Geometric Mean Horizontal Component of PGA, PGV, PGD and 5% Damped Linear Elastic Response Spectra for Periods Ranging from 0.01 to 10 s, Earthquake Spectra Volume 24, Issue 1, pp. 139-172: dated February.

Cao, Tianqing, Bryant, William A., Rowshandel, Badie, Branum, David, and Wills, Christopher J., 2003, The Revised 2002 California Probabilistic Seismic Hazard Maps, Adapted by California Geological Survey (CGS), dated June.

Chiou, B. S.-J., and Youngs, R.R., 2008, An NGA Model for the Average Horizontal Component of Peak Ground Motion and Response Spectra, Earthquake Spectra Volume 24, Issue 1, pp. 173-216: dated February.

City of Dana Point, 1995, Public Safety Element of the General Plan, dated June 27, http://www.danapoint.org/GP/index.html.

City of Dana Point, 2007, Municipal Zoning Codes, Title 9, Chapters 9.27, 9.69 and 9.75, http://ordlink.com/codes/danapnt/index.htm

County of Orange Environmental Management Agency, 1981, Memo and Boring Logs - San Juan Creek Channel Levee Study, dated September 3.

County of Orange Environmental Management Agency, 1982, Plans for Construction of That Portion of the San Juan Creek Channel from Pacific Coast Highway to Stonehill Drive, dated October.

County of Orange Public Facilities & Resources Department, 2003, Topographic Map of San Juan Creek, Pacific Coast Highway (Sta. 10+00 to Stonehill Drive (Sta. 50+23.70), dated March.

Converse, Davis, Dixon and Associates, 1976a, SERRA Ocean Outfall, Logs of Vibratory Core Nos. 1 through 9 and Jet Probe Nos. 1 through 37 for Lowry and Associates, Dana Point, California, dated July 13 through October 24.

Converse, Davis, Dixon and Associates, 1976b, Phase II Geotechnical Investigation, SERRA Ocean Outfall, Dana Point, California, dated December 20.

Dolan, J.F., Christofferson, S.A., Shaw, J.H., 2003, Recognition of Paleoearthquakes on the Puente Hills Blind Thrust Fault, California (Abstract), Journal: Science, Vol. 300, p. 5616.

Geoscience Support Services, Inc (Geoscience), 2005, Dana Point Ocean Desalination Project, Phase I Hydrogeology Investigation, Prepared for Municipal Water District of Orange County, dated October.

Geoscience Support Services, Inc (Geoscience), 2008, Horizontal Well Technology Application in Alluvial Marine Aquifers for Ocean Feedwater Supply and Pretreatment, Prepared for Municipal Water District of Orange County, dated September 30.

GMU Geotechnical, 2014, EIR Level Geotechnical Report for the Proposed Development at 34202 Del Obispo Street, City of Dana Point, California, dated February 13.

Google Earth, 2014, Website: http://earth.google.com.

Grant, L.B. and Shearer, P.M., 2004, Activity of the Offshore Newport-Inglewood Rose Canyon Fault Zone, Coastal Southern California, from Relocated Microseismicity: Bulletin of the Seismological Society of America, Vol. 94, No. 2, pp. 747-752, dated April.

Harding, T.P., 1973, Newport-Inglewood Trend, California—An Example of Wrenching Style Deformation: American Association of Petroleum Geologists Bulletin, v. 57, No. 1, p. 97-116.

Hart, E.W., and Bryant, W.A., 1997, Fault-Rupture Hazard Zones in California, Alquist-Priolo Special Studies Zone Act of 1972 with Index to Special Studies Zones Maps: California Division of Mines and Geology, Special Publication 42.

Jennings, C.W., and Bryant, 2010, Fault Activity Map of California: California Division of Mines and Geology, California Geologic Data Map Series, Map No. 6, Scale 1:750,000.

Lowry and Associates, 1977, South East Regional Reclamation Authority, SERRA Ocean Outfall Project, Plans for Effluent Pump Station Modifications, Including Converse Davis Dixon Associates Logs of Soil Borings, dated June 15.

Morton, D.M., 2004, Preliminary Digital Geologic Map of the Santa Ana 30'x 60' Quadrangle, Southern California, Version 2.0: United States Geological Survey, Open-File Report 99-172, Scale 1:100,000.

Morton, P.K., Miller, R.V, and J.R. Evans, 1976, Environmental Geology of Orange County, California: California Division of Mines and Geology Open File Report 79-8 LA, Scale 1:48,000.

Morton, P.K., Miller, R.V., 1981, Geologic Map of Orange County, California, Showing Mines and Mineral Deposits: California Division of Mines and Geology, Bulletin 204, Scale 1:48,000.

National Earthquake Hazards Reduction Program (NEHRP), 2009, Recommended Seismic Provisions for New Buildings and Other Structures, 2009 Edition.

Ninyo & Moore, 1997, Geotechnical Evaluation, Victoria Wastewater Treatment Plant Upgrade, Dana Point, California, dated June 26.

Ninyo & Moore, 1999, Limited Geotechnical Evaluation, San Juan Creek Properties, Dana Point, June 1 (Ninyo & Moore Project No. 201956001).

Ninyo & Moore, 2001, Geotechnical Evaluation, San Juan Creek Property, Dana Point, California, dated February 19 (Ninyo & Moore Project No. 201956003).

Ninyo & Moore, 2002, Update Geotechnical Recommendations, South Coast Water District, Groundwater Recovery Facility – Phase 1, Dana Point, California, dated October 25 (Ninyo & Moore Project No. 201029002).

Ninyo & Moore, 2003, Update Geotechnical Evaluation, South Coast Water District, Groundwater Recovery Plant, Dana Point, California, dated December 17 (Ninyo & Moore Project No. 201029004).

Ninyo & Moore, 2004a, Geotechnical Evaluation, Lifeguard Headquarters and Visitor Center, Doheny State Beach, Dana Point, California, dated November 24 (Ninyo & Moore Project No. 205974001).

Ninyo & Moore, 2004b, Geotechnical Evaluation, Fuel/Oil Container Pad, J.B. Latham Treatment Plant, Dana Point, California, dated December 3.

Ninyo & Moore, 2006a, As-Graded Geotechnical Report, Groundwater Recovery Plant, Rough Grading (Phase I), South Coast Water District, Dana Point, California, dated March 17 (Ninyo & Moore Project No. 201029004).

Ninyo & Moore, 2006b, As-Graded Geotechnical Report, Groundwater Recovery Plant, Access Road and Improvements (Phase I), South Coast Water District, Dana Point, California, dated April 4 (Ninyo & Moore Project No. 201029005).

Ninyo & Moore, 2006c, Remedial Grading Recommendations, Groundwater Recovery Facility – Offsite Stage II Grading, South Coast Water District, Dana Point, California, dated April 19 (Ninyo & Moore Project No. 201029005).

Ninyo & Moore, 2006d, As-Graded Geotechnical Report, Groundwater Recovery Plant, Offsite Stage II Grading, South Coast Water District, Dana Point, California, dated October 30 (Ninyo & Moore Project No. 201029008).

Ninyo & Moore, 2007a, As-Graded Geotechnical Report, Groundwater Recovery Plant, South Coast Water District, Dana Point, California, dated March 23 (Ninyo & Moore Project No. 201029006).

Ninyo & Moore, 2007b, Geotechnical Evaluation, Power and Pumping Upgrades, J.B. Latham Treatment Plant, Dana Point, California, dated July 13.

Ninyo & Moore, 2007c, As-Graded Geotechnical Report, Victoria Station Soil Restoration, South Coast Water District, Dana Point, California, dated November 9 (Ninyo & Moore Project No. 201029009).

Ninyo & Moore, 2008, Geotechnical Evaluation, South Coast Water District, Operations Center Dana Point, California, dated May 19 (Ninyo & Moore Project No. 201029010).

Ninyo & Moore, 2012, Geotechnical Evaluation, Preliminary Design of Digester No. 5, J.B. Latham Treatment Plant, Dana Point, California, dated April 6.

Ninyo & Moore, 2014a, Proposal for Preliminary Geotechnical Study, Beach Facilities, Doheny Desalination Project, Dana Point, California, dated April 29.

Ninyo & Moore, 2014b, Geotechnical Evaluation, Design of Southside Facility Improvements, J.B. Latham Treatment Plant, Dana Point, California, dated June 17.

Norris, R.M., and Webb, R.W., 1990, Geology of California: John Wiley & Sons, 541 pp.

Oskin, M., Sieh, K., Rockwell T., Miller G., Guptill P., Curtis, M., MCardle, S., Elliot, P., 2000, Active Parasitic Folds on the Elysian Park Anticline: Implications for Seismic Hazard in Central Los Angeles, California (Abstract), Journal: Geological Society of America Bulletin, Vol. 112, Issue 15, pp. 693-707.

Peterson, M.D., Bryant, W.A., Cramer, C.H., Cao, T., Reichle, M.S., Frankel, A.D., Lienkaemper, J.J., McCrory, P.A., and Schwartz, D.P., 1996, Probabilistic Seismic Hazard Assessment for the State of California: California Department of Conservation, Division of Mines and Geology Open File Report 96-08.

Pratt, P.L., Shaw, J.H., Dolan, J.F., Christofferson, S.A., Williams, R.A., Odum, J.K., Plesch, A., 2002, Shallow Seismic Imaging of Folds Above the Puente Hills Blind-Thrust Fault, Los Angeles, California: Geophysical Research Letter, Vol. 29, No. 9, 1304, pp. 18-1 through 18-4.

Rogers, T.H., 1966, Geologic Map of California, Santa Ana Sheet, Olaf P. Jenkins Edition: California Division of Mines and Geology, Scale 1:250,000.

Seed, H.B., and Idriss, I.M., 1982, Ground Motions and Soil Liquefaction During Earthquakes, Earthquake Engineering Research Institute Monograph, Oakland, California.

Shaw, J.H., Plesch, A., Dolan, J.F., Pratt, T.L., Fiore, P., 2002, Puente Hills Blind-Thrust System, Los Angeles, California: Bulletin of the Seismological Society of America, Vol. 92, No. 8, pp. 2946-2960.

State of California Department of Transportation (Caltrans), 1976, Log of Test Borings, San Juan Creek Bridge As-Built Plans, dated April 1.

Lowry and Associates, 1977, South East Regional Reclamation Authority (SERRA) Ocean Outfall Project Plans, dated June 15.

Southern California Earthquake Center (SCEC), 2004, Index of Faults of California: http://www.data.scec.org/fault_index/, dated June 17.

State of California Coastal Conservancy, 2009, Policy Statement on Climate Change, Adopted June 4.

Tan, S.S., 1984, Classification of Landslide Propensity in the Dana Point Quadrangle, Orange County, California: California Division of Mines and Geology Open File Report 84-57, Scale 1:12,000.

Tan, S.S,, 1999, Geologic Map of the Dana Point 7.5'Quadrangle, Orange County, California: A Digital Database, Version 1.0, California Division of Mines and Geology.

Tokimatsu, K., and Seed, H.B., 1987, Evaluation of Settlements in Sands Due to Earthquake Shaking, Journal of the Geotechnical Engineering Division, ASCE, Vol. 113, No. 8, pp. 861-878.

Treiman, J.A. and Lundberg, M.M, compilers, 1999, Fault Number 127a, Newport-Inglewood-Rose Canyon fault zone, north Los Angeles Basin section, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, http://earthquakes.usgs.Gov/regional/qfaults, accessed 06/07/2007, 05:27 PM.

United States Geological Survey, 1968 (Photorevised 1975), Dana Point, California Quadrangle Map, 7.5 Minute Series: Scale 1:24,000.

United States Geological Survey and Southern California Earthquake Center, 2010, Open Seismic Hazard Analysis, http://www.opensha.org/.

United States Geological Survey, 2014a, 2008 National Seismic Hazard Maps – Fault Parameters; http://geohazards.usgs.gov/efusion/hazardfaults_search/hf_search_main.efm.

United States Geological Survey, 2014b, U.S. Seismic Design Maps, Version 3.1.0; http://earthquake.usgs.gov/hazards/designmaps/usdesign.php.

United States Geological Survey, 2014c, Earthquake Ground Motion Parameter Java Application, Java Ground Motion Parameter Calculator – Version 5.1.0; http://earthquake.usgs.gov/research/hazmaps/design/.

Yeats, R.S., compiler, 2005, Active Faults in the Los Angeles Metropolitan Region, Southern California Earthquake Center Group C, Website: http://www.scec.org/research/special/SCE001activefaultsLA.pdf.

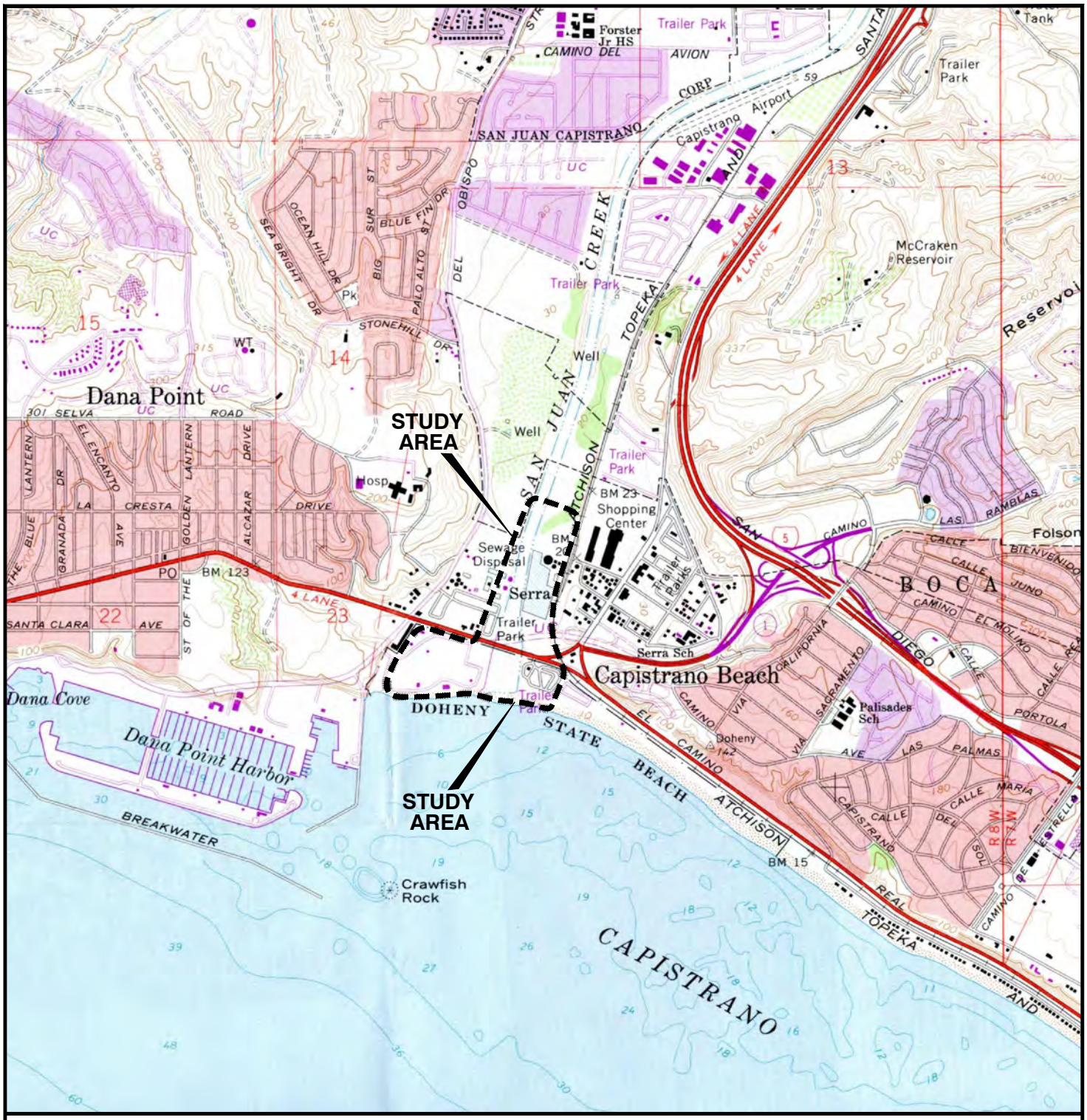
Youd, T.L., and Idriss, I.M. (Editors), 1997, Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils, Salt Lake City, Utah, January 5 through 6, 1996, NCEER Technical Report NCEER-97-0022, Buffalo, New York.

Youd, T.L., Hanse, C.M., and Bartlett, S.F., 2002, Revised MLR Equations for Predicting Lateral Spread Displacement, Journal of Geotechnical and Geoenvironmental Engineering, Volume 128, Number 12, pp. 1007-1017, dated December.

Youd, T.L., Idriss, I.M., Andrus, R.D., Arango, I., Castro, G., Christian, J.T., Dobry, R., Finn, W.D., Harder, L.F., Hynes, M.E., Ishihara, K., Koester, J.P., Liao, S.S.C., Marcuson, W.F., Martin, G.R., Mitchell, J.K., Moriwaki, Y., Power, M.S., Robertson, P.K., Seed, R.B., and Stokoe, K.H., II., 2001, Liquefaction Resistance of Soils: Summary Report

from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils, Journal of Geotechnical and Geoenvironmental Engineering: American Society of Civil Engineering 124(10), pp. 817-833.

AERIAL PHOTOGRAPHS				
Source	**Date**	**Flight**	**Numbers**	**Scale**
USDA	12-12-52	AXK-3K	61 and 62	1:20,000
Californiacoastline.org	1972	Image 7239017		Oblique photo
Californiacoastline.org	5-3-79	Image 7953090		Oblique photo
Californiacoastline.org	9-16-06	Images 200603374 and 200603375		Oblique photo
Californiacoastline.org	9-29-13	Images 201311379, 201311380 and 201311381		Oblique photo
Google Earth	4-16-13	-		-



REFERENCE: 7.5 MINUTE USGS TOPOGRAPHIC MAP OF DANA POINT, CALIFORNIA QUADRANGLE, DATED 1968, SCALE 1:24,000.

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore	STUDY AREA	FIGURE
PROJECT NO. 201029014 / DATE 2/15	DOHENY DESALINATION PROJECT BEACH FACILITIES DANA POINT, CALIFORNIA	1

201029014_SA.dwg 14:43:05 02/05/2015 GK



REFERENCE: GOOGLE EARTH, PHOTOGRAPH DATED APRIL 16, 2013.

N

SCALE IN FEET

0 800 1,600

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore	SITE PLAN	FIGURE
PROJECT NO. 201029014 / DATE 2/15	DOHENY DESALINATION PROJECT BEACH FACILITIES DANA POINT, CALIFORNIA	2

201029014_SP.dwg 14:46:05 02/05/2015 GK



REFERENCE: COPYRIGHT © 2002-2013, KENNETH AND GABRIEL ADELMAN, CALIFORNIA COASTAL RECORDS PROJECT, WWW.CALIFORNIACOASTLINE.ORG, DATE OF PHOTOGRAPH: MARCH 30, 2010.

NOT TO SCALE

N

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore

PROJECT NO.	DATE
201029014	2/15

EXISTING SITE CONDITIONS - WEST

DOHENY DESALINATION PROJECT BEACH FACILITIES
DANA POINT, CALIFORNIA

FIGURE

3A

201029014_ESC.dwg 15:23:08 09/08/2014 GK



REFERENCE: COPYRIGHT © 2002-2013, KENNETH AND GABRIEL ADELMAN, CALIFORNIA COASTAL RECORDS PROJECT, WWW.CALIFORNIACOASTLINE.ORG, DATE OF PHOTOGRAPH: MARCH 30, 2010.

NOT TO SCALE

N

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore

PROJECT NO.	DATE
201029014	2/15

EXISTING SITE CONDITIONS - EAST

DOHENY DESALINATION PROJECT BEACH FACILITIES
DANA POINT, CALIFORNIA

FIGURE

3B

201029014_ESC2.dwg 15:23:08 09/08/2014 GK



REFERENCE: COPYRIGHT © 2002-2013, KENNETH AND GABRIEL ADELMAN, CALIFORNIA COASTAL RECORDS PROJECT, WWW.CALIFORNIACOASTLINE.ORG, DATE OF PHOTOGRAPH:1972.

NOT TO SCALE

N

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore		1972 AERIAL PHOTOGRAPH	FIGURE
PROJECT NO.	DATE	DOHENY DESALINATION PROJECT BEACH FACILITIES DANA POINT, CALIFORNIA	4
201029014	2/15		

201029014_AP-1972.dwg 15:23:08 09/08/2014 GK



REFERENCE: COPYRIGHT © 2002-2013, KENNETH AND GABRIEL ADELMAN, CALIFORNIA COASTAL RECORDS PROJECT, WWW.CALIFORNIACOASTLINE.ORG, DATE OF PHOTOGRAPH: MAY 3, 1979.

NOT TO SCALE

N

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore

PROJECT NO.	DATE
201029014	2/15

1979 AERIAL PHOTOGRAPH

DOHENY DESALINATION PROJECT BEACH FACILITIES
DANA POINT, CALIFORNIA

FIGURE

5

201029014_AP-1979.dwg 15:23:08 09/08/2014 GK



REFERENCES: GOOGLE EARTH, PHOTOGRAPH DATED APRIL 16, 2013.
BOYLE ENGINEERING CORPORATION, 2007, DANA POINT OCEAN DESALINATION PROJECT - ENGINEERING FEASIBILITY REPORT, DATED MARCH.

SCALE IN FEET
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N

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore

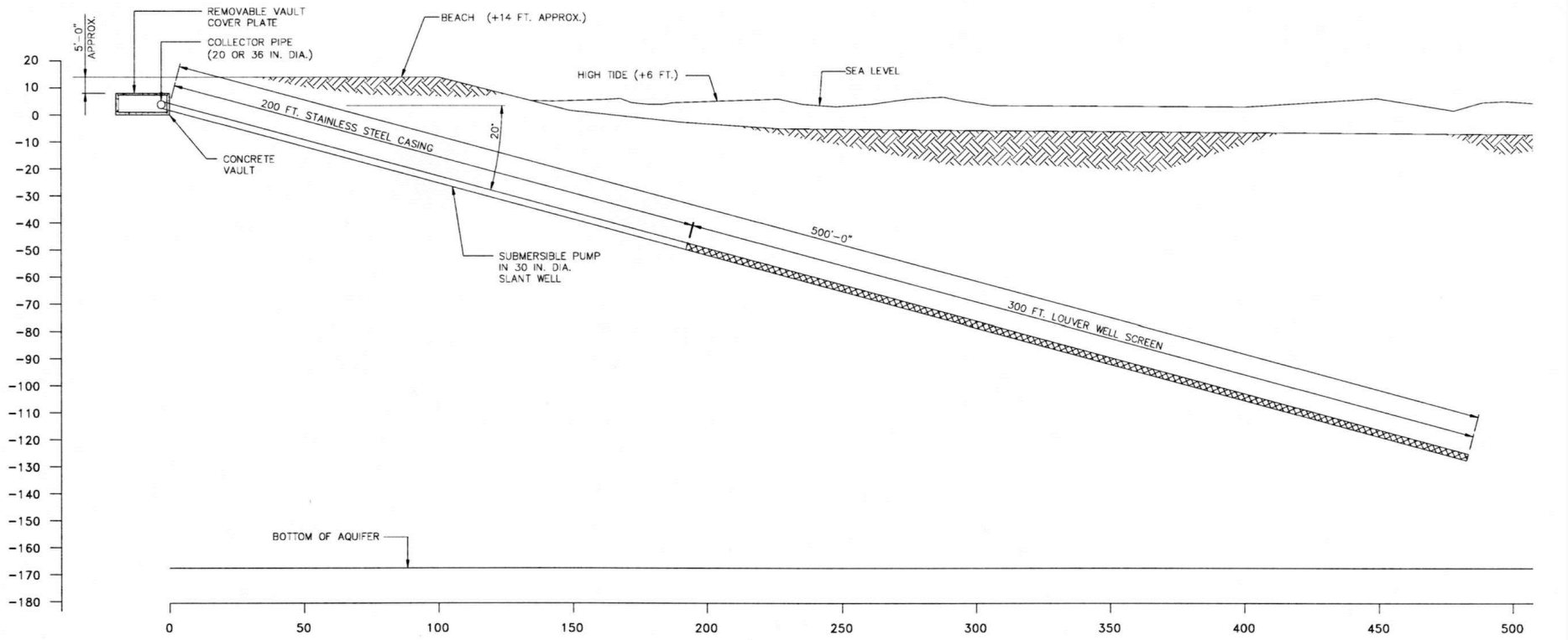
PROPOSED CLUSTER ARRAY INTAKE WELLS

PROJECT NO.	DATE
201029014	2/15

DOHENY DESALINATION PROJECT BEACH FACILITIES
DANA POINT, CALIFORNIA

FIGURE
6

201029014_CAIW.dwg 16:12:08 09/08/2014 GK



REFERENCE: BOYLE ENGINEERING CORPORATION, 2007, DANA POINT OCEAN DESALINATION PROJECT - ENGINEERING FEASIBILITY REPORT, DATED MARCH.

SCALE IN FEET

0 60 120

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore	PROPOSED SLANT WELL CONFIGURATION	FIGURE
PROJECT NO. 201029014 / DATE 2/15	DOHENY DESALINATION PROJECT BEACH FACILITIES DANA POINT, CALIFORNIA	7

201029014_PSWC.dwg 15:23:08 09/08/2014 GK



REFERENCE: GOOGLE EARTH, PHOTGRAPH DATED APRIL 16, 2013.
BOYLE ENGINEERING CORPORATION, 2007, DANA POINT OCEAN DESALINATION PROJECT - ENGINEERING FEASIBILITY REPORT, DATED MARCH.

SCALE IN FEET
0 600 1,200
NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore	PROPOSED CONVEYANCE PIPELINES - OPTION 1	FIGURE
PROJECT NO. 201029014 / DATE 2/15	DOHENY DESALINATION PROJECT BEACH FACILITIES DANA POINT, CALIFORNIA	8A

201029014_PCP1.dwg 15:23:08 09/08/2014 GK



REFERENCE: GOOGLE EARTH, PHOTGRAPH DATED APRIL 16, 2013.
BOYLE ENGINEERING CORPORATION, 2007, DANA POINT OCEAN DESALINATION PROJECT - ENGINEERING FEASIBILITY REPORT, DATED MARCH.

SCALE IN FEET

0 600 1,200

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore	PROPOSED CONVEYANCE PIPELINES - OPTION 1A	FIGURE
PROJECT NO. 201029014 / DATE 2/15	DOHENY DESALINATION PROJECT BEACH FACILITIES DANA POINT, CALIFORNIA	8B

201029014_PCP2.dwg 15:23:08 09/08/2014 GK



REFERENCE: GOOGLE EARTH, PHOTGRAPH DATED APRIL 16, 2013.
BOYLE ENGINEERING CORPORATION, 2007, DANA POINT OCEAN DESALINATION PROJECT - ENGINEERING FEASIBILITY REPORT, DATED MARCH.

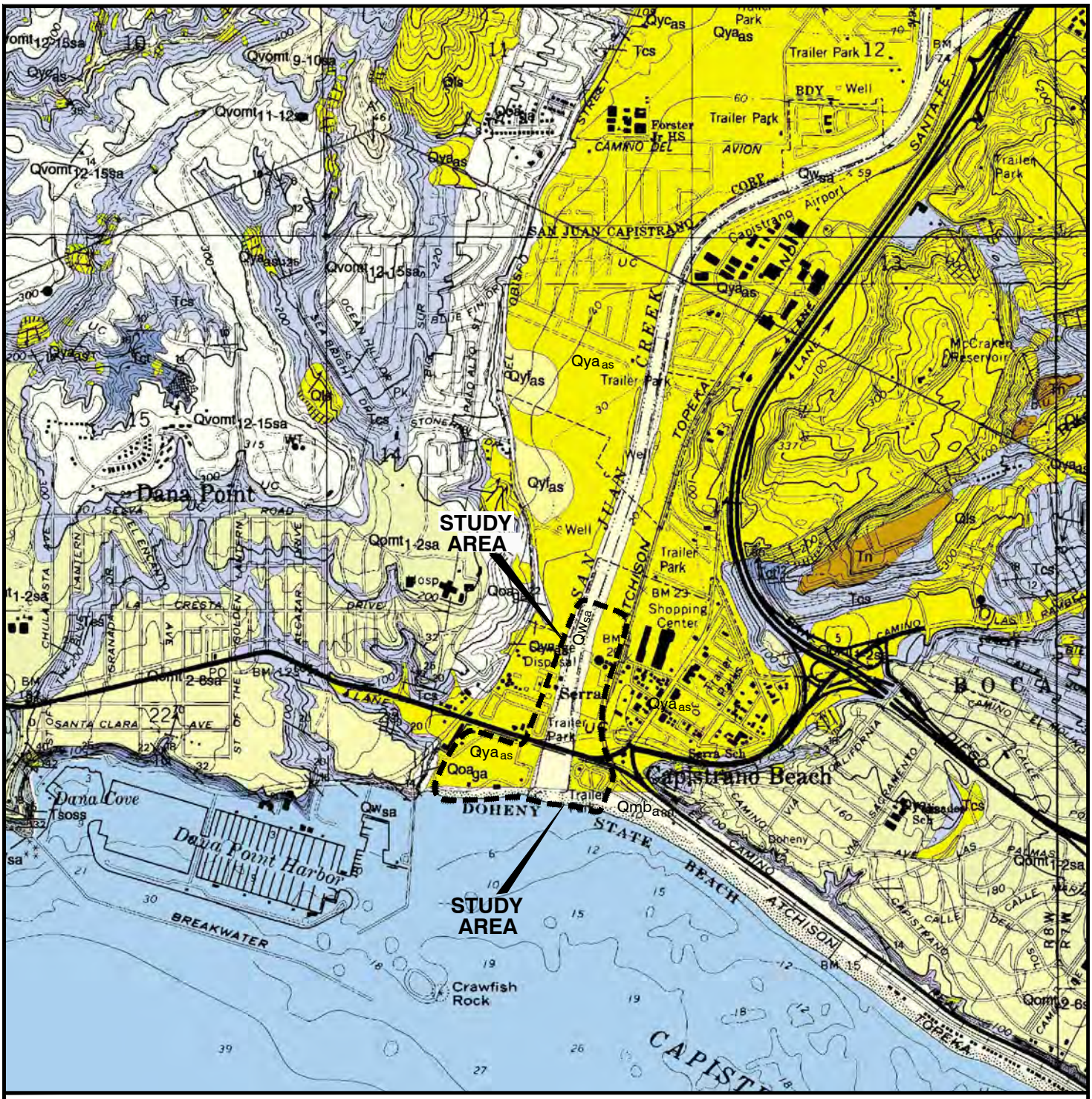
SCALE IN FEET

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NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore	PROPOSED CONVEYANCE PIPELINES - OPTION 4	FIGURE
PROJECT NO. 201029014 / DATE 2/15	DOHENY DESALINATION PROJECT BEACH FACILITIES DANA POINT, CALIFORNIA	8C

201029014_PCP3.dwg 15:23:08 09/08/2014 GK



REFERENCE: SIANG S. TAN, 1999, GEOLOGIC MAP OF THE DANA POINT QUADRANGLE, ORANGE COUNTY, CALIFORNIA.

N

SCALE IN FEET

0 2,000 4,000

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

LEGEND

Qw_{sa}	ACTIVE CHANNEL AND WASH DEPOSITS
Qmb_a	ACTIVE MARINE BEACH DEPOSITS
Qya_{as}	YOUNGER (HOLOCENE, (NOT ACTIVE) ALLUVIAL FLOOD PLAIN DEPOSITS
	GEOLOGIC CONTACT

Ninyo & Moore

REGIONAL GEOLOGY

FIGURE 9

PROJECT NO.	DATE
201029014	2/15

DOHENY DESALINATION PROJECT BEACH FACILITIES
DANA POINT, CALIFORNIA

201029014_RG.dwg 14:42:05 02/05/2015 GK



LEGEND

B-5	BORING; PCH BRIDGE (STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION, 1976)
B-7	BORING; SERRA OUTFALL (CONVERSE DAVIS DIXON ASSOCIATES, 1976)
B-4	BORING; CHANNEL LEVEE (COUNTY OF ORANGE ENVIRONMENTAL MANAGEMENT AGENCY, 1981)
B-9	BORING; SCWD 30-ACRE SITE (NINYO & MOORE, 1997)
B-4	BORING; LIFEGUARD BUILDING (NINYO & MOORE, 2004)
B-4	BORING; HYDROGEOLOGY STUDY (GEOSCIENCE, 2005)
B-1	BORING; J.B. LATHAM TREATMENT PLANT (NINYO & MOORE, 2004b, 2007)
CPT-14	CONE PENETRATION TEST;DEL OBISPO DEVELOPMENT (GMU, 2014)
C' C"	GEOLOGIC CROSS SECTION

REFERENCE: GOOGLE EARTH AERIAL PHOTOGRAPH DATED APRIL 16, 2013.

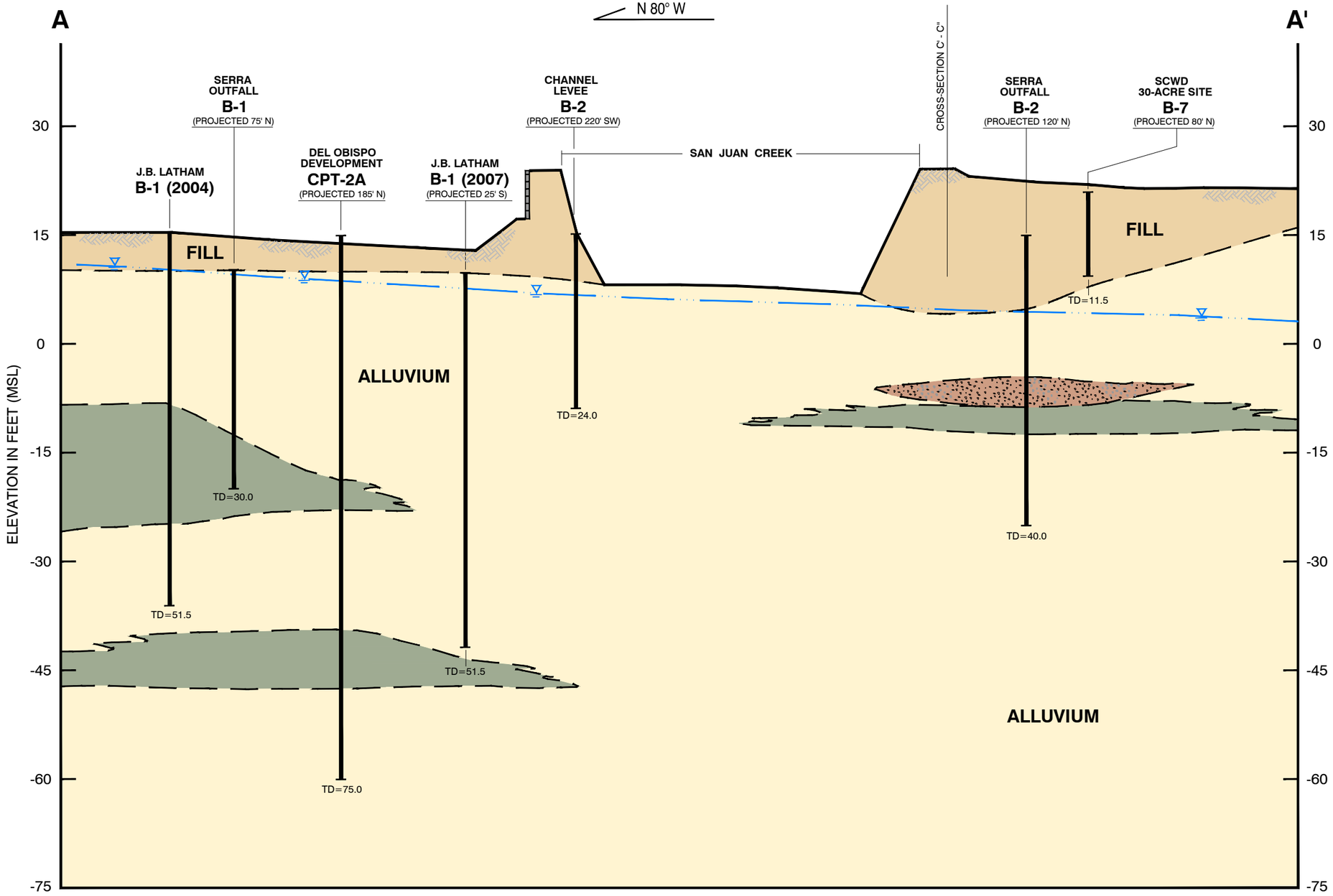
SCALE IN FEET
0 500 1,000

N

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

201029014_VBL.dwg 15:23:08 09/08/2014 GK

Ninyo & Moore	VICINITY BORING LOCATIONS	FIGURE
PROJECT NO. 201029014 / DATE 2/15	DOHENY DESALINATION PROJECT BEACH FACILITIES DANA POINT, CALIFORNIA	10



REFERENCES: COUNTY OF ORANGE, 2003; GMU, 2014; LOWRY AND ASSOCIATES, 1977; NINYO & MOORE, 1997; NINYO & MOORE, 2003; NINYO & MOORE, 2004B.

LEGEND

- FILL (SAND, SILTY SAND AND SILT WITH GRAVEL AND CONCRETE DEBRIS)
- ALLUVIAL SAND AND SILTY SAND WITH GRAVEL AND COBBLES
- ALLUVIAL GRAVEL AND COBBLE ZONES
- ALLUVIAL SILT AND CLAY
- B-7 / TD=11.5 — BORING; TD=TOTAL DEPTH IN FEET
- CPT-2A / TD=75.0 — CONE PENETRATION TEST; TD=TOTAL DEPTH IN FEET
- GROUNDWATER LEVEL
- EXISTING GROUND SURFACE
- GEOLOGIC CONTACT

HORIZONTAL SCALE IN FEET

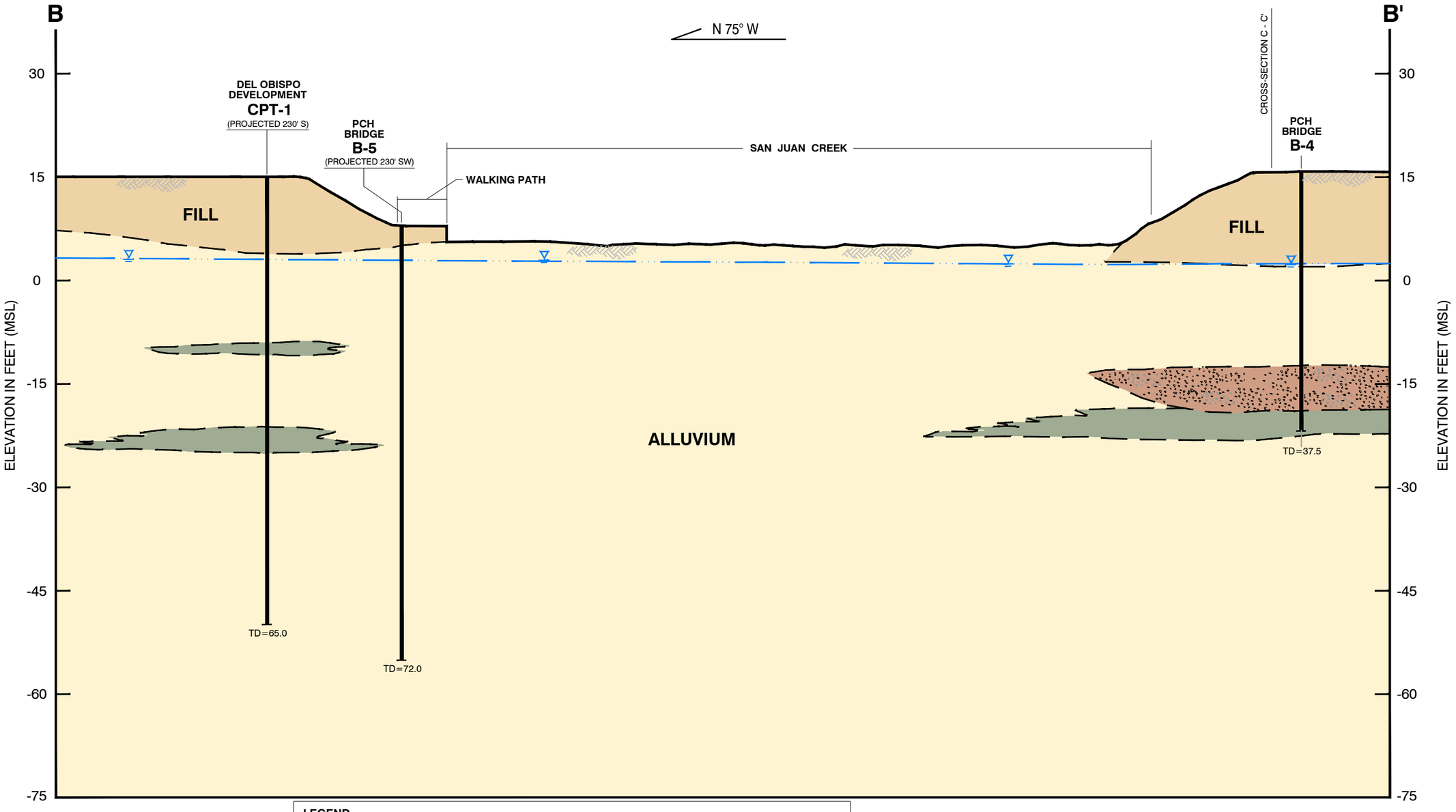
0 60 120

4 X VERTICAL EXAGGERATION

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore	CROSS SECTION A-A'	FIGURE
PROJECT NO. 201029014 / DATE 2/15	DOHENY DESALINATION PROJECT BEACH FACILITIES DANA POINT, CALIFORNIA	11A

201029014_CS1.dwg 15:55:19 09/19/2014 GK



LEGEND

- FILL (SILTY SAND, SILT AND CLAY)
- ALLUVIAL SAND AND SILTY SAND WITH GRAVEL AND COBBLES
- ALLUVIAL GRAVEL AND COBBLE ZONES
- ALLUVIAL SILT AND CLAY
- B-5 (TD=72.0): BORING; TD=TOTAL DEPTH IN FEET
- CPT-1 (TD=75.0): CONE PENETRATION TEST; TD=TOTAL DEPTH IN FEET
- GROUNDWATER LEVEL
- EXISTING GROUND SURFACE
- GEOLOGIC CONTACT

HORIZONTAL SCALE IN FEET

0 60 120

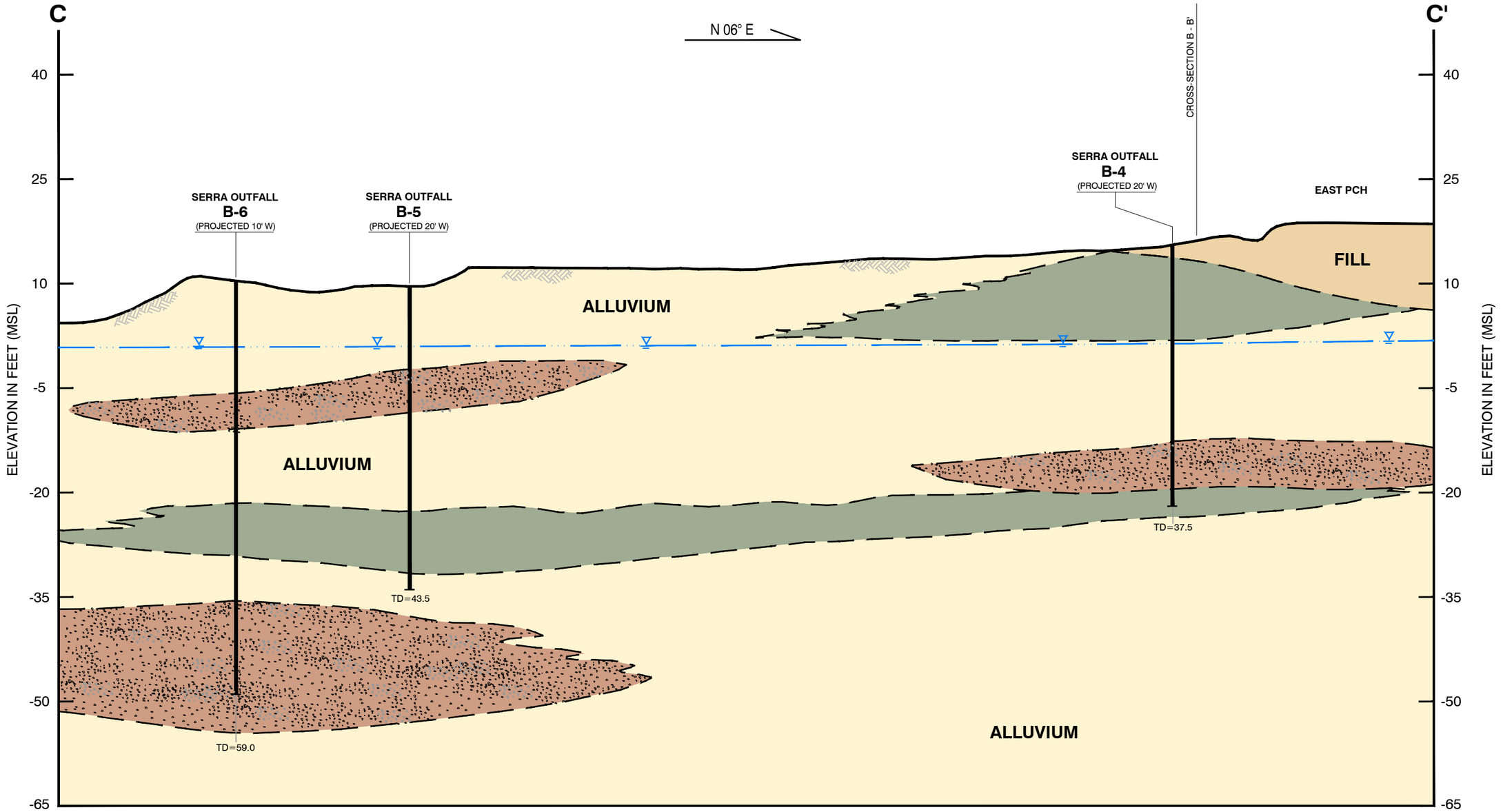
4 X VERTICAL EXAGGERATION

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

REFERENCES: BOYLE ENGINEERING CORP., 2007; COUNTY OF ORANGE, 2003; GOOGLE EARTH, 2014; GMU, 2014; LOWRY AND ASSOCIATES, 1977; CALTRANS, 1976.

Ninyo & Moore	CROSS SECTION B-B'	FIGURE
PROJECT NO. 201029014 / DATE 2/15	DOHENY DESALINATION PROJECT BEACH FACILITIES DANA POINT, CALIFORNIA	11B

201029014_CS2.dwg 14:28:19 09/19/2014 GK



LEGEND

- FILL (SAND, SILTY SAND AND SANDY SILT)
- ALLUVIAL SAND AND SILTY SAND WITH GRAVEL AND COBBLES
- ALLUVIAL GRAVEL AND COBBLE ZONES
- ALLUVIAL SILT AND CLAY
- B-6 / TD=59.0 — BORING; TD=TOTAL DEPTH IN FEET
- GROUNDWATER LEVEL
- EXISTING GROUND SURFACE
- GEOLOGIC CONTACT

HORIZONTAL SCALE IN FEET

0 60 120

4 X VERTICAL EXAGGERATION

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

REFERENCE: LOWRY AND ASSOCIATES, 1977.

Ninyo & Moore	CROSS SECTION C-C'	FIGURE
PROJECT NO. 201029014 / DATE 2/15	DOHENY DESALINATION PROJECT BEACH FACILITIES DANA POINT, CALIFORNIA	11C

201029014_CS3.dwg 14:28:19 09/19/2014 GK

C'

C"

N 06° W

N 10° E

BEND IN SECTION

CROSS-SECTION A - A'

SAN JUAN CREEK

SERRA OUTFALL
B-3
(PROJECTED 15' W)

PCH BRIDGE
B-4
(PROJECTED 95' W)

SERRA OUTFALL
B-2
(PROJECTED 70' W)

SCWD
30-ACRE SITE
B-7
(PROJECTED 95' W)

FILL

FILL

ALLUVIUM

ALLUVIUM

ALLUVIUM

TD=35.5

TD=66.7

TD=11.5

TD=40.0

ELEVATION IN FEET (MSL)

40
25
10
-5
-20
-35
-50
-65

HORIZONTAL SCALE IN FEET
0 60 120

4 X VERTICAL EXAGGERATION

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

LEGEND

- FILL (SAND, SILTY SAND AND SILT WITH GRAVEL AND CONCRETE DEBRIS)
- ALLUVIAL SAND AND SILTY SAND WITH GRAVEL AND COBBLES
- ALLUVIAL GRAVEL AND COBBLE ZONES
- ALLUVIAL SILT AND CLAY
- B-7 / TD=11.5 — BORING; TD=TOTAL DEPTH IN FEET
- GROUNDWATER LEVEL
- EXISTING GROUND SURFACE
- GEOLOGIC CONTACT

REFERENCES: COUNTY OF ORANGE, 2003; LOWRY AND ASSOCIATES, 1977; CALTRANS, 1976; NINYO & MOORE, 1997.

Ninyo & Moore

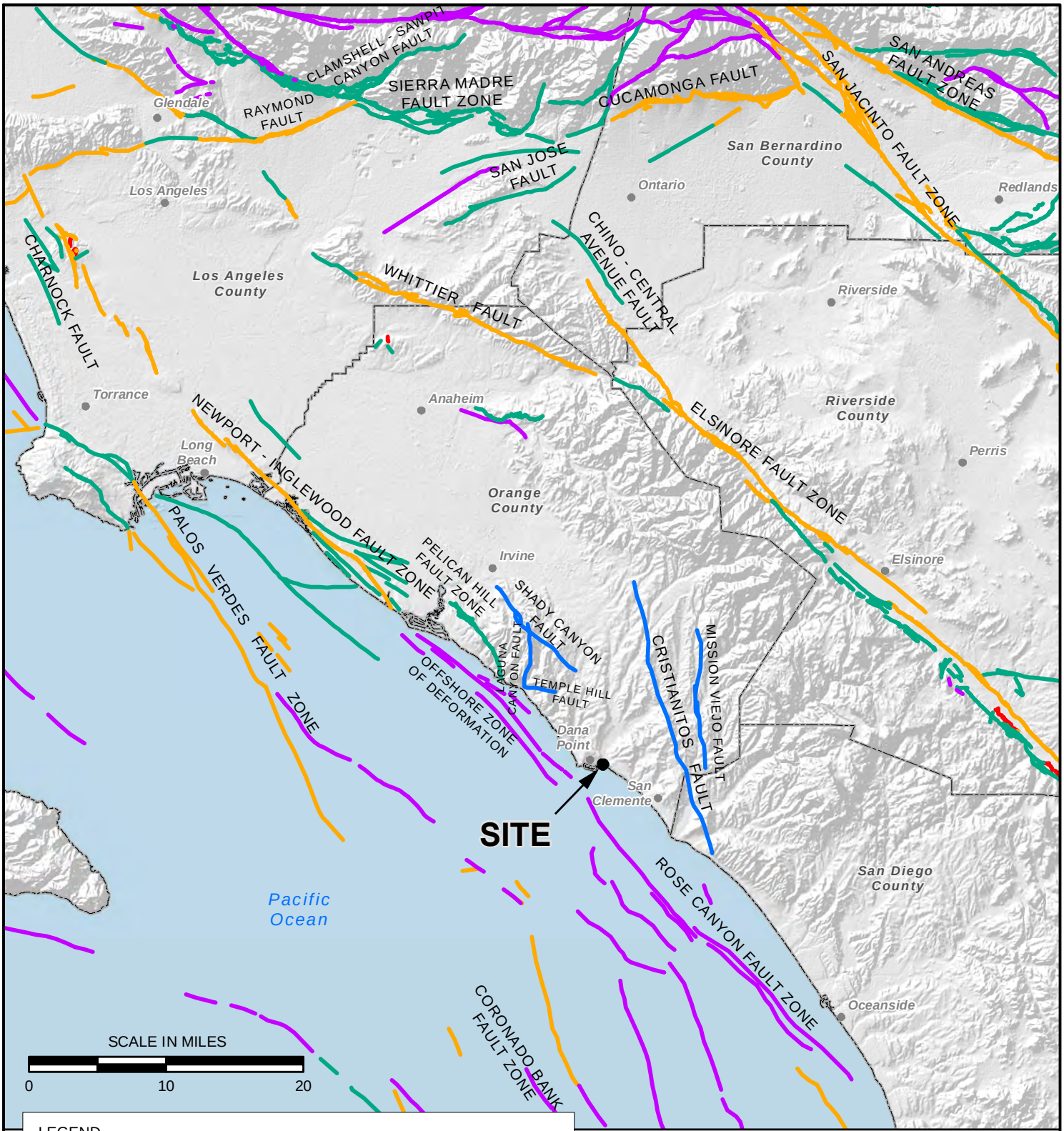
CROSS SECTION C'-C"

FIGURE **11D**

PROJECT NO.	DATE
201029014	2/15

DOHENY DESALINATION PROJECT BEACH FACILITIES
DANA POINT, CALIFORNIA

201029014_CS4.dwg 14:28:19 09/19/2014 GK



DATA SOURCE: U.S. GEOLOGICAL SURVEY AND CALIFORNIA GEOLOGICAL SURVEY, 2006, QUATERNARY FAULT AND FOLD DATABASE FOR THE UNITED STATES, ACCESSED 2011, FROM USGS WEB SITE: HTTP//EARTHQUAKES.USGS.GOV/REGIONAL/QFAULTS/.

REFERENCES: CALIFORNIA DIVISION OF MINES AND GEOLOGY, 1976, ENVIRONMENTAL GEOLOGY OF ORANGE COUNTY, CALIFORNIA, OPEN FILE REPORT 79-8.; JENNINGS, C.W., AND BRYANT, 2010, FAULT ACTIVITY MAP OF CALIFORNIA

NOTE: DIRECTIONS, DIMENSIONS AND LOCATIONS ARE APPROXIMATE.

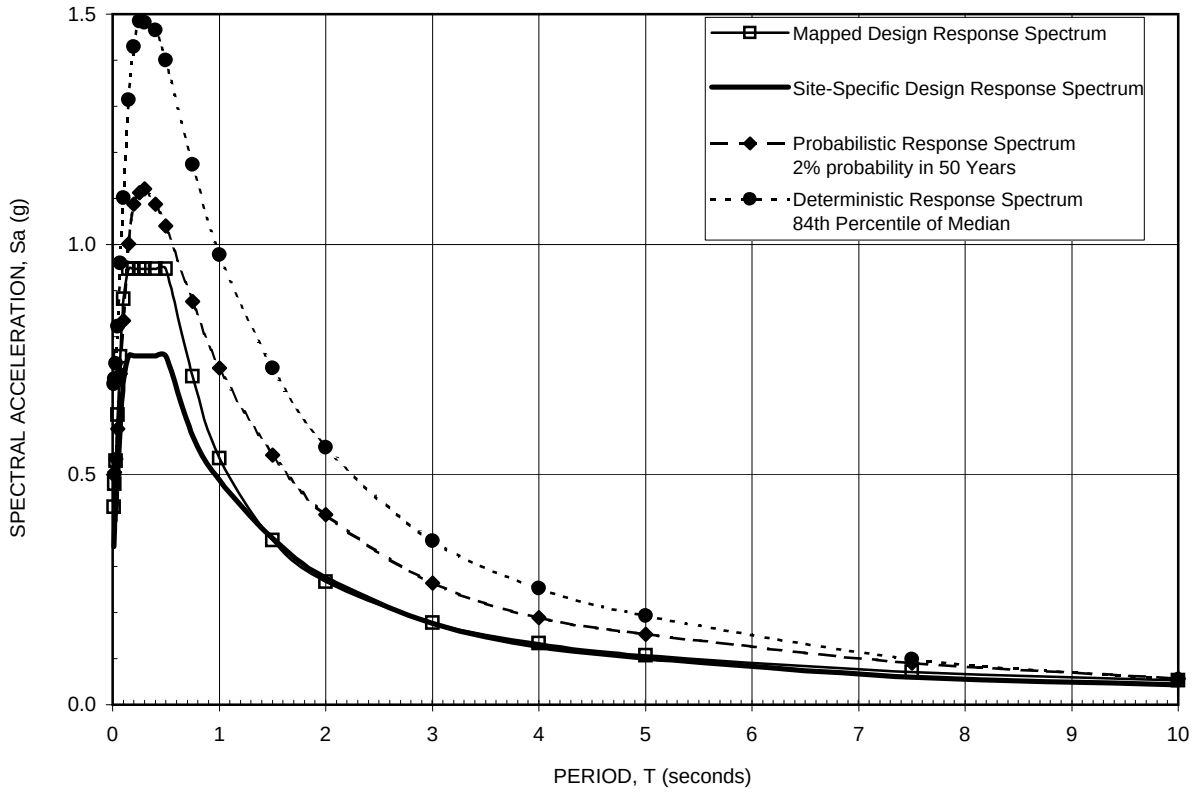
Ninyo & Moore	FAULT LOCATIONS	FIGURE
PROJECT NO. 201029014 / DATE 2/15	DOHENY DESALINATION PROJECT BEACH FACILITIES DANA POINT, CALIFORNIA	12

201029014_FL.mxd 2/5/2015 5:20:30 PM JDL

PERIOD (seconds)	SITE-SPECIFIC DESIGN RESPONSE SPECTRUM Sa, (g)
0.010	0.343
0.020	0.383
0.030	0.424
0.050	0.504
0.075	0.604
0.100	0.705
0.150	0.757
0.200	0.757
0.250	0.757
0.300	0.757
0.400	0.757

PERIOD (seconds)	SITE-SPECIFIC DESIGN RESPONSE SPECTRUM Sa, (g)
0.500	0.757
0.750	0.584
1.000	0.487
1.500	0.361
2.000	0.276
3.000	0.176
4.000	0.126
5.000	0.102
7.500	0.060
10.000	0.043

S_{DS} =	0.757	S_{D1} =	0.551	PGA_M =	0.541



NOTES:

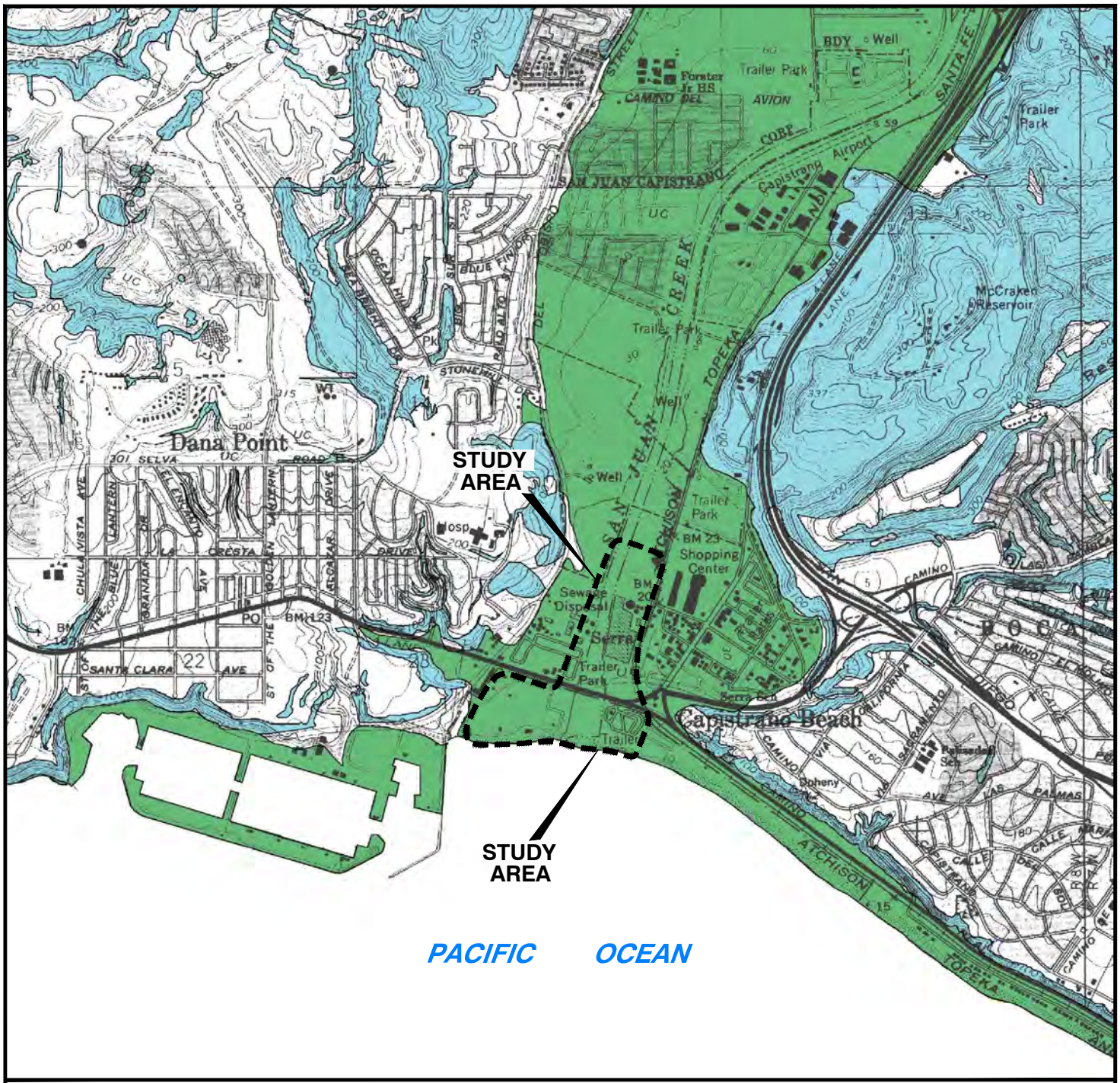
1 Probabilistic Ground Motion is for Risk-targeted Maximum Considered Earthquake (MCE_R) with ground motion having 2% probability of exceedance In 50 years using Chiou & Youngs (2008), Campbell & Bozorgnia (2008), and Boore & Atkinson (2008) attenuation relationships and the risk coeff.

2 Deterministic ARS is 84th percentile of the median values from attenuation relationships by Chiou & Youngs (2008), Campbell & Bozorgnia (2008), and Boore & Atkinson (2008) for deep soils considering a Mw 7.1 event on the Newport-Inglewood offshore fault located 4.8 kilometers from the site. It conforms with the lower bound limit per ASCE 7-10 Section 21.2.2 as modified by 2009 NEHRP Recommended Seismic Provisions.

3 Site-Specific MCE_R is the lesser of spectral ordinates of deterministic and probabilistic ARS at each period per ASCE 7-10 Section 21.2.3. Site-Specific Design Response Spectrum conforms with lower bound limit per ASCE 7-10 Section 21.3.

4 Mapped Design Response Spectrum is computed from mapped spectral ordinates modified for Site Class D (stiff soil profile) per ASCE 7-10 Section 11.4. It is presented for comparison.

Ninyo & Moore	ACCELERATION RESPONSE SPECTRA	FIGURE
PROJECT NO. / DATE	DOHENY DESALINATION PROJECT BEACH FACILITIES	13
201029014 / 2/15	DANA POINT, CALIFORNIA	



REFERENCE: CALIFORNIA DEPARTMENT OF CONSERVATION, DIVISION OF MAPS AND GEOLOGY, STATE OF CALIFORNIA, 2001, SEISMIC HAZARD ZONES MAP OFFICIAL REVISED MAP DANA POINT QUADRANGLE, 7.5-MINUTE SERIES: SCALE 1:24,000.

N

SCALE IN FEET

0 2,000 4,000

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

LEGEND

EARTHQUAKE-INDUCED LANDSLIDES

Areas where previous occurrence of landslide movement, or local topographic, geological, geotechnical and subsurface water conditions indicate a potential for permanent ground displacements such that mitigation as defined in Public Resources Code Section 2693(c) would be required.

LIQUEFACTION:

Areas where historic occurrence of liquefaction, or local geological, geotechnical and groundwater conditions indicate a potential for permanent ground displacements such that mitigation as defined in Public Resources Code Section 2693(c) would be required.

Ninyo & Moore

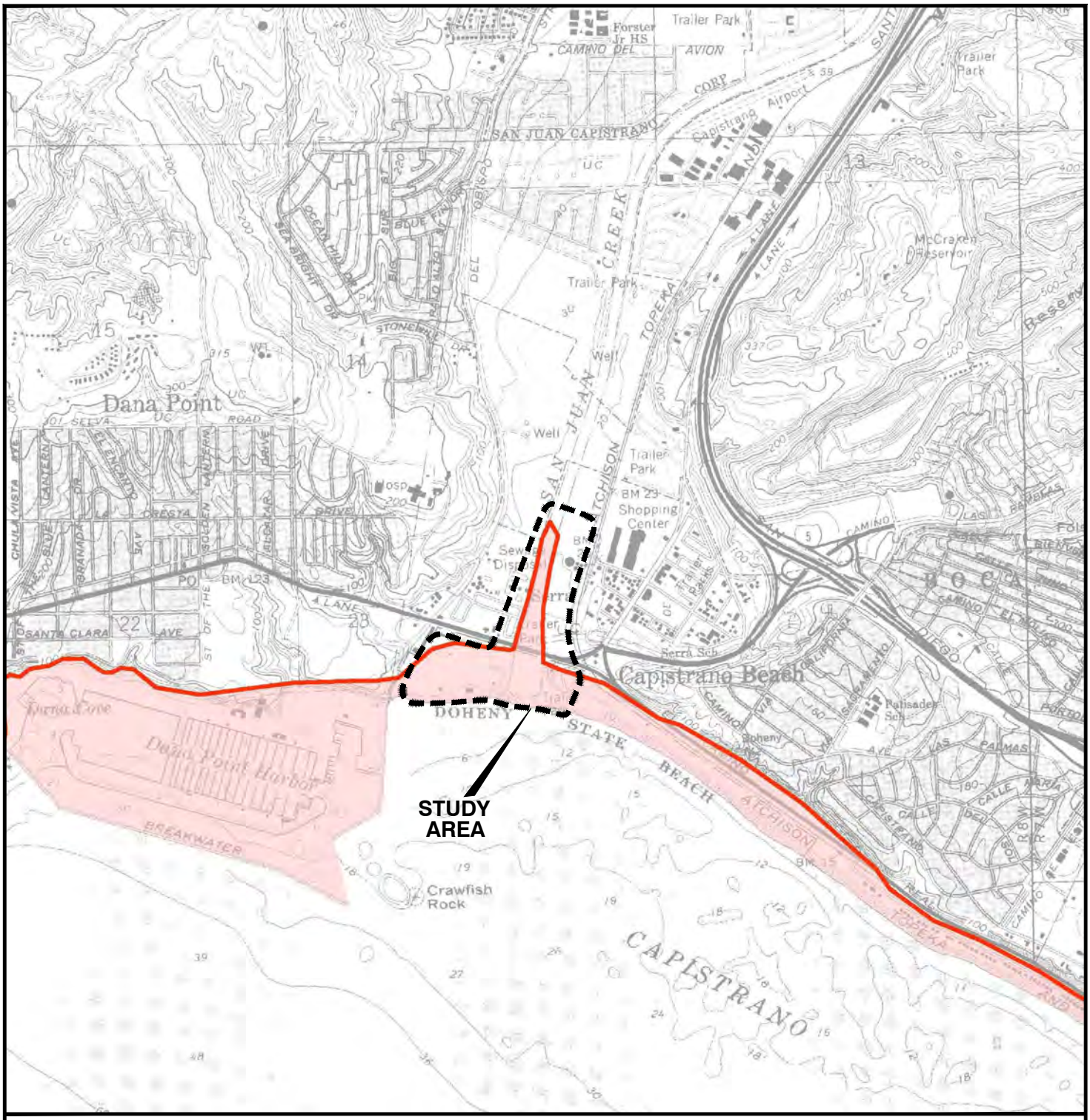
SEISMIC HAZARD ZONES

FIGURE 14

PROJECT NO.	DATE
201029014	2/15

DOHENY DESALINATION PROJECT BEACH FACILITIES
DANA POINT, CALIFORNIA

201029014_SHZ.dwg 14:48:05 02/05/2015 GK



REFERENCE: STATE OF CALIFORNIA, 2009, TSUNAMI INUNDATION MAP FOR EMERGENCY PLANNING, COUNTY OF ORANGE,DANA POINT QUADRANGLE QUADRANGLE, SAN JUAN CAPISTRANO QUADRANGLE, DATED MARCH 15.

SCALE IN FEET

0 2,000 4,000

N

LEGEND

TSUNAMI INUNDATION LINE

TSUNAMI INUNDATION AREA

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore

TSUNAMI INUNDATION

FIGURE 15

PROJECT NO.	DATE
201029014	2/15

DOHENY DESALINATION PROJECT BEACH FACILITIES
DANA POINT, CALIFORNIA

201029014_TI.dwg 14:54:05 02/05/2015 GK

APPENDIX A

REFERENCED EXPLORATORY BORING LOGS

AND CPT SOUNDINGS

CALTRANS 1976

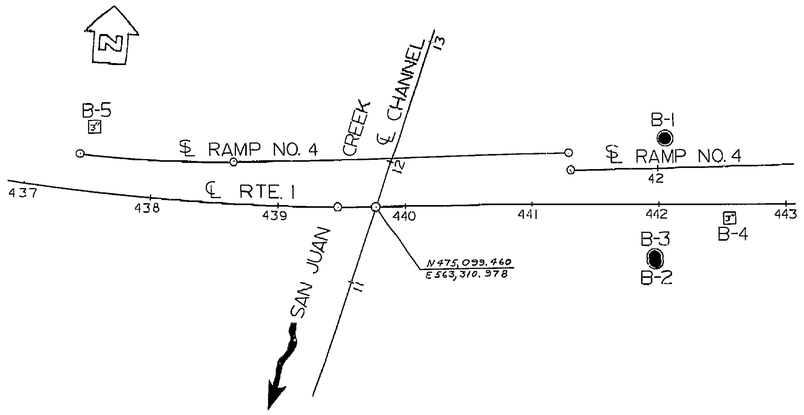
PCH BRIDGE BORING LOGS

DIST.	COUNTY	ROUTE	POST MILES—TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
07	ORA	1	R0.4/1.1	101	120

A. E. Bachus
DESIGN SECTION SUPERVISOR — REGISTERED CIVIL ENGINEER NO. 8358
DATE APPROVED March 11, 1974

BENCH MARKS

SM" 1A — Elev. 18.67
Lead and tack on NE corner of Bridge abutment on P.M.C. over S.J. Creek.

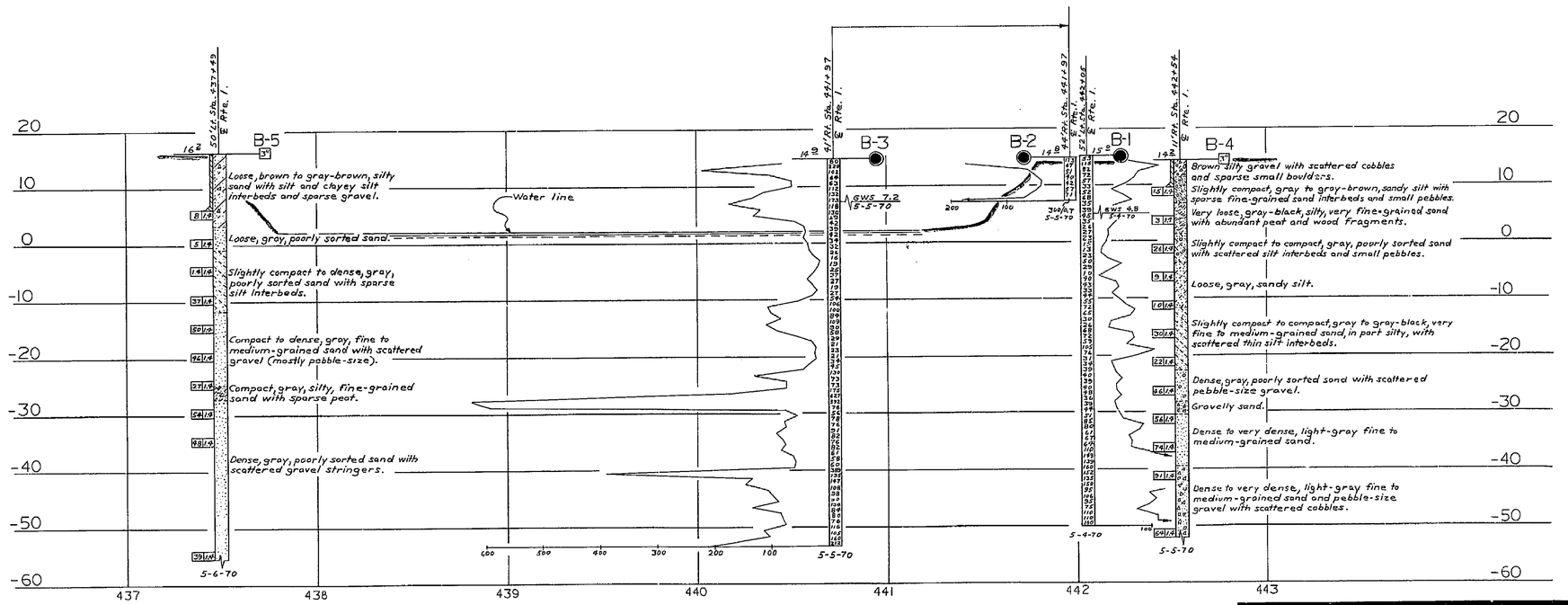


PLAN

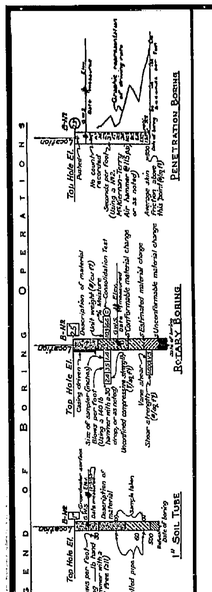
Scale: 1" = 50'

PROFILE

Scale: Vert. 1"=10'
Horiz. 1"=30'



LEGEND OF BORING OPERATIONS



LEGEND OF EARTH MATERIALS

GRAVEL	SILTY CLAY OR CLAYEY SILT	SEDIMENTARY ROCK	TEST PIT
SAND	PEAT AND ORGANIC MATTER	IGNEOUS ROCK	METAMORPHIC ROCK
SILT	FILL MATERIAL		
CLAY	SANDY CLAY OR CLAYEY SAND	SANDY SILT OR SILTY SAND	

CLASSIFICATION OF MATERIAL BASED ON STANDARD GRADE SIZE LIMITS

Diagram showing the data for estimated classification of soils according to determination of class names.

If gravel is present in appreciable quantities the word "gravelly" may be added to the class name, viz. "gravelly sand". The terms "cobbles" or "boulders" may be added when used to describe sand, silt and gravel. Refer to Standard Grade Size Limits.

NOTE: Classification of earth material as shown on this sheet is based upon field inspection and is not to be construed to imply mechanical analysis.

FIELD STUDY	H.D.B. CRAWFORD 5-4-70
DRAWN	W.E.S. JIMENEZ 5-11-70
CHECKED	W.O. MIKELS 5-15-70

Approx. Recommended by [signature] Engineering Geologist

BRIDGE DEPARTMENT
ENGINEERING GEOLOGY SECTION

101

MICROFILMED
MAY 21 1976

AS BUILT PLANS
Contract No. 07-158914
Date Completed
Document No. 7000 7429

AS BUILT AS of 5-10-76
NO CORRECTIONS BY E. Amon
CONTRACT NO. 07-158914
DATE 4-1-76

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

SAN JUAN CREEK BRIDGE

LOG OF TEST BORINGS

BRIDGE NO.	POST MILE	DRAWING NO.	SHEET	OF
55-547	0.9		13	13

WO 158911
CU 07207

Disregard prints bearing earlier revision dates →

REVISION DATES (PRELIMINARY STAGE ONLY)
4/1/76

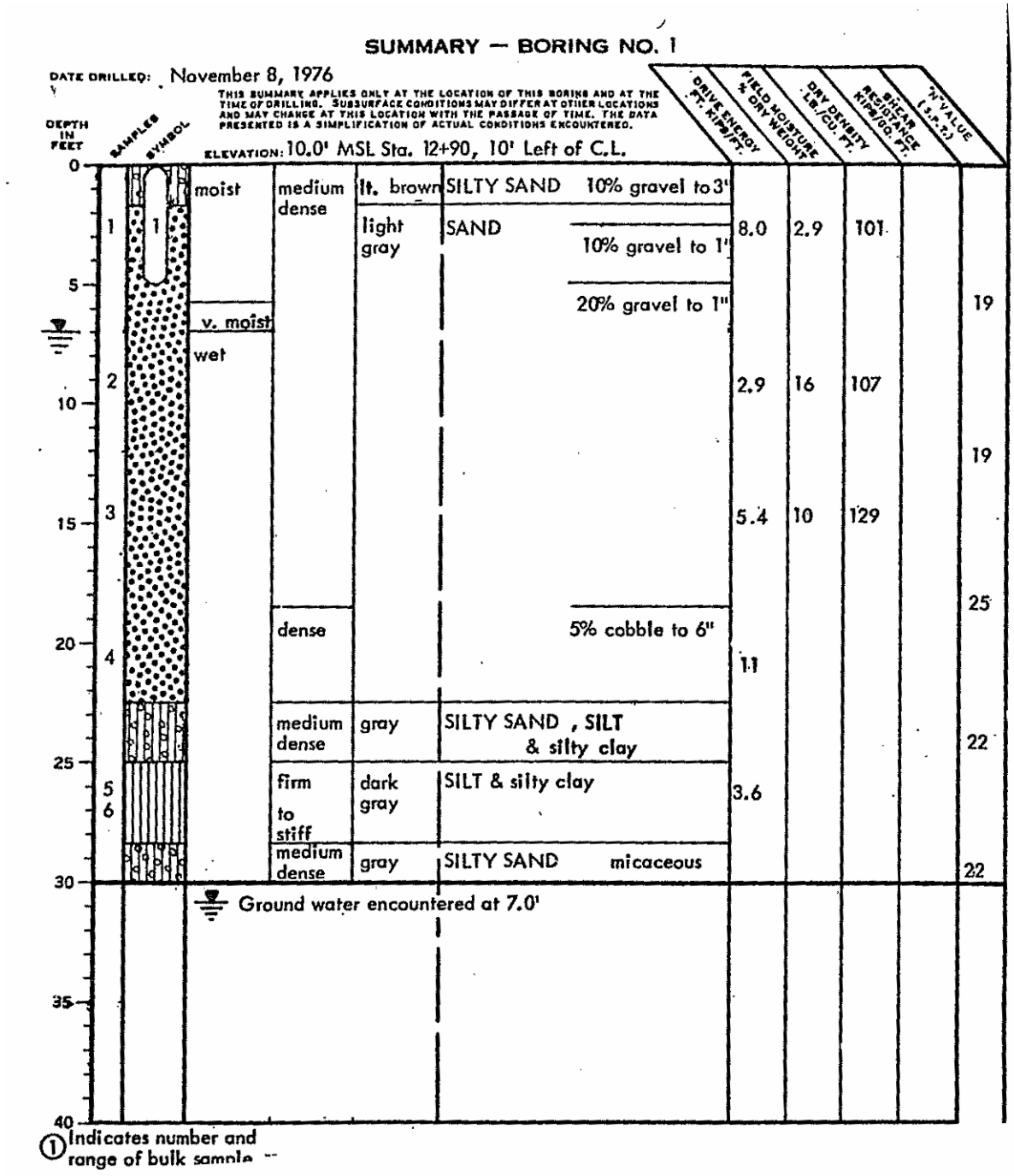
I HEREBY CERTIFY THAT THIS IS A TRUE AND ACCURATE COPY OF THE ABOVE DOCUMENT TAKEN UNDER MY DIRECTION AND CONTROL ON THIS DATE IN SACRAMENTO, CALIFORNIA PURSUANT TO AUTHORIZATION BY THE DIRECTOR OF TRANSPORTATION.

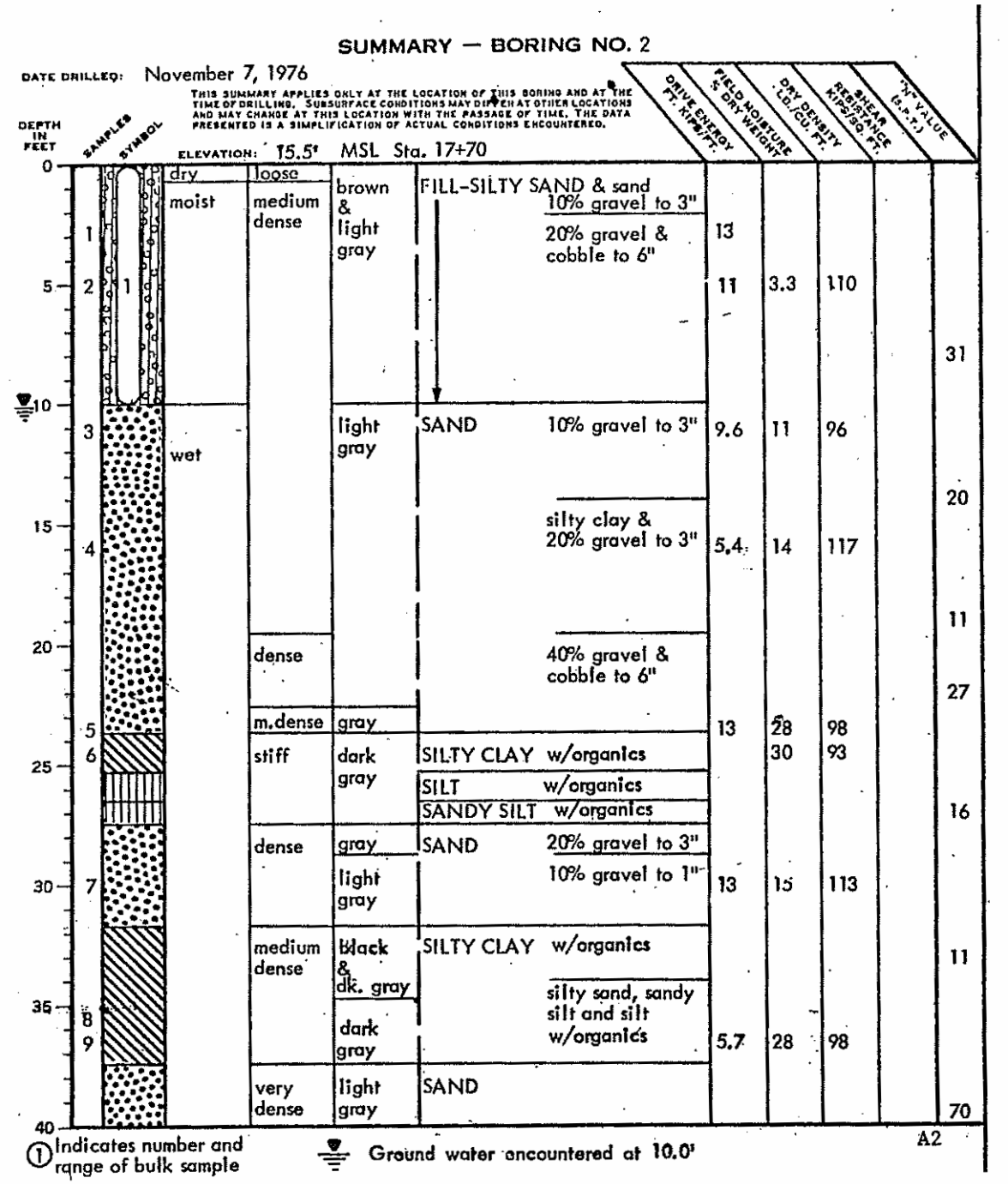
DATE 5-7-76 SIGNATURE [signature] TITLE Transcriber

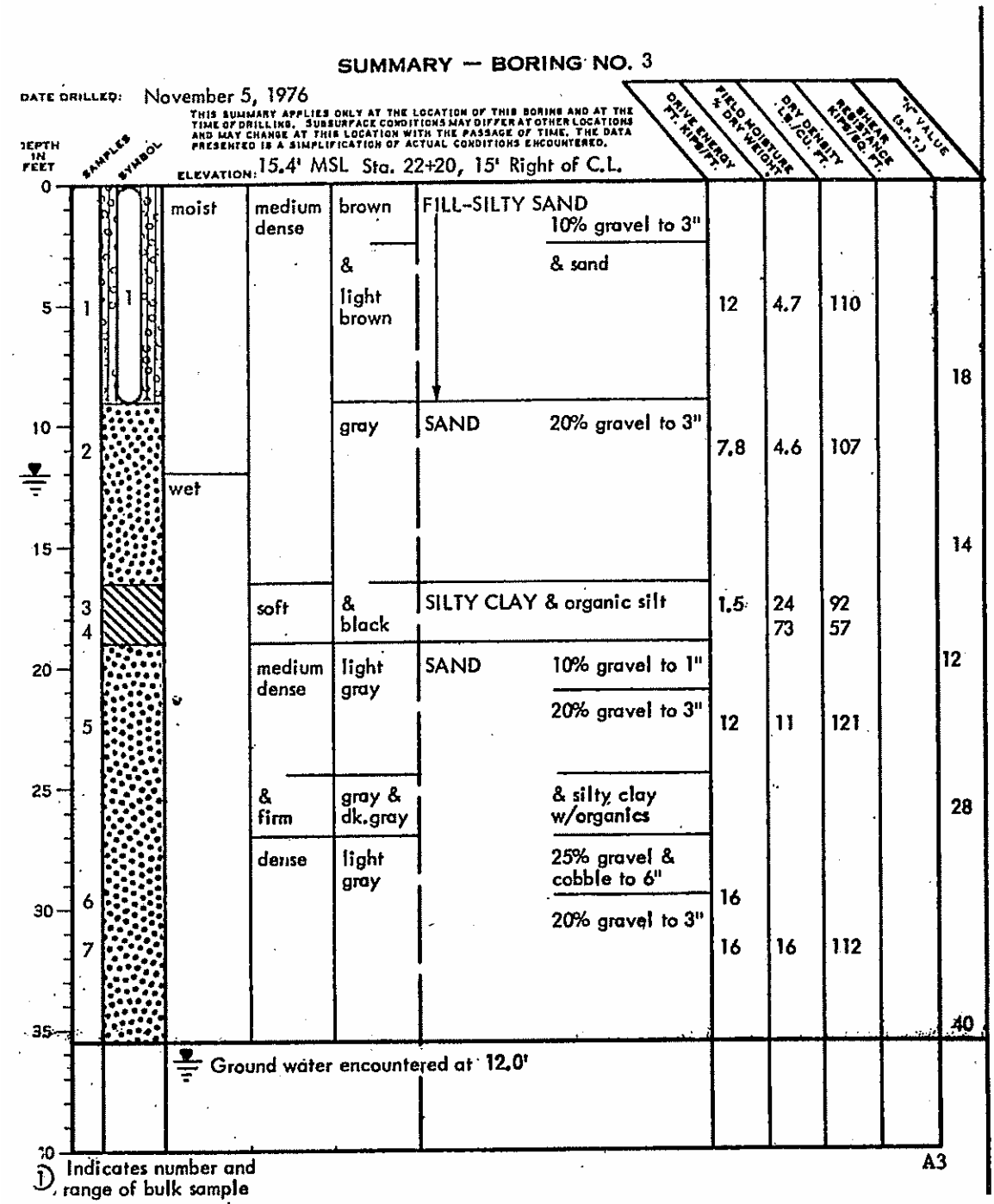
ClibPDF - www.fastio.com

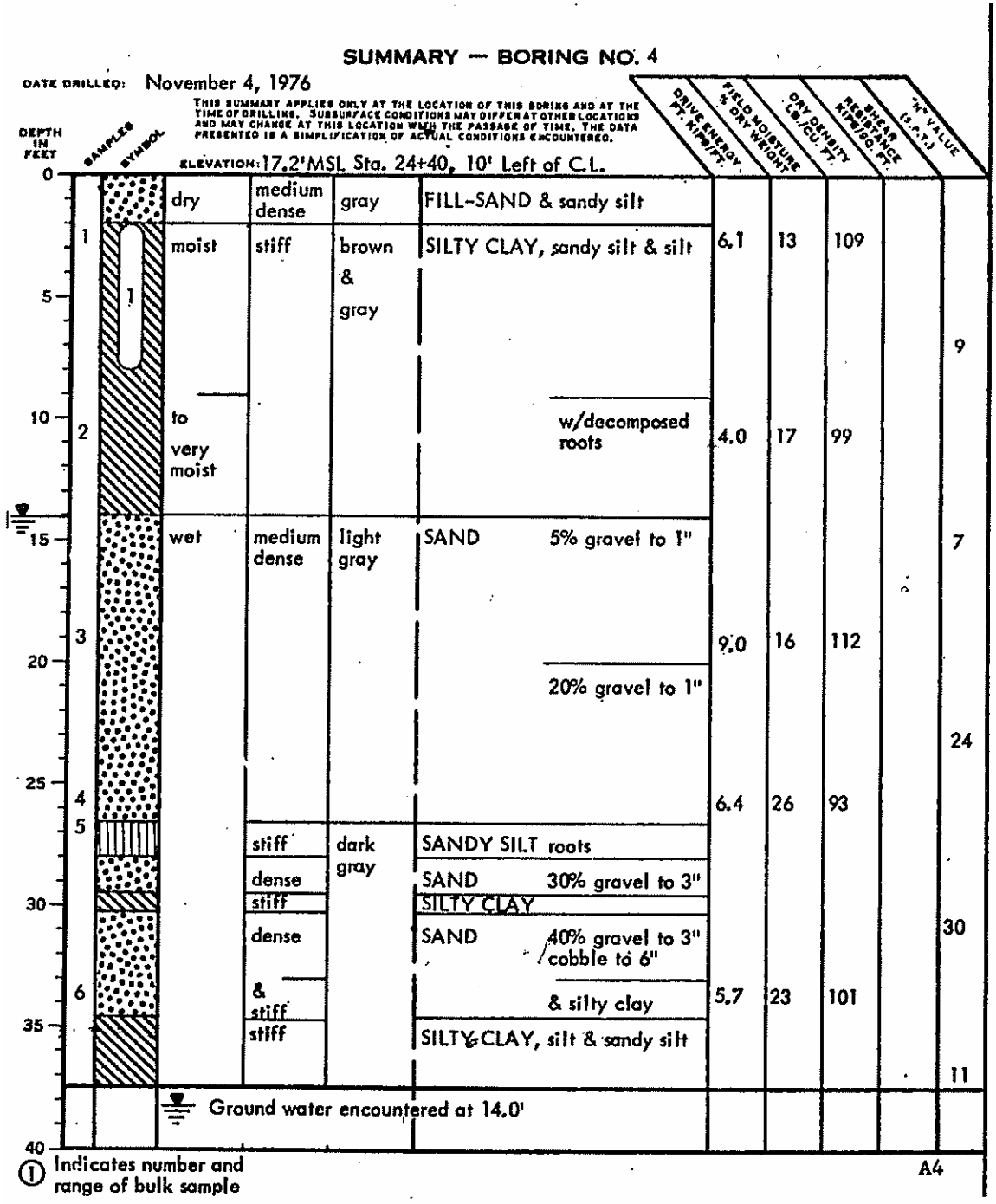
CONVERSE, DAVIS, DIXON AND ASSOCIATES 1976

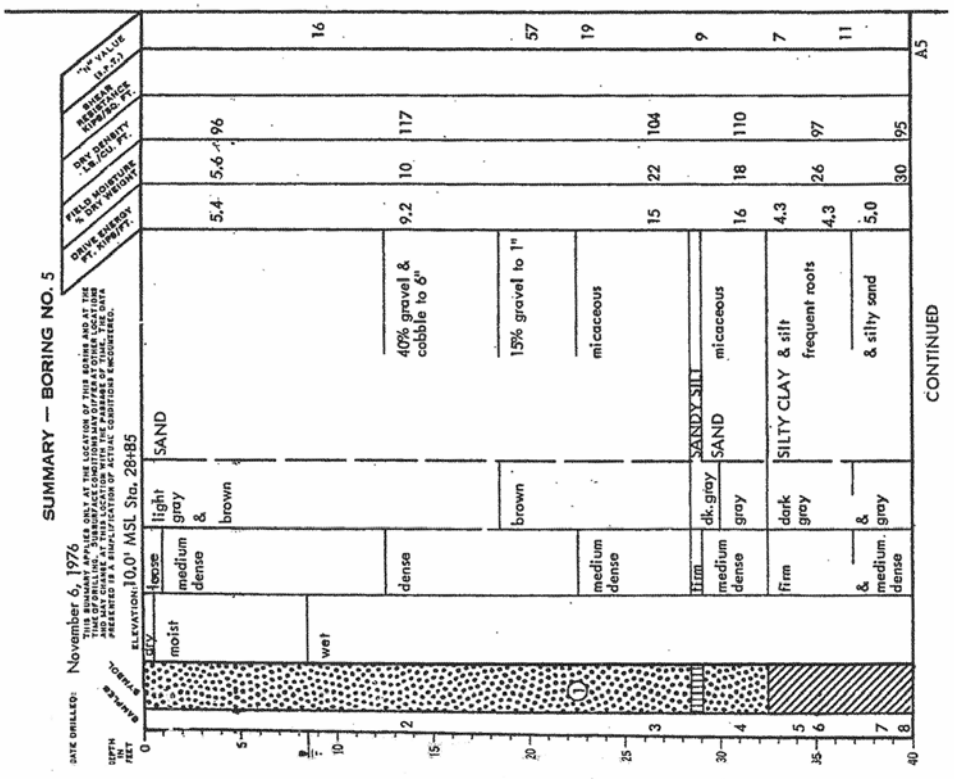
SERRA OCEAN OUTFALL BORING LOGS

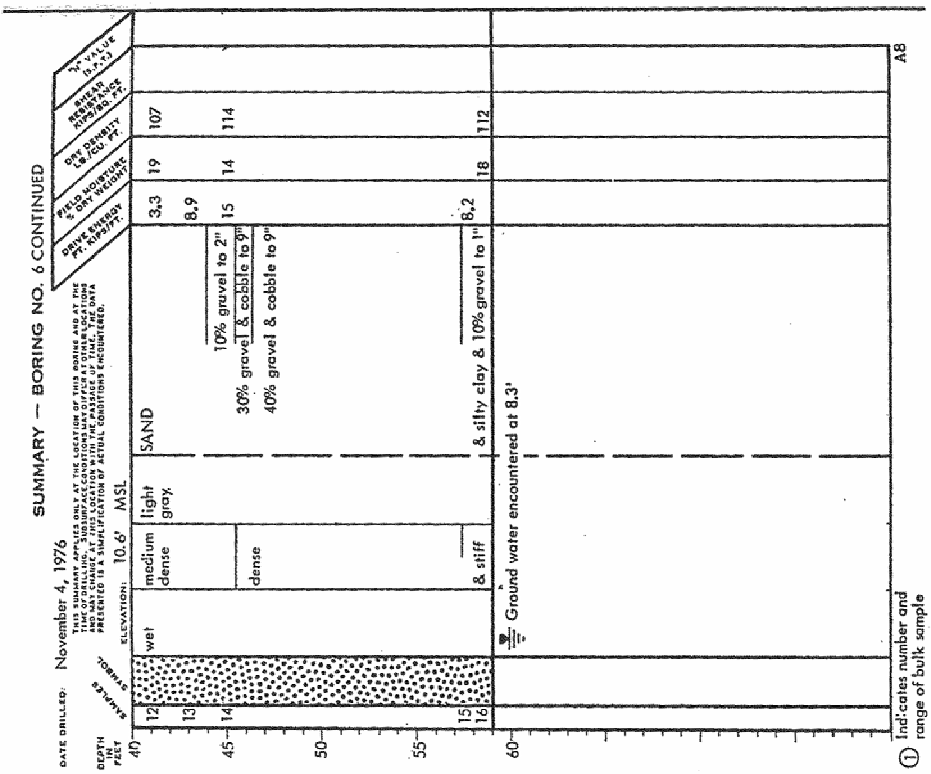

SUMMARY — BORING NO. 1
DATE DRILLED: November 8, 1976
THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF ACTUAL CONDITIONS ENCOUNTERED.
ELEVATION: 10.0' MSL Sta. 12+90, 10' Left of C.L.
DEPTH IN FEET
SAMPLES SYMBOL
DRIVE ENERGY FT.-KIPS/FT.
FIELD MOISTURE % DRY WEIGHT
DRY DENSITY LB./CU. FT.
SHEAR RESISTANCE KIPS/SQ. FT.
"N" VALUE (S.P.T.)
0
5
10
15
20
25
30
35
40
1
2
3
4
5
6
moist
medium dense
lt. brown
SILTY SAND
10% gravel to 3"
light gray
SAND
8.0
2.9
101
10% gravel to 1"
20% gravel to 1"
19
v. moist
wet
2.9
16
107
19
5.4
10
129
dense
5% cobble to 6"
25
11
medium dense
gray
SILTY SAND , SILT & silty clay
22
firm to stiff
dark gray
SILT & silty clay
3.6
medium dense
gray
SILTY SAND
micaceous
22
Ground water encountered at 7.0'
① Indicates number and range of bulk sample

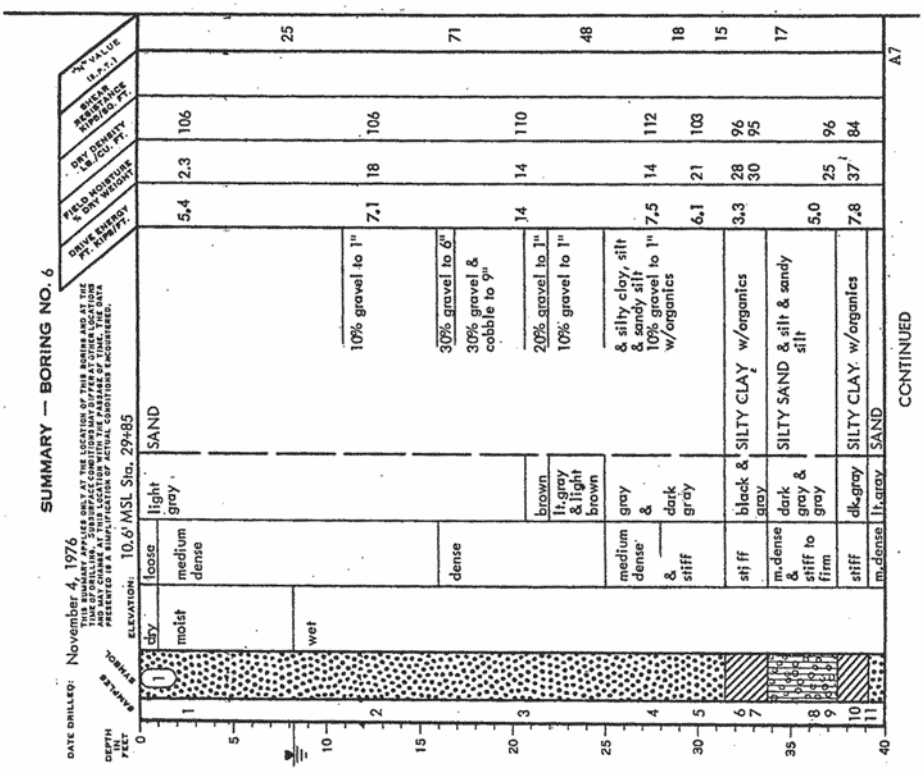

SUMMARY — BORING NO. 2
DATE DRILLED: November 7, 1976
THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF ACTUAL CONDITIONS ENCOUNTERED.
ELEVATION: 15.5' MSL Sta. 17+70
DEPTH IN FEET
SAMPLES SYMBOL
DRIVE ENERGY FT. KIPS/FT.
FIELD MOISTURE % DRY WEIGHT
DRY DENSITY LBS/CU. FT.
SHEAR RESISTANCE KIPS/SQ FT.
"N" VALUE (BLOWS/FT.)
0
5
10
15
20
25
30
35
40
1
2
3
4
5
6
7
8
9
1
dry
moist
wet
loose
medium dense
dense
m.dense
stiff
dense
medium dense
very dense
brown & light gray
light gray
gray
dark gray
light gray
black & dk. gray
dark gray
light gray
FILL-SILTY SAND & sand
10% gravel to 3"
20% gravel & cobble to 6"
SAND
10% gravel to 3"
silty clay & 20% gravel to 3"
40% gravel & cobble to 6"
SILTY CLAY w/organics
SILT w/organics
SANDY SILT w/organics
SAND
20% gravel to 3"
10% gravel to 1"
SILTY CLAY w/organics
silty sand, sandy silt and silt w/organics
SAND
13
11
9.6
5.4
13
13
5.7
3.3
11
14
28
30
15
28
110
96
117
98
93
113
98
31
20
11
27
16
11
70
A2
① Indicates number and range of bulk sample
Ground water encountered at 10.0'

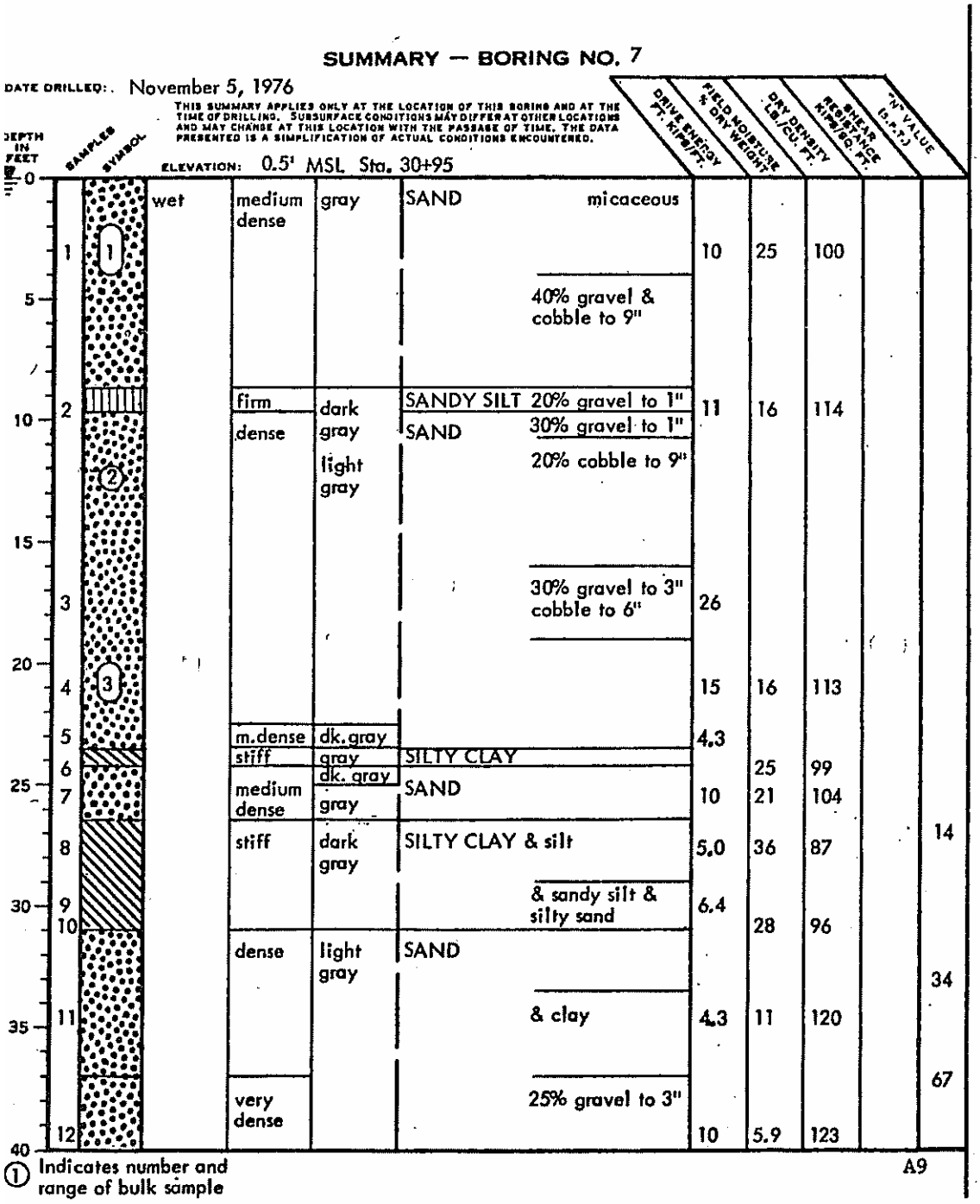

SUMMARY — BORING NO. 3
DATE DRILLED: November 5, 1976
THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF ACTUAL CONDITIONS ENCOUNTERED.
ELEVATION: 15.4' MSL Sta. 22+20, 15' Right of C.L.
DEPTH IN FEET
SAMPLES
SYMBOL
DRIVE ENERGY FT. RIPS/FT.
FIELD MOISTURE & DRY WEIGHT
DRY DENSITY LB./CU. FT.
SHEAR RESISTANCE KIPS/SQ. FT.
"N" VALUE (S.P.T.)
0
5
10
15
20
25
30
35
40
1
2
3
4
5
6
7
moist
wet
medium dense
soft
medium dense
& firm
dense
brown
& light brown
gray
& black
light gray
gray & dk.gray
light gray
FILL-SILTY SAND
10% gravel to 3"
& sand
SAND
20% gravel to 3"
SILTY CLAY & organic silt
SAND
10% gravel to 1"
20% gravel to 3"
& silty clay w/organics
25% gravel & cobble to 6"
20% gravel to 3"
12
4.7
110
18
7.8
4.6
107
14
1.5
24
73
92
57
12
12
11
121
28
16
16
16
112
40
Ground water encountered at 12.0'
A3
Indicates number and range of bulk sample


SUMMARY — BORING NO. 4
DATE DRILLED: November 4, 1976
THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF ACTUAL CONDITIONS ENCOUNTERED.
ELEVATION: 17.2' MSL Sta. 24+40, 10' Left of C.L.
DEPTH IN FEET
SAMPLES SYMBOL
DRIVE ENERGY FT.-KIPS/FT.
FIELD MOISTURE % DRY WEIGHT
DRY DENSITY LB./CU. FT.
SHEAR RESISTANCE KIPS/SQ. FT.
"N" VALUE (S.P.T.)
0
5
10
15
20
25
30
35
40
dry
medium dense
gray
FILL-SAND & sandy silt
1
moist
stiff
brown & gray
SILTY CLAY, sandy silt & silt
6.1
13
109
9
to very moist
w/decomposed roots
4.0
17
99
wet
medium dense
light gray
SAND
5% gravel to 1"
7
3
9.0
16
112
20% gravel to 1"
24
4
6.4
26
93
5
stiff
dark gray
SANDY SILT roots
dense
SAND
30% gravel to 3"
stiff
SILTY CLAY
dense
SAND
40% gravel to 3" cobble to 6"
30
6
& stiff
& silty clay
5.7
23
101
stiff
SILTY CLAY, silt & sandy silt
11
Ground water encountered at 14.0'
① Indicates number and range of bulk sample
A4


SUMMARY — BORING NO. 5
DATE DRILLED: November 6, 1976
ELEVATION: 10.0' MSL Sta. 28+85
SAMPLES
DEPTH IN FEET
DRIVE ENERGY FT. KIPS/FT.
FIELD MOISTURE % DRY WEIGHT
DRY DENSITY LB./CU. FT.
SHEAR RESISTANCE KIPS/SQ. FT.
"N" VALUE (S.P.T.)
gray
moist
wet
loose
medium dense
dense
light gray & brown
SAND
40% gravel & cobble to 6"
9.2
10
117
brown
15% gravel to 1"
micaceous
medium dense
5.4
5.6
96
15
22
104
16
57
19
firm
dk. gray
SANDY SILT
medium dense
gray
SAND
micaceous
16
18
110
9
dark gray
SILTY CLAY & silt
frequent roots
4.3
26
97
7
& gray
& medium dense
& silty sand
5.0
30
95
11
A5
CONTINUED
SUMMARY — BORING NO. 5 CONTINUED
DATE DRILLED: November 6, 1976
ELEVATION: 10.0' MSL
wet
medium dense
gray
light gray
SILTY CLAY & sandy silt
SAND
28
Ground water encountered at 8.5'
A6
① Indicates number and range of bulk sample


SUMMARY — BORING NO. 6 CONTINUED
DATE DRILLED: November 4, 1976
ELEVATION: 10.6' MSL
SAND
10% gravel to 2" cobble to 9"
30% gravel & cobble to 9"
40% gravel & cobble to 9"
& silty clay & 10% gravel to 1"
Ground water encountered at 8.3'
① Indicates number and range of bulk sample
A8


SUMMARY — BORING NO. 6
DATE DRILLED: November 4, 1976
ELEVATION: 10.6' MSL Sta. 29+85
SAND
10% gravel to 1"
30% gravel to 6"
30% gravel & cobble to 9"
20% gravel to 1"
10% gravel to 1"
& silty clay, silt & sandy silt 10% gravel to 1" w/organics
SILTY CLAY w/organics
SILTY SAND & silt & sandy silt
SILTY CLAY w/organics
SAND
CONTINUED
A7


SUMMARY — BORING NO. 7
DATE DRILLED: November 5, 1976
THIS SUMMARY APPLIES ONLY AT THE LOCATION OF THIS BORING AND AT THE TIME OF DRILLING. SUBSURFACE CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH THE PASSAGE OF TIME. THE DATA PRESENTED IS A SIMPLIFICATION OF ACTUAL CONDITIONS ENCOUNTERED.
ELEVATION: 0.5' MSL Sta. 30+95
DEPTH IN FEET
SAMPLES SYMBOL
DRIVE ENERGY FT. KIPS/FT.
FIELD MOISTURE % DRY WEIGHT
DRY DENSITY LB./CU. FT.
SHEAR RESISTANCE KIPS/SQ. FT.
'N' VALUE (B.P.F.)
wet
medium dense
gray
SAND
micaceous
40% gravel & cobble to 9"
firm
dense
dark gray
light gray
SANDY SILT
20% gravel to 1"
SAND
30% gravel to 1"
20% cobble to 9"
30% gravel to 3" cobble to 6"
m.dense
stiff
dk. gray
gray
SILTY CLAY
medium dense
dk. gray
gray
SAND
stiff
dark gray
SILTY CLAY & silt
& sandy silt & silty sand
dense
light gray
SAND
& clay
very dense
25% gravel to 3"
10
25
100
11
16
114
26
15
16
113
4.3
25
99
10
21
104
14
5.0
36
87
6.4
28
96
34
4.3
11
120
67
10
5.9
123
A9
① Indicates number and range of bulk sample

COUNTY OF ORANGE 1981

CHANNEL LEVEE BORING LOGS

COUNTY OF ORANGE

Sheet 1 of 8

ENVIRONMENTAL MANAGEMENT AGENCY
BORING LOG

PROJECT San Juan Creek Channel LOCATION Sta. 14 ~ 178' Lt. of CL

BORING Nº 1 SURF. ELEV. 19.5' LOGGED BY DGS DATE 8-3-81

Sample Nº Field	Sample Nº Lab.	Depth	Log	Remarks
	81	0		
				Gravelly Sand
		5		Hard layer
		7		
	1035			Drive sample (20,26,50) blows/ 1 ft., %P200:4.1
		8.5		Cohesionless Sand, +No.4: 15%, Passing No.20(
	1036			Sieve : 7%
		10		
		12		Cave-in
		13	▽	Ground Water
	1037			
		15		Tan, Gravelly Sand + No.4: 17%
				Passing No. 200: 7%
				Sieve
		20		
	1038			Tan, Gravelly Sand + No.4: 14%
				Passing No. 200: 8%
				Sieve
		25		T.D.

F 0250-141 .(DRS)

COUNTY OF ORANGE

Sheet 2 of 8

ENVIRONMENTAL MANAGEMENT AGENCY
BORING LOG

PROJECT San Juan Creek Channel LOCATION Sta. 20+35 143' Lt. of CL

BORING Nº 2 SURF. ELEV. 15.5' LOGGED BY DGS DATE 8-3-81

Sample Nº Field	Sample Nº Lab.	Depth	Log	Remarks
	81	0		
				Dark Brown, Clayey Sand, Moist
		5'		
		7'		
	1039			Drive sample (2,2,1) blows/ ft., %H_2O: 22.5
		8.5'		Ø : 24°, C : 350 psf, RC : 76%
	1040			In-place Dens. : 98.5 pcf (Dry)
		10'		Ground water
		11'		
	1041			Tan, Sand + No.4 : 5%
				Passing No.200 Sieve : 8%
		15'		
	1042			Tan, Sand + No.4 : 12%
				Passing No.200 Sieve : 9%
		18'		
		20'		
	1043			Gravelly Sand, + No.4 : 23%
				Passing No.200 Sieve : 8%
		24'		T.D.
				Ground water at 8.8'

F 0250-141.(RS)

COUNTY OF ORANGE

Sheet 3 of 8

ENVIRONMENTAL MANAGEMENT AGENCY
BORING LOG

PROJECT San Juan Creek Channel LOCATION Sta. 25+40 East Levee

BORING Nº 3 SURF. ELEV. levee road LOGGED BY DGS DATE 8-3-8

Sample Nº Field	Sample Nº Lab.	Depth	Log	Remarks
	81	0		
		5'		Gravelly Sand
		10'		
	1044	11.5'		Drive sample (4,12,12) blows/ ½ ft., %H_2O:5.3
				Ø : 38°, C : 85 psf, RC : 86%
				In-place Dens. : 108.5pcf (Dry)
		13'		Ground water
	1045	15'		Gravelly Sand, + No.4 : 23%
				Passing No.200 Sieve : 8%
		18'		
	1046	20'		Gravelly Sand, + No.4 : 7%
				Passing No.200 Sieve : 15%
	1047			Sand + No.4 : 5%
				Passing No.200 Sieve : 14%
		25'		T.D.
				Cave-in at 12.9'
				Ground water at approx. 13'

F 0250-141.

COUNTY OF ORANGE

Sheet 4 of 8

ENVIRONMENTAL MANAGEMENT AGENCY
BORING LOG

PROJECT San Juan Creek Channel LOCATION Sta. 30+50 East Levee

BORING Nº 4 SURF. ELEV. Levee road LOGGED BY DGS DATE 8-5-81

Sample Nº Field	Sample Nº Lab.	Depth	Log	Remarks
	81	0		
				Loose Gravelly Sand
		3.5'		
		5'		
		9'		Cohesionless Sand Sample lost
	1055	10'		Drive sample (20,23,27) blows/ ½ ft., %H_2O: 4.5
		10.5'		
				Gravelly Sand + No.4: 14%
	1056			Passing No. 200 Sieve: 10%
		15'		
		18'		
		20'		Gravelly Sand + No.4 : 12%
	1057			Passing No. 200 Sieve : 6%
		24'		T.D.
				Cave-in at 13.5'

F 0250-141.

NINYO & MOORE 1997

SCWD 30-ACRE SITE BORING LOGS

DATE DRILLED 3/5/97 BORING NO. B-1

GROUND ELEVATION 22' ±(MSL) SHEET 1 OF 3

METHOD OF DRILLING 8" Hollow stem auger (Scott's Drilling)

DRIVE WEIGHT 140 lbs. DROP 30 inches

SAMPLED BY GMM LOGGED BY GMM REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						CL	FILL: Brown, dry to damp, stiff, silty CLAY; black mottles.
	Driven	11					
5	Driven	11	19.7				
10	Driven	9	14.9	103.5			Firm; some silty sand layers in sample.
						SW-SM	ALLUVIUM: Grayish brown to dark gray, wet, medium dense, well-graded to silty SAND; scattered gravel up to approximately 1 inch in diameter.
15	Driven	20	▽				@ 15': Groundwater encountered during drilling; saturated.
20							

Ninyo & Moore

BORING LOG

Victoria Wastewater Treatment Plant Upgrade
Dana Point, California

PROJECT NO.	DATE	FIGURE
201029-01	6/97	

DATE DRILLED 3/5/97 BORING NO. B-1

GROUND ELEVATION 22' ±(MSL) SHEET 2 OF 3

METHOD OF DRILLING 8" Hollow stem auger (Scott's Drilling)

DRIVE WEIGHT 140 lbs. DROP 30 inches

SAMPLED BY GMM LOGGED BY GMM REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
20	Driven	58				SW-SM	ALLUVIUM: (Continued) Grayish brown to dark gray, saturated, medium dense, well-graded to silty SAND; scattered gravel.
25	Driven	8					Loose.
30	Driven	62					Medium dense.
35	Driven	45					Dense.
40							

Ninyo & Moore

BORING LOG

Victoria Wastewater Treatment Plant Upgrade
Dana Point, California

PROJECT NO.	DATE	FIGURE
201029-01	6/97	

DATE DRILLED 3/5/97 BORING NO. B-1

GROUND ELEVATION 22' ±(MSL) SHEET 3 OF 3

METHOD OF DRILLING 8" Hollow stem auger (Scott's Drilling)

DRIVE WEIGHT 140 lbs. DROP 30 inches

SAMPLED BY GMM LOGGED BY GMM REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
40	Driven	83				SW-SM	ALLUVIUM: (Continued) Grayish brown to dark gray, saturated, dense, well graded to silty SAND; scattered gravel.
45	Driven	20					Medium dense.
50	Driven	31					Dark gray silt in tip of sampler.
							Total Depth = 51.5 feet. Groundwater encountered at approximately 15 feet during drilling. Backfilled on 3/5/97.
55							
60							

Ninyo & Moore

BORING LOG

Victoria Wastewater Treatment Plant Upgrade
Dana Point, California

PROJECT NO.	DATE	FIGURE
201029-01	6/97	

DATE DRILLED 3/10/97 BORING NO. B-7

GROUND ELEVATION 21' ±(MSL) SHEET 1 OF 1

METHOD OF DRILLING 8" Hollow stem auger (Scott's Drilling)

DRIVE WEIGHT 140 lbs. DROP 30 inches

SAMPLED BY GMM LOGGED BY GMM REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						ML	FILL: Brown, damp, stiff, clayey SILT; scattered gravel. Concrete debris.
		15	15.1	108.3			
5		13					Orange-brown; increasing sand.
10		27	12.3	113.1			Very stiff; concrete debris.
							Total Depth = 11.5 feet. No groundwater encountered. Backfilled on 3/10/97.
15							
20							

Ninyo & Moore

BORING LOG

Victoria Wastewater Treatment Plant Upgrade
Dana Point, California

PROJECT NO.	DATE	FIGURE
201029-01	6/97	

DATE DRILLED 3/10/97 BORING NO. B-8

GROUND ELEVATION 19' ±(MSL) SHEET 1 OF 1

METHOD OF DRILLING 8" Hollow stem auger (Scott's Drilling)

DRIVE WEIGHT 140 lbs. DROP 30 inches

SAMPLED BY GMM LOGGED BY GMM REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0		20				SM/ML	FILL: Brown, damp, very stiff, sandy SILT to silty SAND; abundant gravel in upper 2 inches. Cobbles and concrete debris.
5		59					Drive sample at 5 to 6-1/2 feet encountered cobbles or concrete, blow counts not representative. @ 6 - 8': Cobble layer.
10		13	▽			SP/SM	ALLUVIUM: Grayish brown, wet, medium dense, silty to poorly graded SAND. @ 9': Groundwater encountered during drilling; saturated.
15							Total Depth = 11.5 feet. Groundwater encountered at approximately 9 feet during drilling. Backfilled on 3/10/97.
20							

Ninyo & Moore

BORING LOG

Victoria Wastewater Treatment Plant Upgrade
Dana Point, California

PROJECT NO.	DATE	FIGURE
201029-01	6/97	A-20

DATE DRILLED 3/10/97 BORING NO. B-9

GROUND ELEVATION 20' ±(MSL) SHEET 1 OF 1

METHOD OF DRILLING 8" Hollow stem auger (Scott's Drilling)

DRIVE WEIGHT 140 lbs. DROP 30 inches

SAMPLED BY GMM LOGGED BY GMM REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						CL	FILL: Brown, dry to damp, very stiff, silty CLAY; abundant gravel; white mottles.
		34	13.0	103.9			
5		8	24.2				Some gravel; seepage. Orange-brown; firm.
10		19	▽			SP/SM	ALLUVIUM: Gray, wet, loose, silty to poorly graded SAND. @ 11': Groundwater encountered during drilling; saturated.
							Total Depth = 11.5 feet. Groundwater encountered at approximately 11 feet during drilling. Backfilled on 3/10/97.
15							
20							

Ninyo & Moore

BORING LOG

Victoria Wastewater Treatment Plant Upgrade
Dana Point, California

PROJECT NO.	DATE	FIGURE
201029-01	6/97	A-21

NINYO & MOORE 2004

LIFEGUARD BUILDING BORING LOGS

DATE DRILLED 8/9/04 BORING NO. B-1

GROUND ELEVATION 13' ± (MSL) SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Jet Drilling)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						SM	FILL: Yellowish brown, moist, medium dense, silty SAND; few rootlets; grass on surface.
	Driven	28	12.2	113.7			
5						SC	ALLUVIUM: Brown, moist, medium dense, clayey SAND; few gravel.
	Driven	14					
						SP-SM	Yellowish brown to grayish brown, moist, medium dense, poorly graded SAND with silt.
			▽				@9.0': Groundwater encountered during drilling.
10	Bulk	2	19.4	95.8			Saturated; very loose; few beds of poorly graded sand; laminations of silt and peat.
						SP	Gray, saturated, dense, poorly graded medium SAND.
15	Driven	28					
20							

Ninyo & Moore

BORING LOG

Doheny Lifeguard Headquarters and Visitor Center
Dana Point, California

PROJECT NO.	DATE	FIGURE
205974001	11/2004	A-1

DATE DRILLED 8/9/04 BORING NO. B-1

GROUND ELEVATION 13' ± (MSL) SHEET 2 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Jet Drilling)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
20		27				SP	ALLUVIUM: (Continued) Gray, saturated, dense, poorly graded SAND.
							Total Depth = 21.5 feet. Groundwater encountered during drilling at approximately 9 feet. Backfilled with on-site soils on 8/9/04.
25							
30							
35							
40							

Ninyo & Moore

BORING LOG

Doheny Lifeguard Headquarters and Visitor Center
Dana Point, California

PROJECT NO.	DATE	FIGURE
205974001	11/2004	A-2

DATE DRILLED 8/9/04 BORING NO. B-2

GROUND ELEVATION 14' ± (MSL) SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Jet Drilling)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						SM	FILL: Reddish brown, moist, medium dense, silty SAND; few rootlets; grass on surface.
		17	5.4	104.8		SC	Brown and reddish brown, moist, medium dense, clayey SAND; few gravel.
5		16	17.2	98.6		CL	ALLUVIUM: Dark brown, moist, vey stiff, sandy CLAY.
						SP-SM	Light grayish brown, moist, loose, poorly graded SAND with silt.
10		3	▽			SP	Grayish brown, moist, very loose to loose, poorly graded SAND. @10.0': Groundwater encountered during drilling. Saturated.
15		12	20.1	95.1		SP-SM	Grayish brown, saturated, loose, poorly graded SAND with silt.
20							

Ninyo & Moore

BORING LOG

Doheny Lifeguard Headquarters and Visitor Center
Dana Point, California

PROJECT NO.	DATE	FIGURE
205974001	11/2004	A-3

DATE DRILLED 8/9/04 BORING NO. B-2

GROUND ELEVATION 14' ± (MSL) SHEET 2 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Jet Drilling)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
20		24				SP-SM	ALLUVIUM: (Continued) Light grayish brown, saturated, dense, medium to coarse poorly graded SAND with silt; few to little fine gravel.
							Total Depth = 21.5 feet. Groundwater encountered during drilling at approximately 10 feet. Backfilled with on-site soils on 8/9/04.
25							
30							
35							
40							

Ninyo & Moore

BORING LOG

Doheny Lifeguard Headquarters and Visitor Center
Dana Point, California

PROJECT NO.	DATE	FIGURE
205974001	11/2004	A-4

DATE DRILLED 8/9/04 BORING NO. B-3

GROUND ELEVATION 14.5' ± (MSL) SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Jet Drilling)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						SM	FILL: Light yellowish brown, damp, very loose, silty SAND. Yellowish brown; moist; loose.
		16	21.6	98.6			Medium dense; trace reddish oxidation; few thin layers of brown clay.
						SM	ALLUVIUM: Yellowish brown, moist, dense, silty SAND.
5		45	6.9	115.5			
			▽				@8.0': Groundwater encountered during drilling.
						SP-SM	Brown, saturated, loose, poorly graded SAND with silt; few beds of poorly graded sand.
10		4					
15		8					Medium dense; few to little coarse sand.
20							

Ninyo & Moore

BORING LOG

Doheny Lifeguard Headquarters and Visitor Center
Dana Point, California

PROJECT NO.	DATE	FIGURE
205974001	11/2004	A-5

DATE DRILLED 8/9/04 BORING NO. B-3

GROUND ELEVATION 14.5' ± (MSL) SHEET 2 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Jet Drilling)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
20		14				SP-SM	ALLUVIUM: (Continued) Gray, saturated, medium dense, poorly graded SAND with silt; few interbeds of poorly graded SAND.
							Total Depth = 21.5 feet. Groundwater encountered during drilling at approximately 8 feet. Backfilled with on-site soils on 8/9/04.
25							
30							
35							
40							

Ninyo & Moore

BORING LOG

Doheny Lifeguard Headquarters and Visitor Center
Dana Point, California

PROJECT NO.	DATE	FIGURE
205974001	11/2004	A-6

DATE DRILLED 8/9/04 and 8/19/04 BORING NO. B-4

GROUND ELEVATION 14.5' ± (MSL) SHEET 1 OF 3

METHOD OF DRILLING Truck Mounted; Mud Rotary (Jet Drilling)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						SM	FILL: Light yellowish brown, damp, very loose, silty SAND.
						SP	Brown, moist, medium dense, poorly graded SAND; few gravel.
	Driven	36	7.2	105.1			
						SP-SM	ALLUVIUM: Yellowish brown and grayish brown, moist, dense, poorly graded SAND with silt; few thin beds with coarse sand.
5	Driven	23					
	Driven	28	▽				@8.0': Groundwater encountered during drilling; saturated.
						SP-SM	Light brown, saturated, dense, poorly graded SAND with silt.
10	Driven	45					
15	Driven	24				GP	Brown to black, saturated, dense, poorly graded fine GRAVEL with sand; interbeds of light brown, poorly graded sand; gradational and sharp contacts.
							Fine to coarse gravel with few to little cobbles.
20							

Ninyo & Moore

BORING LOG

Doheny Lifeguard Headquarters and Visitor Center
Dana Point, California

PROJECT NO.	DATE	FIGURE
205974001	11/2004	A-7

DATE DRILLED 8/9/04 and 8/19/04 BORING NO. B-4

GROUND ELEVATION 14.5' ± (MSL) SHEET 2 OF 3

METHOD OF DRILLING Truck Mounted; Mud Rotary (Jet Drilling)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
20		17				GP	ALLUVIUM: (Continued) Dark gray, saturated, medium dense, fine to coarse poorly graded GRAVEL; few to little cobbles.
						SP-SM	Gray, saturated, medium dense, poorly graded SAND with silt; few thin beds of poorly graded fine gravel.
25		23					Hollow stem auger used to case the hole to a depth of approximately 25 feet. Dense.
						CL	Grayish brown, saturated, firm to stiff, CLAY.
30		5				ML+SM	Grayish brown, saturated, firm to stiff, clayey to fine sandy SILT and silty fine SAND; gradational; thinly bedded; few very thin beds of clay.
35		14					Medium dense; decrease in clayey silt; increase in fine sandy silt.
40						SM	Grayish brown, saturated, dense, silty fine SAND; interbedded with fine sandy silt; thinly bedded; gradational; few very thin beds of clay.

Ninyo & Moore

BORING LOG

Doheny Lifeguard Headquarters and Visitor Center
Dana Point, California

PROJECT NO.	DATE	FIGURE
205974001	11/2004	A-8

DATE DRILLED 8/9/04 and 8/19/04 BORING NO. B-4

GROUND ELEVATION 14.5' ± (MSL) SHEET 3 OF 3

METHOD OF DRILLING Truck Mounted; Mud Rotary (Jet Drilling)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
40		21				SM	ALLUVIUM: (Continued) Grayish brown, saturated, dense, silty fine SAND; interbedded with fine sandy silt; thinly bedded; gradational; few very thin beds of CLAY.
						SP	Gray, saturated, medium dense, poorly graded medium SAND.
						SM	Grayish brown, saturated, dense to very dense, silty SAND; few interbeds of poorly graded sand.
45		33					
						SP-SM	Gray, saturated, very dense, poorly graded SAND with silt.
50		36					
							Total Depth = 51.5 feet. Groundwater encountered during drilling at approximately 8 feet. Backfilled with bentonite grout and on-site soils on 8/19/04.
55							
60							

Ninyo & Moore

BORING LOG

Doheny Lifeguard Headquarters and Visitor Center
Dana Point, California

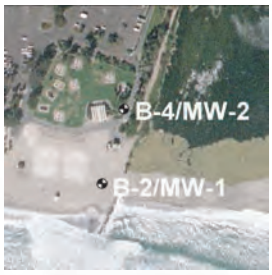
PROJECT NO.	DATE	FIGURE
205974001	11/2004	A-9

GEOSCIENCE 2005

HYDROGEOLOGY STUDY BORING LOGS

GEOSCIENCE
P.O. Box 220
Claremont, CA 91711
Telephone: (909) 920-0707
Fax: (909) 920-0403
www.gssiwater.com

WELL LOCATION MAP



MAP SCALE: 625 ft:1 in.

WELL NUMBER
B-2/MW-1

BOREHOLE LITHOLOGIC LOG

CLIENT / PROJECT NUMBER: Municipal Water District of Orange County / 1250-04	LOCATION: **Dana Point, California** **South of Main Life Guard Tower, Doheny State Beach**
REPORT DATE: OCT-05	
DRILLING CONTRACTOR / DRILLER: Boart Longyear Environmental Drilling	LOGGED BY: **T. Watkins and D. Field**

		SCREEN / BLANK	TOP DEPTH (ft bgs)	BOTTOM DEPTH (ft bgs)	LENGTH (ft)	MATERIAL	WALL THICKNESS (in.)	DIAMETER (in.)	SCREEN TYPE	PERF. SIZE (in.)
DRILLING RIG TYPE	Roto-Sonic									
DRILLING METHOD	Sonic Drilling Method									
SAMPLING METHOD	Core									
BOREHOLE DIAMETER	10 in									
SURFACE ELEVATION										
TOC ELEVATION										
START DATE	2/28/05									
FINISH DATE	3/01/05									

Lithologic Log

Depth bgs (feet)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
1			SAND WITH GRAVEL AND COBBLES (SP): grayish brown (10YR 5/2), 70% fine to coarse grained sand, subrounded; 15% fine to coarse gravel up to 75mm, subrounded; 15% cobbles up to 110mm; poorly sorted; moist sample; contains quartz, feldspar and mica.	1		
2	Native Sand			2		
3			SAND (SP): dark yellowish brown (10YR 4/4), 100% fine to coarse grained sand, subrounded; trace clay, low plasticity; poorly sorted; moist sample; contains quartz, feldspar and mica.	3		
4	Cement seal			4		
5			SAND (SP): brown (10YR 4/3), 100% fine to coarse grained sand, subrounded; trace fine to coarse gravel up to 25mm, subrounded; poorly sorted; moist sample; contains quartz, feldspar and mica.	5		
6				6		
7			SAND (SP): brown (10YR 4/3), 100% fine to coarse grained sand, subrounded, color change, pale yellow at 7.0 ft bgs; poorly sorted; moist sample; contains quartz, feldspar and mica.	7		
8	3/01/05		SAND (SP): olive (5Y 5/3), 100% fine to coarse grained sand, subrounded; trace fine gravel up to 5mm, subrounded; poorly sorted; contains quartz, feldspar and mica, with visible alteration.	8		
9	Blank casing			9		
10				10		

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WELL NUMBER **B-2/MW-1**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	Lithologic Log NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
11	Blank casing			SAND (SP): light olive brown (2.5Y 5/3), 100% fine to coarse grained sand, subrounded; trace fine gravel up to 8mm, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	11		
12					12		
13	Blank casing			SAND (SP): light yellowish brown (2.5Y 6/4), 100% fine to coarse grained sand, subangular to subrounded, mostly medium sand; trace fine to coarse gravel up to 25mm, subangular to subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	13		
14				SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 75% fine to coarse grained sand, subangular to subrounded; 25% fine to coarse gravel up to 70mm, subangular to subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	14		
15	Well screen			SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 80% fine to coarse grained sand, subangular to subrounded; 20% fine to coarse gravel up to 75mm, subangular to subrounded; trace cobbles; trace fines; poorly sorted; wet sample; contains quartz, feldspar and mica.	15		
16					16		
17	Filter pack			SAND WITH GRAVEL (SP): very dark gray (2.5Y 3/1), 80% fine to coarse grained sand, subangular to subrounded; 20% fine to coarse gravel up to 65mm, subangular to subrounded; trace fines; poorly sorted; wet sample; contains quartz, feldspar and mica.	17		
18				SAND (SP): dark gray (5Y 4/1), 100% fine to coarse grained sand, subangular to subrounded, mostly medium sand; trace fine gravel up to 18mm, subangular to subrounded; medium sorted; wet sample; contains quartz, feldspar and mica.	18		
19					19		
20				SAND (SP): very dark gray (N3), 90% fine to coarse grained sand, subrounded; 10% fine to coarse gravel up to 22mm, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	20		
21					21		
22				SAND (SP): very dark gray (N3), 100% fine to coarse grained sand, subrounded, mostly fine to medium sand; trace fine to coarse gravel up to 60mm, subrounded, granitic and metasedimentary origins; poorly sorted; wet sample; contains quartz, feldspar and mica.	22		
23	Cement seal				23		

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Lithologic Log

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
24				CLAYEY SAND (SC): very dark gray (N3), 70% fine to coarse grained sand, subrounded, interbedded with fine and medium sand; 30% clay, low plasticity; trace fine to coarse gravel up to 20mm, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	24		
25	Blank casing			SAND (SP): very dark gray (N3), 100% fine to coarse grained sand, subangular to subrounded, mostly fine to medium sand; trace fine gravel up to 15mm, subangular to subrounded; medium sorted; moist sample; contains quartz, feldspar and mica.	25		
26				FAT CLAY WITH SAND (CH): very dark gray (N3), 85% clay, high plasticity; 15% fine to coarse grained sand, subrounded; wet sample; contains quartz, feldspar and mica.	26		
27	Blank casing			FAT CLAY (CH): (5GY 3/1), 95% clay, high plasticity; 5% fine to coarse grained sand, subrounded, small cemented sand/clay fragments; moist sample; contains quartz, feldspar and mica.	27		
28				FAT CLAY (CH): (5GY 3/1), 95% clay, some small cemented fragments; 5% fine to medium grained sand, subrounded; moist sample; contains quartz, feldspar and mica.	28		
29	Cement seal			CLAYEY SAND (SC): (5GY 3/1), 85% fine grained sand, subrounded; 15% clay; well sorted; moist sample; contains quartz, feldspar and mica.	29		
30				CLAYEY SAND (SC): (5GY 3/1), 85% fine to medium grained sand, subrounded; 15% clay; poorly sorted; wet sample; contains quartz, feldspar and mica.	30		
31				CLAYEY SAND (SC): (5GY 3/1), 85% fine to medium grained sand, subrounded; 15% clay, low plasticity; poorly sorted; wet sample; contains quartz, feldspar and mica.	31		
32				CLAY (CL): (5GY 3/1), 95% clay, medium plasticity, lower plasticity than above; 5% fine to medium grained sand; moist sample.	32		
33					33		
34					34		
35				CLAY (CL): (5GY 3/1), 90% clay; 10% fine to medium grained sand, subrounded; wet sample; contains quartz, feldspar and mica.	35		
36					36		
				CLAYEY SAND (SC): (5GY 2.5/1), 70% fine to medium grained sand,			

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BOREHOLE LITHOLOGIC LOG (continued)

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Lithologic Log

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
37				subrounded; 30% clay, low to medium plasticity, with very small cemented clay fragments; poorly sorted; wet sample; contains quartz, feldspar and mica.	37		
38				SAND (SP): (5GY 2.5/1), 100% fine to coarse grained sand, subrounded, color lightens to dark gray (5Y 4/1) at 38.5 to 40 ft bgs; trace fine to coarse gravel up to 20mm, subrounded; trace clay, low to medium plasticity; poorly sorted; wet sample; contains quartz, feldspar and mica.	38		
39	Filter pack				39		
40				SAND (SP): dark gray (2.5Y 4/1), 100% fine to coarse grained sand, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	40		
41	Well screen				41		
42					42		
43				SAND (SP): dark gray (2.5Y 4/1), 100% fine to coarse grained sand, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	43		
44					44		
45				SAND (SP): dark gray (2.5Y 4/1), 80% fine to coarse grained sand, subrounded; 15% fine to coarse gravel up to 75mm, subrounded, granitic, metasedimentary and igneous volcanic origins; 5% cobbles up to 145mm; poorly sorted; wet sample; contains quartz, feldspar and mica.	45		
46					46		
47					47		
48				SAND (SP): dark gray (2.5Y 4/1), 90% fine to coarse grained sand, subangular to subrounded; 10% fine to coarse gravel up to 75mm, subangular to subrounded, trace granitic and metasedimentary origins; trace large silty clay balls; poorly sorted; wet sample; contains quartz, feldspar and mica.	48		
49					49		
50					50		

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Lithologic Log

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
51	Filter pack			SAND (SP): dark gray (2.5Y 4/1), 95% fine to coarse grained sand, subrounded; 5% fine to coarse gravel up to 75mm, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	51		
52					52		
53	Well screen			SAND (SP): dark gray (2.5Y 4/1), 100% fine to coarse grained sand, subrounded, mostly fine to medium sand; poorly sorted; wet sample; contains quartz, feldspar and mica.	53		
54					54		
55	Blank casing			SAND (SP): dark gray (2.5Y 4/1), 90% fine to coarse grained sand, subrounded; 10% fine to coarse gravel up to 65mm, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	55		
56					56		
57					57		
58				SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 85% fine to coarse grained sand, subrounded; 15% fine to coarse gravel up to 60mm, subrounded, granitic and metasedimentary origins; poorly sorted; wet sample; contains quartz, feldspar and mica.	58		
59					59		
60				CLAYEY SAND (SC): dark gray (2.5Y 4/1), 80% fine to coarse grained sand, subangular to subrounded; 15% clay, low plasticity; 5% fine to coarse gravel up to 70mm, subangular to subrounded; poorly sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	60		
61				SAND (SP): dark gray (2.5Y 4/1), 90% fine to coarse grained sand, subrounded; 10% fine to coarse gravel up to 55mm, subrounded; trace clay balls; poorly sorted; contains quartz, feldspar and mica, with visible alteration.	61		
62					62		
63				SAND (SP): dark gray (2.5Y 4/1), 100% fine to coarse grained sand, subrounded; trace fine to coarse gravel up to 50mm, subrounded; trace clay balls; poorly sorted; contains quartz, feldspar and mica, with visible alteration.	63		

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Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
64				SAND (SP): dark gray (2.5Y 4/1), 90% fine to coarse grained sand, subrounded; 10% fine to coarse gravel up to 55mm, subrounded; poorly sorted; contains quartz, feldspar and mica, with visible alteration.	64		
65	Filter pack			SAND (SP): dark gray (2.5Y 4/1), 100% fine to coarse grained sand, subrounded; trace fine to coarse gravel up to 30mm, subrounded; poorly sorted; contains quartz, feldspar and mica, with visible alteration.	65		
66					66		
67	Well screen				67		
68					68		
69	Blank casing				69		
70					70		
71					71		
72					72		
73				SAND (SP): dark gray (2.5Y 4/1), 95% fine to coarse grained sand, subrounded; 5% fine to coarse gravel up to 40mm, subrounded, metasedimentary origins; poorly sorted; contains quartz, feldspar and mica.	73		
74					74		
75				SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 80% fine to coarse grained sand, subrounded; 20% fine to coarse gravel up to 60mm, subrounded, metasedimentary origins; poorly sorted; contains quartz, feldspar and mica.	75		
76					76		

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77	Filter pack				77		
				SAND (SP): dark gray (2.5Y 4/1), 100% fine to coarse grained sand, subrounded; trace fine gravel up to 8mm, subrounded; poorly sorted; contains quartz, feldspar and mica.			
78					78		
79	Well screen				79		
				SAND (SP): dark gray (2.5Y 4/1), 95% fine to medium grained sand, mostly fine sand; 5% clay; medium sorted; contains quartz, feldspar and mica.			
80				SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 60% fine to coarse grained sand, subangular to subrounded; 40% fine to coarse gravel up to 50mm, subangular to subrounded; poorly sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	80		
81	Blank casing				81		
				SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 60% fine to coarse grained sand, subangular to subrounded; 40% fine to coarse gravel up to 75mm, subangular to subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.			
82					82		
83					83		
				SAND (SP): dark gray (2.5Y 4/1), 100% fine to coarse grained sand, subangular to subrounded; trace fine to coarse gravel up to 55mm, subangular to subrounded; poorly sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.			
84					84		
85					85		
				SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 85% fine to coarse grained sand, subrounded; 15% fine to coarse gravel up to 75mm, subrounded, metasedimentary origins; poorly sorted; wet sample; contains quartz, feldspar and mica.			
86					86		
87					87		
				SAND (SP): dark gray (2.5Y 4/1), 100% fine to coarse grained sand, subrounded, mostly fine to medium sand; poorly sorted; wet sample; contains quartz, feldspar and mica.			
88					88		
89					89		
90					90		

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Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
91					91		
92	Filter pack			SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 65% fine to coarse grained sand, subrounded; 35% fine to coarse gravel up to 75mm, subrounded, metasedimentary origins; poorly sorted; wet sample; contains quartz, feldspar and mica.	92		
93					93		
94	Well screen				94		
95					95		
96	Blank casing			GRAVEL WITH SAND (SP): dark gray (2.5Y 4/1), 70% fine to coarse gravel up to 75mm, subrounded, metasedimentary origins; 25% fine to coarse grained sand, subrounded; 5% cobbles up to 120mm; poorly sorted; contains quartz, feldspar and mica.	96		
97					97		
98					98		
99				SAND (SP): dark gray (2.5Y 4/1), 95% fine to coarse grained sand, subrounded; 5% fine to coarse gravel up to 75mm, subrounded, metasedimentary origins; poorly sorted; contains quartz, feldspar and mica.	99		
100					100		
101				GRAVEL WITH SAND (GP): dark gray (2.5Y 4/1), 70% fine to coarse gravel up to 75mm, subangular to subrounded, metasedimentary origins, grading with depth; 25% fine to coarse grained sand, subangular to subrounded; 5% cobbles up to 130mm; poorly sorted; contains quartz, feldspar and mica.	101		
102					102		
103				CLAY WITH SAND (CL): (5PB 4/1), 75% clay, medium plasticity; 15% fine to coarse grained sand, subrounded; 10% fine to coarse gravel up to 50mm, subrounded; contains quartz, feldspar and mica, with visible alteration. SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 80% fine to coarse grained sand, subrounded; 20% fine to coarse gravel up to 58mm, subrounded, metasedimentary origins; poorly sorted; contains quartz,	103		

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				feldspar and mica.			
104					104		
105	Well screen			SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 70% fine to coarse grained sand, subrounded; 30% fine to coarse gravel up to 75mm, subrounded, metasedimentary origins; trace clay balls; poorly sorted; contains quartz, feldspar and mica.	105		
106					106		
107	Blank casing				107		
108				SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 70% fine to coarse grained sand, subrounded; 30% fine to coarse gravel up to 75mm, subrounded, metasedimentary origins; trace clay balls; poorly sorted; contains quartz, feldspar and mica.	108		
109					109		
110				GRAVEL WITH SAND (GP): dark gray (2.5Y 4/1), 80% fine to coarse gravel up to 65mm, subrounded to rounded, metasedimentary origins; 20% fine to coarse grained sand, subrounded to rounded; poorly sorted; moist sample; contains quartz and feldspar, with visible alteration.	110		
111				SAND WITH GRAVEL (SP): grayish brown (2.5Y 5/2), 80% fine to coarse grained sand, subrounded; 15% fine to coarse gravel up to 75mm, subrounded; 5% cobbles up to 160mm; poorly sorted; contains quartz, feldspar and mica.	111		
112					112		
113				SAND (SP): dark gray (2.5Y 4/1), 90% fine to coarse grained sand, subrounded; 10% fine to coarse gravel up to 45mm, subrounded; poorly sorted; contains quartz, feldspar and mica.	113		
114				CLAY (CL): dark gray (2.5Y 4/1), 95% clay, medium plasticity; 5% fine grained sand; contains quartz, feldspar and mica, trace wood fragments.	114		
115					115		
116				SAND (SP): dark gray (5Y 4/1), 100% fine to medium grained sand, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	116		

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117					117		
118				SAND (SP): dark greenish gray (5GY 4/1), 100% fine to coarse grained sand, subrounded, mostly fine to medium sand; poorly sorted; wet sample; contains quartz, feldspar and mica.	118		
119					119		
120					120		
121				SILTY SAND WITH GRAVEL (SM): dark greenish gray (5GY 4/1), 45% fine to medium grained sand, subangular to subrounded, mostly fine to medium sand; 30% silt; 25% fine to coarse gravel up to 45mm, subangular to subrounded; poorly sorted; contains quartz, feldspar and mica.	121		
122				GRAVEL WITH SAND (GP): dark grayish brown (2.5Y 4/2), 60% fine to coarse gravel up to 75mm, subangular to subrounded, granitic, metasedimentary origins, fine silty well-cemented sandstone; 40% fine to coarse grained sand, subangular to subrounded; poorly sorted; contains quartz, feldspar and mica.	122		
123				GRAVEL WITH SAND (GP): dark grayish brown (2.5Y 4/2), 60% fine to coarse gravel up to 75mm, subangular to subrounded, granitic, metasedimentary, fine silty well-cemented sandstone; 40% fine to coarse grained sand, subangular to subrounded; poorly sorted; contains quartz, feldspar and mica.	123		
124					124		
125				GRAVEL WITH SAND (GP): dark grayish brown (2.5Y 4/2), 60% fine to coarse gravel up to 75mm, subrounded, metasedimentary origins; 35% fine to coarse grained sand, subrounded; 5% cobbles up to 130mm; poorly sorted; wet sample; contains quartz, feldspar and mica.	125		
126					126		
127					127		
128	Filter pack			GRAVEL WITH SAND AND COBBLES (GP): olive (5Y 4/3), 55% fine to coarse gravel up to 75mm, subrounded, granitic and metasedimentary origins; 25% fine to coarse grained sand, subrounded; 10% cobbles up to 180mm; poorly sorted; wet sample; contains quartz, feldspar and mica.	128		
129	Well screen / Blank casing				129		
130					130		

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BOREHOLE LITHOLOGIC LOG (continued)

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LOCATION **Dana Point, California**

(continued)

Depth bgs (feet)	Zone Test	Graphic Log	Lithologic Log NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
131			GRAVEL WITH SAND (GP): dark gray (5Y 4/1), 60% fine to coarse gravel up to 75mm, subrounded; 40% fine to coarse grained sand, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	131		
132			SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 85% fine to coarse grained sand, subangular to subrounded; 15% fine to coarse gravel up to 60mm, subangular to subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica, No core-lithology from split spoon.	132		
133			GRAVEL WITH SAND (GP): dark gray (2.5Y 4/1), 75% fine to coarse gravel up to 50mm, subangular to subrounded; 25% fine to coarse grained sand, subangular to subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	133		
134			CLAY (CL): black (2.5Y 2.5/1), 90% clay, low to medium plasticity; 10% fine to medium grained sand, subrounded; moist sample; contains quartz, feldspar and mica.	134		
135				135		
136			CLAYEY GRAVEL WITH SAND (GC): dark gray (5Y 4/1), 60% fine to coarse gravel up to 75mm, subrounded, metasedimentary origins and quartzite; 25% fine to coarse grained sand, subrounded; 15% clay, low to medium plasticity; poorly sorted; wet sample; contains quartz, feldspar and mica.	136		
137				137		
138			CLAYEY GRAVEL WITH SAND (GC): dark gray (5Y 4/1), 60% fine to coarse gravel up to 75mm, subrounded, metasedimentary origins and quartzite; 20% fine to coarse grained sand, subrounded; 15% clay, low to medium plasticity; 5% cobbles up to 115mm; poorly sorted; wet sample; contains quartz, feldspar and mica.	138		
139				139		
140			CLAYEY GRAVEL WITH SAND AND COBBLES (GC): dark gray (5Y 4/1), 55% fine to coarse gravel up to 75mm, subrounded, metasedimentary origins and quartzite; 20% fine to coarse grained sand, subrounded; 15% clay, low to medium plasticity; 10% cobbles up to 200mm; poorly sorted; wet sample; contains quartz, feldspar and mica.	140		
141				141		
142				142		
143			CLAYEY GRAVEL WITH SAND AND COBBLES (GC): dark gray (5Y 4/1), 55% fine to coarse gravel up to 75mm, subrounded, metasedimentary origins and quartzite; 20% fine to coarse grained sand, subrounded; 15% clay, low to medium plasticity; 10% cobbles up to	143		

Blank casing with end cap
Blank casing
Cement seal
Sand
Filter pack
Well screen

WELL CONSTRUCTION LOG MWDOC_BH-2_MW1.GPJ GEOSCIENCE.GDT 9/2/05

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WELL NUMBER **B-2/MW-1**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Lithologic Log

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
				110mm; poorly sorted; wet sample; contains quartz, feldspar and mica.			
144				SAND (SP): dark yellowish brown (10YR 4/4), 100% fine to coarse grained sand, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	144		
145	Filter pack			SAND (SP): greenish gray (5GY 6/1), 100% fine to coarse grained sand, subrounded; trace fine gravel up to 8mm, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	145		
146				SAND (SP): greenish gray (5GY 6/1), 100% fine to coarse grained sand, subrounded; trace fine gravel up to 8mm, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	146		
147	Well screen			CLAY WITH GRAVEL AND COBBLES (CL): greenish gray (5GY 6/1), 80% clay, dense, moderate cementation; 5% fine to coarse gravel silty fine sandstone, easily broken; 5% fine to medium grained sand; 10% cobbles up to 85mm; wet sample; moderate cementation; hydrogen sulfide smell.	147		
148				CLAY WITH GRAVEL AND COBBLES (CL): greenish gray (5GY 6/1), 80% clay, dense, moderate cementation; 5% fine to coarse gravel up to 50mm, silty fine sandstone, easily broken; 5% fine to medium grained sand; 10% cobbles up to 85mm; wet sample; moderate cementation; hydrogen sulfide smell.	148		
149				CLAYEY SAND (SC): dark gray (N4), 80% fine to coarse grained sand, subrounded, mostly fine sand, interbedded clay/sand; 20% clay, low plasticity; poorly sorted; wet sample; contains quartz, feldspar and mica, hydrogen sulfide smell.	149		
150				SAND (SP): dark gray (N4), 100% fine to coarse grained sand, subrounded; trace fine gravel up to 10mm, subrounded; trace clay, low plasticity; poorly sorted; wet sample; contains quartz, feldspar and mica, hydrogen sulfide smell.	150		
151					151		
152					152		
153				SAND (SP): dark gray (N4), 100% fine to coarse grained sand, subrounded; trace fine gravel up to 10mm, subrounded; trace clay, low plasticity; poorly sorted; wet sample; contains quartz, feldspar and mica, hydrogen sulfide smell.	153		
154					154		
155					155		
156				SAND (SP): dark gray (N4), 100% fine to coarse grained sand, subrounded; trace fine gravel up to 10mm, subrounded; trace clay, low plasticity; poorly sorted; wet sample; contains quartz, feldspar and mica, hydrogen sulfide smell.	156		

WELL CONSTRUCTION LOG MWDOC_BH-2_MW1.GPJ GEOSCIENCE.GDT 9/2/05

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WELL NUMBER **B-2/MW-1**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Lithologic Log

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
157				SAND (SP): dark greenish gray (5GY 4/1), 100% fine to coarse grained sand, subrounded; trace clay, low to medium plasticity; poorly sorted; wet sample; contains quartz, feldspar and mica, hydrogen sulfide smell.	157		
158				CLAY (CL): (N2.5), 90% clay, low plasticity; 10% fine to medium grained sand, subrounded, mostly fine sand; moist sample; contains quartz and mica.	158		
159				CLAY WITH GRAVEL AND COBBLES (CL): (5GY 3/1), 80% clay, low plasticity, moderate cementation; 5% fine to coarse gravel up to 45mm, subrounded, silty fine sandstone, easily broken; 5% fine to coarse grained sand, subrounded; 10% cobbles up to 100mm; wet sample; moderate cementation; contains quartz and mica.	159		
160				CLAYEY SAND (SC): very dark gray (N3), 80% fine to coarse grained sand, subrounded; 20% clay, low to medium plasticity; poorly sorted; wet sample; contains quartz, feldspar and mica, hydrogen sulfide smell.	160		
161					161		
162					162		
163	Filter pack			SANDY CLAY (CL): very dark gray (N3), 60% clay, low to medium plasticity; 40% fine to medium grained sand, subrounded; wet sample; contains quartz, feldspar and mica, hydrogen sulfide smell.	163		
164				GRAVEL WITH SAND (GP): dark greenish gray (5GY 4/1), 60% fine to coarse gravel up to 75mm, angular to subangular, friable silty-sandstone; 40% fine to coarse grained sand, angular to subangular; poorly sorted; dry sample; moderate cementation; contains quartz, feldspar and mica, with visible alteration.	164		
165	Well screen			CLAY (CL): dark greenish gray (5GY 4/1), 100% clay, low to medium plasticity; fine grained sand; dry sample; moderate cementation; hydrogen sulfide smell.	165		
166				SANDY CLAY (CL): (5GY 3/1), 60% clay, low to medium plasticity; 40% fine grained sand, subrounded; dry sample; contains quartz, feldspar and mica, hydrogen sulfide smell.	166		
167	Blank casing with end cap				167		
168				SAND (SP): very dark gray (N3), 95% fine to coarse grained sand, subrounded; 5% clay, low plasticity; poorly sorted; wet sample; contains quartz, feldspar and mica, hydrogen sulfide smell.	168		
169	Backfill				169		
170					170		

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WELL NUMBER
B-2/MW-1

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04

LOCATION
Dana Point, California

Lithologic Log

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
171				SAND (SP): very dark gray (N3), 95% fine to coarse grained sand, subrounded; 5% clay, low plasticity; poorly sorted; contains quartz, feldspar and mica, hydrogen sulfide smell.	171		
172	Backfill				172		
173				SAND (SP): very dark gray (N3), 95% fine to coarse grained sand, subrounded; 5% clay; poorly sorted; contains quartz, feldspar and mica, hydrogen sulfide smell.	173		
174					174		
175				Bottom of borehole at 175 feet.	175		

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WELL LOCATION MAP



MAP SCALE: 625 ft:1 in.

WELL NUMBER **B-3**

BOREHOLE LITHOLOGIC LOG

CLIENT / PROJECT NUMBER: Municipal Water District of Orange County / 1250-04	LOCATION: **Dana Point, California**
REPORT DATE: OCT-05	**North Day Use Area, Doheny State Beach**
DRILLING CONTRACTOR / DRILLER: Boart Longyear Environmental Drilling	LOGGED BY: **T. Watkins and D. Field**

		SCREEN/ BLANK	TOP DEPTH (ft bgs)	BOTTOM DEPTH (ft bgs)	LENGTH (ft)	MATERIAL	WALL THICKNESS (in.)	DIAMETER (in.)	SCREEN TYPE	PERF. SIZE (in.)
DRILLING RIG TYPE	Roto-Sonic									
DRILLING METHOD	Sonic Drilling Method									
SAMPLING METHOD	Core									
BOREHOLE DIAMETER	9 in									
SURFACE ELEVATION										
TOC ELEVATION										
START DATE	2/16/05									
FINISH DATE	2/18/05									

Lithologic Log

Depth bgs (feet)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
1–2			SAND (SP): yellowish brown (10YR 5/6), 100% fine to coarse grained sand, subangular to subrounded, trace coarse sand; trace fine gravel up to 15mm, subangular to subrounded; medium sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	1–2		
3			CLAY (CL): dark grayish brown (10YR 4/2), 90% clay, high plasticity; 10% fine to medium grained sand, subangular to subrounded; moist sample; contains quartz, feldspar and mica, with visible alteration.	3		
4–6	Backfill		SAND (SP): yellowish brown (10YR 5/6), 100% fine to medium grained sand, subangular to subrounded; trace clay, trace medium plasticity clay balls; medium sorted; contains quartz, feldspar and mica, with visible alteration; split spoon sample at 5-6.5 ft.	4–6		
7–15	2/18/05 ▼		SAND (SP): pale olive (5Y 6/3), 100% fine to coarse grained sand, subangular to subrounded, trace coarse sand; trace fine gravel up to 10mm, subangular to subrounded; trace silt, from 6.5-7.0 ft. bgs; medium sorted; contains quartz, feldspar and mica, with visible alteration; split spoon samples at 10-11.5 ft.	7–15		
16–20			SAND (SP): olive gray (5Y 4/2), 90% fine to coarse grained sand, subangular to subrounded; 10% fine to coarse gravel up to 25mm, subangular to subrounded; well sorted; contains quartz, feldspar and mica, with visible alteration; split spoon sample at 15-16.5 ft.	16–20		

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WELL NUMBER **B-3**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Lithologic Log

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
21				SAND (SP): dark yellowish brown (10YR 4/6), 95% fine to coarse grained sand, subangular to rounded; 5% fine gravel up to 18mm, subangular to rounded; poorly sorted; moist sample; contains quartz, feldspar and mica, with visible alteration; split spoon sample at 20-21.5 ft.	21		
22					22		
23					23		
24				SAND WITH SILT (SP-SM): (5GY 3/1), 90% fine to coarse grained sand, subangular to subrounded, trace medium sand; 10% silt; well sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	24		
25					25		
26				CLAYEY SAND (SC): dark gray (5Y 4/1), 80% fine to coarse grained sand, subangular to subrounded; 15% clay; 5% fine gravel up to 18mm, subangular to subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	26		
27				CLAY (CL): dark gray (5Y 4/1), 95% clay, high plasticity; 5% fine grained sand, subrounded; wet sample; contains quartz.	27		
28					28		
29				CLAY WITH SAND (CL): dark gray (5Y 4/1), 80% clay, high plasticity; 20% fine grained sand, subrounded; wet sample; contains quartz.	29		
30					30		
31				CLAYEY SAND (SC): dark gray (5Y 4/1), 85% fine to medium grained sand, subrounded, mostly fine sand; 15% clay; well sorted; wet sample; contains quartz, feldspar and mica.	31		
32					32		
33					33		
34					34		
35	Backfill				35		
36		ZONE 1 32-42 ft		SAND (SP): dark gray (5Y 4/1), 100% fine to coarse grained sand, subrounded, trace coarse sand; trace silt; medium sorted; wet sample; contains quartz, feldspar and mica.	36		
37					37		
38					38		
39					39		
40					40		
41				SAND (SP): dark gray (5Y 4/1), 100% fine to medium grained sand, subrounded; medium sorted; wet sample; contains quartz, feldspar and mica.	41		
42					42		
43					43		
44					44		
45					45		
46					46		

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WELL NUMBER **B-3**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	Lithologic Log NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
47					47		
48					48		
49					49		
50	Backfill			SAND (SP): gray (2.5Y 5/1), 100% fine to medium grained sand, subrounded; medium sorted; wet sample; contains quartz, feldspar and mica.	50		
51					51		
52					52		
53					53		
54					54		
55					55		
56					56		
57				SAND (SP): gray (2.5Y 5/1), 95% fine to medium grained sand, subrounded; 5% clay; medium sorted; wet sample; contains quartz, feldspar and mica.	57		
58					58		
59				SAND (SP): gray (2.5Y 5/1), 100% fine to coarse grained sand, subangular to subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	59		
60					60		
61					61		
62					62		
63					63		
64				SAND (SP): gray (2.5Y 5/1), 95% fine to coarse grained sand, subrounded to rounded; 5% fine to coarse gravel up to 33mm, subrounded to rounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	64		
65					65		
66				SAND WITH GRAVEL (SP): olive gray (5Y 5/2), 60% fine to coarse grained sand, subrounded to rounded; 40% fine to coarse gravel up to 70mm, subrounded to rounded; trace clay; poorly sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	66		
67					67		
68				SAND (SP): olive gray (5Y 5/2), 90% fine to coarse grained sand, subrounded to rounded; 10% fine to coarse gravel up to 30mm, subrounded to rounded; poorly sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	68		
69					69		
70					70		
71					71		
72					72		
73					73		

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WELL NUMBER **B-3**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	Lithologic Log NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
74					74		
75	Backfill				75		
76				SAND (SP): dark gray (2.5Y 4/1), 100% fine to medium grained sand, subangular to rounded; trace fine to coarse gravel up to 30mm, subangular to rounded; trace silt; well sorted; moist sample; contains quartz, feldspar and mica.	76		
77					77		
78					78		
79					79		
80					80		
81					81		
82					82		
83					83		
84				SAND (SP): dark gray (2.5Y 4/1), 95% fine to medium grained sand, subangular to subrounded; 5% clay; well sorted; moist sample; contains quartz, feldspar and mica.	84		
85				SAND (SP): grayish brown (10YR 5/2), 95% fine to coarse grained sand, subangular to rounded; 5% fine to coarse gravel up to 50mm, subangular to rounded, interbedded gravel flat beds, approximately 2-4 inches thick; poorly sorted; moist sample; contains quartz, feldspar and mica.	85		
86					86		
87					87		
88					88		
89					89		
90				CLAYEY SAND (SC): dark gray (2.5Y 4/1), 65% fine to coarse grained sand, subangular to rounded; 30% clay; 5% fine gravel up to 10mm, subangular to rounded; poorly sorted; moist sample; contains quartz and feldspar.	90		
91				SAND (SP): gray (2.5Y 5/1), 100% fine to coarse grained sand, subangular to subrounded, trace coarse sand; poorly sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	91		
92				CLAY (CL): dark gray (5Y 4/1), 90% clay, high plasticity, interbedded with clayey sand; 10% fine to coarse grained sand, subangular to subrounded, trace coarse sand; moist sample; contains quartz and feldspar.	92		
93					93		
94				CLAY (CL): dark gray (5Y 4/1), 95% clay, high plasticity; 5% fine grained sand; moist sample; contains mica.	94		
95					95		
96					96		
97					97		
98				CLAY WITH SAND (CL): dark gray (5Y 4/1), 80% clay, medium plasticity, interbedded with clayey sand and sandy clay; 20% fine to medium grained sand, subangular to subrounded; moist sample; contains quartz, feldspar and mica.	98		
99					99		
100				SAND (SP): dark gray (2.5Y 4/1), 100% fine to coarse grained sand, subangular to subrounded, trace coarse sand; medium sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	100		

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WELL NUMBER **B-3**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	Lithologic Log NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
101					101		
102					102		
103				CLAYEY SAND (SC): dark gray (2.5Y 4/1), 70% fine to coarse grained sand, subangular to rounded; 30% clay; trace fine to coarse gravel up to 30mm, subangular to rounded; poorly sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	103		
104					104		
105					105		
106				SAND WITH GRAVEL AND COBBLES (SP): very dark grayish brown (2.5Y 3/2), 80% fine to coarse grained sand, subangular to rounded; 20% fine to coarse gravel up to 75mm, subangular to rounded, with cobbles up to 100mm; poorly sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	106		
107					107		
108					108		
109					109		
110				SAND (SP): dark grayish brown (10YR 4/2), 100% fine to medium grained sand, subrounded to rounded, with interbedded sand and gravel; trace fine to coarse gravel up to 30mm, subrounded to rounded; trace clay, 4-inch bed at 110 ft. bgs; well sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	110		
111					111		
112					112		
113					113		
114					114		
115	Backfill				115		
116					116		
117					117		
118				SAND WITH GRAVEL (SP): gray (10YR 5/1), 85% fine to medium grained sand, subrounded to rounded; 15% fine to coarse gravel up to 40mm, subrounded to rounded; poorly sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	118		
119					119		
120					120		
121				SAND (SP): dark grayish brown (10YR 4/2), 90% fine to coarse grained sand, subangular to rounded; 10% fine to coarse gravel up to 35mm, subangular to rounded; trace silt; poorly sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	121		
122					122		
123					123		
124					124		
125					125		
126					126		
				GRAVEL AND COBBLES WITH SAND (GP): very dark gray (2.5Y 3/1), 85% fine to coarse gravel up to 75mm, subrounded to rounded, with			

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WELL NUMBER **B-3**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Lithologic Log

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
127				cobbles up to 100mm; 15% fine to coarse grained sand, subrounded to rounded; poorly sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	127		
128					128		
129					129		
130					130		
131				SAND WITH GRAVEL AND COBBLES (SP): dark gray (2.5Y 4/1), 80% fine to coarse grained sand, subrounded to rounded; 20% fine to coarse gravel up to 75mm, subrounded to rounded, with cobbles up to 125mm; trace clay; poorly sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	131		
132	Backfill				132		
133					133		
134					134		
135					135		
136				SAND WITH GRAVEL AND COBBLES (SP): grayish brown (2.5Y 5/2), 60% fine to coarse grained sand, subrounded to rounded; 40% fine to coarse gravel up to 75mm, subrounded to rounded, with cobbles up to 125mm; trace clay; poorly sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	136		
137					137		
138				SAND (SP): gray (2.5Y 5/1), 100% fine to coarse grained sand, subrounded; trace cobbles up to 125mm; medium sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	138		
139					139		
140					140		
141				SAND WITH GRAVEL AND COBBLES (SP): very dark gray (2.5Y 3/1), 80% fine to coarse grained sand, subangular to rounded; 20% fine to coarse gravel up to 75mm, subangular to rounded, meta-sedimentary origins, with cobbles up to 125mm; poorly sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	141		
142					142		
143					143		
144					144		
145				SAND (SP): gray (2.5Y 5/1), 100% fine to medium grained sand, subrounded; medium sorted; moist sample; contains quartz, feldspar and mica, with visible alteration.	145		
146				SAND WITH GRAVEL AND COBBLES (SP): dark greenish gray (5GY 4/1), 60% fine to coarse grained sand, subrounded to rounded; 40% fine to coarse gravel up to 75mm, subrounded to rounded, meta-sedimentary origins, with cobbles up to 80mm; trace clay; poorly sorted; wet sample; contains quartz, feldspar and mica, with visible alteration.	146		
147					147		
148					148		
149					149		
150					150		
151				SAND WITH CLAY (SP-SC): dark greenish gray (5GY 4/1), 90% fine to coarse grained sand, subrounded to rounded; 10% clay; trace cobbles up to 80mm; trace fine to coarse gravel up to 75mm, subrounded to rounded, meta-sedimentary origins; poorly sorted; contains quartz, feldspar and mica, with visible alteration.	151		
152					152		
153					153		
				SAND WITH GRAVEL AND COBBLES (SP): dark greenish gray (5GY			

WELL CONSTRUCTION LOG MWDOC_BH-3.GPJ GEOSCIENCE.GDT 9/2/05

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WELL NUMBER **B-3**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	Lithologic Log NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
154				4/1), 80% fine to coarse grained sand, subrounded to rounded; 15% fine to coarse gravel up to 75mm, subrounded to rounded, meta-sedimentary origins, with cobbles up to 90mm; 5% clay; poorly sorted; contains quartz, feldspar and mica, with visible alteration.	154		
155	Backfill				155		
156				CLAYEY SAND (SC): dark greenish gray (5GY 4/1), 80% fine to coarse grained sand, subrounded, mostly fine sand, trace coarse sand; 20% clay; medium sorted; moderate cementation; contains quartz, feldspar and mica, with visible alteration.	156		
157					157		
158					158		
159					159		
160					160		
161					161		
162					162		
163					163		
164					164		
165					165		
166				SAND WITH CLAY (SP-SC): dark greenish gray (5GY 4/1), 90% fine to coarse grained sand, subangular to subrounded, mostly fine sand; 10% clay; poorly sorted; moderate cementation; contains quartz, feldspar and mica, with visible alteration; hydrogen sulfide odor.	166		
167					167		
168				CLAY (CL): dark greenish gray (5GY 4/1), 90% clay, medium plasticity, organic and thinly laminated; 10% fine to medium grained sand, subangular to subrounded, mostly fine sand; moderate cementation; contains quartz, feldspar and mica, with visible alteration; hydrogen sulfide odor.	168		
169					169		
170					170		
171				SAND WITH CLAY (SP-SC): dark greenish gray (5GY 4/1), 90% fine to medium grained sand, subangular to subrounded, mostly fine sand; 10% clay; well sorted; moderate cementation; contains quartz, feldspar and mica, with visible alteration; hydrogen sulfide odor.	171		
172					172		
173				CLAY (CL): dark greenish gray (5GY 4/1), 90% clay, medium plasticity, organic and thinly laminated; 10% fine to medium grained sand, subangular to subrounded, mostly fine sand; moderate cementation; contains quartz, feldspar and mica, with visible alteration; hydrogen sulfide odor.	173		
174					174		
175					175		
176				SAND WITH CLAY (SP-SC): dark greenish gray (5GY 4/1), 90% fine to medium grained sand, subangular to subrounded; 10% clay; medium sorted; moderate cementation; contains quartz, feldspar and mica, hydrogen sulfide odor.	176		
177					177		
178				CLAY (CL): dark greenish gray (5GY 4/1), 90% clay, organic and thinly laminated; 10% sand, subangular to subrounded; moderate cementation; contains quartz, feldspar and mica, hydrogen sulfide odor.	178		
179					179		
180					180		

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WELL NUMBER **B-3**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Lithologic Log

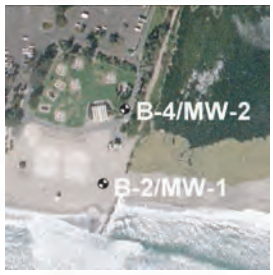
Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
181					181		

Bottom of borehole at 181 feet.

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WELL LOCATION MAP



MAP SCALE: 625 ft:1 in.

WELL NUMBER
B-4/MW-2

BOREHOLE LITHOLOGIC LOG

CLIENT Municipal Water District of Orange County	LOCATION **Dana Point, California**
PROJECT NUMBER 1250-04	**North of Main Life Guard Tower, Doheny State Beach**
REPORT DATE OCT-05	
DRILLING CONTRACTOR Boart Longyear Environmental Drilling	LOGGED BY **T. Watkins and D. Field**
DRILLER	

		SCREEN / BLANK	TOP DEPTH (ft bgs)	BOTTOM DEPTH (ft bgs)	LENGTH (ft)	MATERIAL	WALL THICKNESS (in.)	DIAMETER (in.)	SCREEN TYPE	PERF. SIZE (in.)
DRILLING RIG TYPE	Roto-Sonic									
DRILLING METHOD	Sonic Drilling Method									
SAMPLING METHOD	Core									
BOREHOLE DIAMETER	10 in									
SURFACE ELEVATION										
TOC ELEVATION										
START DATE	3/07/05									
FINISH DATE	3/08/05									

Lithologic Log

Depth bgs (feet)		Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
1	Cement seal			SAND (SP): very dark gray (10YR 3/1), 100% fine to coarse grained sand, subrounded; poorly sorted; moist sample; contains quartz, feldspar and mica.	1		
2	Blank casing				2		
3	Blank casing				3		
4	Blank casing			CLAYEY SAND (SC): very dark gray (10YR 3/1), 70% fine to coarse grained sand, subrounded; 30% clay, low to medium plasticity; poorly sorted; moist sample; contains quartz, feldspar and mica.	4		
5				NO SAMPLE.	5		
6				SAND (SP): brown (10YR 4/3), 95% fine to coarse grained sand, subrounded; 5% clay, low plasticity, increasing clay with depth; poorly sorted; moist sample; contains quartz, feldspar and mica.	6		
7	Filter pack			CLAY WITH SAND (CL): dark gray (10YR 4/1), 80% clay, low to medium plasticity; 20% fine to coarse grained sand, subrounded; moist sample; contains quartz, feldspar and mica.	7		
8				SANDY CLAY (CL): dark grayish brown (10YR 4/2), 70% clay, low to medium plasticity; 30% fine to medium grained sand, subrounded; trace silt; moist sample; contains quartz, feldspar and mica, trace plant	8		

WELL CONSTRUCTION LOG MWDOC_BH-4_MW2.GPJ GEOSCIENCE.GDT 9-2-05

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WELL NUMBER **B-4/MW-2**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	Lithologic Log NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
				fragments.			
9	Blank casing			CLAY (CL): very dark gray (10YR 3/1), 95% clay, low to medium plasticity; 5% fine grained sand; trace silt; moist sample; contains mica.	9		
10	2/07/05 ▼			SAND (SP): very dark gray (N3), 100% fine to coarse grained sand, subrounded; trace fine gravel up to 18mm, subrounded, meta-sedimentary origin; poorly sorted; wet sample; contains quartz, feldspar and mica.	10		
11	Well screen				11		
				SAND (SP): gray (2.5Y 5/1), 100% fine to coarse grained sand, subrounded; trace fine to coarse gravel up to 32mm, subrounded, meta-sedimentary origin; poorly sorted; wet sample; contains quartz, feldspar and mica.		
12	Blank casing				12		
				SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 75% fine to coarse grained sand, subrounded; 25% fine to coarse gravel up to 45mm, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.		
13	Blank casing				13		
14	Filter pack				14		
15				SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 70% fine to coarse grained sand, subrounded; 30% fine to coarse gravel up to 20mm, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica, "kelp" or sticks in sample.	15		
16					16		
17				SAND (SP): dark gray (2.5Y 4/1), 95% fine to coarse grained sand, subangular to subrounded; 5% fine to coarse gravel up to 50mm, subangular to subrounded, meta-sedimentary origin, some broken gravel; poorly sorted; wet sample; contains quartz, feldspar and mica.	17		
18				SAND WITH GRAVEL (SP): very dark gray (N3), 85% fine to coarse grained sand, subrounded; 15% fine to coarse gravel up to 35mm, subrounded, meta-sedimentary origin; poorly sorted; wet sample; contains quartz, feldspar and mica.	18		

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WELL NUMBER **B-4/MW-2**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Lithologic Log

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
19					19		
20	Filter pack			SAND (SP): very dark gray (N3), 100% fine to coarse grained sand, subrounded; trace fine gravel up to 10mm, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	20		
21	Well screen				21		
22	Blank casing			SAND (SP): very dark gray (N3), 90% fine to coarse grained sand, subrounded; 10% fine to coarse gravel up to 35mm, subrounded, meta-sedimentary origin; trace low plasticity clay balls; poorly sorted; contains quartz, feldspar and mica.	22		
				GRAVEL WITH SAND (GP): very dark gray (N3), 60% fine to coarse gravel up to 75mm, subangular to subrounded, meta-sedimentary origin; 40% fine to coarse grained sand, subangular to subrounded; trace cobbles up to 85mm; poorly sorted; contains quartz, feldspar and mica.			
23	Blank casing			GRAVEL WITH SAND (GP): very dark gray (N3), 70% fine to coarse gravel up to 40mm, subrounded, meta-sedimentary origin; 30% fine to coarse grained sand, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	23		
				SAND (SP): very dark gray (N3), 95% fine to coarse grained sand, subrounded; 5% fine to coarse gravel up to 30mm, subrounded; trace cobbles up to 110mm; poorly sorted; wet sample; contains quartz, feldspar and mica.			
24					24		
25				FAT CLAY (CH): (10Y 3/1), 95% clay, high plasticity; 5% fine to coarse grained sand, subrounded; weak cementation; contains quartz, feldspar and mica.	25		
26	Blank casing with end cap				26		
				FAT CLAY (CH): (10Y 2.5/1), 100% clay, high plasticity, some small cemented clay fragments; moist sample; weak cementation.			
27					27		
				SANDY FAT CLAY (CH): (10Y 4/1), 60% clay, medium plasticity, some small cemented clay fragments; 40% fine to medium grained sand, subrounded; wet sample; weak cementation; contains quartz, feldspar and mica.			
28					28		
29					29		

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WELL NUMBER **B-4/MW-2**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Lithologic Log

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
30					30		
				SAND WITH GRAVEL (SP): very dark gray (N3), 85% fine to coarse grained sand, subrounded; 15% fine gravel up to 11mm, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.			
31	Cement seal				31		
				SAND (SP): dark greenish gray (5GY 4/1), 95% fine to medium grained sand, subrounded; 5% silt; poorly sorted; wet sample; contains quartz, feldspar and mica.			
32	Blank casing				32		
				FAT CLAY (CH): (10Y 4/1), 100% clay, high plasticity; trace fine grained sand; trace silt; moist sample; contains quartz, feldspar and mica.			
33	Blank casing				33		
34					34		
				SAND (SP): (10Y 4/1), 100% fine to coarse grained sand, subrounded, trace coarse sand; trace silt; poorly sorted; wet sample; contains quartz, feldspar and mica.			
35					35		
				SAND (SP): very dark gray (N3), 100% fine to coarse grained sand, subrounded, sand grades finer with depth; trace clay; poorly sorted; wet sample; contains quartz, feldspar and mica.			
36					36		
				CLAYEY SAND (SC): very dark gray (N3), 60% fine to coarse grained sand, subrounded; 40% clay, medium plasticity; poorly sorted; wet sample; contains quartz, feldspar and mica.			
37					37		
				SAND WITH CLAY (SP-SC): (10Y 3/1), 90% fine to coarse grained sand, subrounded; 10% clay, low plasticity; poorly sorted; wet sample; contains quartz, feldspar and mica.			
38	Filter pack				38		
39					39		
				SAND (SP): dark gray (2.5Y 4/1), 95% fine to medium grained sand, subrounded; 5% clay, some low plasticity clay balls; medium sorted; wet sample; contains quartz, feldspar and mica.			
40					40		

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WELL NUMBER **B-4/MW-2**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	Lithologic Log NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
41	Filter pack			SAND (SP): (10Y 4/1), 100% fine to coarse grained sand, subrounded; trace fine to coarse gravel up to 28mm, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	41		
42	Well screen				42		
43	Blank casing			SAND (SP): dark gray (2.5Y 4/1), 100% fine to medium grained sand, subrounded; medium sorted; wet sample; contains quartz, feldspar and mica.	43		
44				SAND (SP): dark gray (2.5Y 4/1), 100% fine to coarse grained sand, subrounded; trace fine to coarse gravel up to 60mm, subrounded, meta-sedimentary origins; poorly sorted; wet sample; contains quartz, feldspar and mica.	44		
45					45		
46				SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 85% fine to coarse grained sand, subrounded; 15% fine to coarse gravel up to 50mm, subrounded, meta-sedimentary and granitic origins; poorly sorted; wet sample; contains quartz, feldspar and mica.	46		
47					47		
48				SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 80% fine to coarse grained sand, subrounded; 20% fine to coarse gravel up to 30mm, subrounded; thin clay layer from 48.9-49.0 ft bgs; poorly sorted; wet sample; contains quartz, feldspar and mica.	48		
49				CLAY WITH SAND (CL): very dark gray (N3), 80% clay, low plasticity; 20% fine to coarse grained sand, subrounded; trace fine to coarse gravel up to 20mm, subrounded; moist sample; contains quartz, feldspar and mica.	49		
50				SAND (SP): dark gray (2.5Y 4/1), 90% fine to coarse grained sand, subrounded; 10% fine to coarse gravel up to 50mm, subrounded, meta-sedimentary origins; poorly sorted; contains quartz, feldspar and mica.	50		

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WELL NUMBER **B-4/MW-2**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	Lithologic Log NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
51					51		
52	Filter pack				52		
53	Well screen			SAND (SP): dark gray (2.5Y 4/1), 95% fine to coarse grained sand, subangular to subrounded; 5% fine to coarse gravel up to 42mm, subangular to subrounded, meta-sedimentary and granitic origins, some broken gravel; poorly sorted; contains quartz, feldspar and mica.	53		
54	Blank casing				54		
55				SAND (SP): dark gray (2.5Y 4/1), 95% fine to coarse grained sand, subrounded; 5% fine to coarse gravel up to 30mm, subrounded, meta-sedimentary origins; poorly sorted; contains quartz, feldspar and mica.	55		
56					56		
57					57		
58				SAND (SP): dark gray (2.5Y 4/1), 100% fine to coarse grained sand, subrounded; trace fine to coarse gravel up to 20mm, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	58		
59					59		
60				SAND (SP): dark gray (2.5Y 4/1), 100% fine to coarse grained sand, subrounded; trace fine gravel up to 12mm, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	60		
61					61		

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WELL NUMBER **B-4/MW-2**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Lithologic Log

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
62					62		
63	Filter pack				63		
64	Well screen			SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 60% fine to coarse grained sand, subrounded; 40% fine to coarse gravel up to 45mm, subrounded, meta-sedimentary origins; poorly sorted; wet sample; contains quartz, feldspar and mica.	64		
65	Blank casing			SAND WITH CLAY AND GRAVEL (SP-SC): very dark gray (N3), 75% fine to coarse grained sand, subrounded; 15% fine to coarse gravel up to 45mm, subrounded; 10% clay, low to medium plasicity; poorly sorted; wet sample; contains quartz, feldspar and mica.	65		
66					66		
67					67		
68				CLAY (CL): very dark gray (N3), 100% clay, low to medium plasticity; trace fine grained sand, subrounded; trace silt; wet sample; contains quartz, feldspar and mica.	68		
69				SAND WITH CLAY (SP-SC): very dark gray (N3), 90% fine to coarse grained sand, subrounded; 10% clay, low plasicity; well sorted; wet sample; contains mica.	69		
70				SAND WITH GRAVEL (SP): very dark gray (N3), 60% fine to coarse grained sand, subangular to subrounded; 40% fine to coarse gravel up to 60mm, subangular to subrounded, meta-sedimentary origins; trace silt; poorly sorted; wet sample; contains quartz, feldspar and mica.	70		
71				SAND (SP): very dark gray (N3), 85% fine to coarse grained sand, subrounded; 10% fine to coarse gravel up to 75mm, subrounded, meta-sedimentary origins; 5% clay; trace cobbles up to 105mm; poorly sorted; wet sample; contains quartz, feldspar and mica.	71		
72					72		

WELL CONSTRUCTION LOG MWDOC_BH-4_MW2.GPJ GEOSCIENCE.GDT 9/2/05

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WELL NUMBER **B-4/MW-2**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Lithologic Log

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
73	Filter pack			SAND (SP): dark gray (2.5Y 4/1), 85% fine to coarse grained sand, subrounded, lense of fine to medium sand and silt from 74-74.5 ft bgs; 10% fine to coarse gravel up to 75mm, subrounded; 5% clay; poorly sorted; wet sample; contains quartz, feldspar and mica.	73		
74	Well screen				74		
75	Blank casing			SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 75% fine to coarse grained sand, subrounded; 25% fine to coarse gravel up to 50mm, subrounded, meta-sedimentary origins; poorly sorted; wet sample; contains quartz, feldspar and mica.	75		
76					76		
77					77		
78				SAND (SP): dark gray (2.5Y 4/1), 90% fine to coarse grained sand, subrounded; 10% fine to coarse gravel up to 40mm, subrounded, meta-sedimentary origins; poorly sorted; contains quartz, feldspar and mica.	78		
79					79		
80				SAND (SP): dark gray (2.5Y 4/1), 95% fine to coarse grained sand, subrounded; 5% fine to coarse gravel up to 35mm, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	80		
81					81		
82					82		
				GRAVEL WITH SAND (GP): dark gray (2.5Y 4/1), 65% fine to coarse			

WELL CONSTRUCTION LOG MWDOC_BH-4_MW2.GPJ GEOSCIENCE.GDT 9/2/05

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WELL NUMBER **B-4/MW-2**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Lithologic Log

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
83				gravel up to 35mm, subrounded, meta-sedimentary origins; 35% fine to coarse grained sand, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	83		
				SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 80% fine to coarse grained sand, subrounded; 20% fine to coarse gravel up to 20mm, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.			
84	Filter pack			GRAVEL (GP): dark gray (2.5Y 4/1), 90% fine to coarse gravel up to 25mm, subrounded; 10% fine to coarse grained sand, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	84		
85	Well screen			SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 65% fine to coarse grained sand, subrounded; 35% fine to coarse gravel up to 75mm, subrounded; trace cobbles up to 100mm; poorly sorted; wet sample; contains quartz, feldspar and mica.	85		
86	Blank casing			SAND (SP): dark gray (2.5Y 4/1), 90% fine to coarse grained sand, subrounded; 10% fine to coarse gravel up to 50mm, subrounded; trace clay; poorly sorted; wet sample; contains quartz, feldspar and mica.	86		
87					87		
88				SILTY SAND (SM): (10Y 3/1), 65% fine to medium grained sand, subrounded; 35% silt; poorly sorted; wet sample; contains quartz, feldspar and mica.	88		
89					89		
90				SAND (SP): gray (2.5Y 5/1), 100% fine to coarse grained sand, subrounded; trace fine to coarse gravel up to 25mm, subrounded, meta-sedimentary origins; trace clay; poorly sorted; wet sample; contains quartz, feldspar and mica.	90		
91					91		
92					92		
93				SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 55% fine to coarse grained sand, subrounded; 45% fine to coarse gravel up to 75mm, subrounded; trace cobbles up to 105mm; poorly sorted; wet sample; contains quartz, feldspar and mica.	93		

WELL CONSTRUCTION LOG MWDOC_BH-4_MW2.GPJ GEOSCIENCE.GDT 9/2/05

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WELL NUMBER **B-4/MW-2**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Lithologic Log

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
94	Filter pack				94		
95	Well screen			SAND (SP): dark gray (2.5Y 4/1), 100% fine to coarse grained sand, subrounded; poorly sorted; contains quartz, feldspar and mica.	95		
96	Blank casing				96		
97					97		
98				SAND (SP): grayish brown (2.5Y 5/2), 100% fine to coarse grained sand, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	98		
99					99		
100				GRAVEL WITH SAND (GP): olive gray (5Y 4/2), 65% fine to coarse gravel up to 40mm, subrounded; 35% fine to coarse grained sand, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	100		
101				GRAVEL WITH SAND (GP): olive gray (5Y 4/2), 65% fine to coarse gravel up to 40mm, subrounded; 35% fine to coarse grained sand, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	101		
102				SAND (SP): olive gray (5Y 5/2), 100% fine to coarse grained sand, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	102		
103				SAND WITH GRAVEL (SP): olive gray (5Y 4/2), 75% fine to coarse grained sand, subrounded; 25% fine to coarse gravel up to 75mm, subrounded, meta-sedimentary origins; trace cobbles up to 90mm; trace clay; poorly sorted; wet sample; contains quartz, feldspar and mica.	103		
104					104		

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WELL NUMBER **B-4/MW-2**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Lithologic Log

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
105	Filter pack			GRAVEL WITH SAND (GP): olive gray (5Y 4/2), 70% fine to coarse gravel up to 60mm, subrounded, meta-sedimentary origins; 30% fine to coarse grained sand, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	105		
106	Well screen				106		
107	Blank casing			GRAVEL WITH CLAY AND SAND (GP-GC): very dark gray (5Y 3/1), 60% fine to coarse gravel up to 60mm, subrounded; 30% fine to coarse grained sand, subrounded; 10% clay, low plasicity; poorly sorted; wet sample; contains quartz, feldspar and mica.	107		
108				SAND WITH GRAVEL (SP): dark gray (5Y 4/1), 65% fine to coarse grained sand, subrounded; 35% fine to coarse gravel up to 50mm, subrounded; trace silt; poorly sorted; wet sample; contains quartz, feldspar and mica.	108		
109				SANDY CLAY (CL): very dark gray (5Y 3/1), 70% clay, low to medium plasticity; 30% fine to medium grained sand, subrounded; trace silt; wet sample; contains quartz, feldspar and mica.	109		
110				SANDY SILT (ML): dark gray (5Y 4/1), 60% silt; 40% fine to coarse grained sand, subrounded; up to 60mm; wet sample; contains quartz, feldspar and mica.	110		
111				SAND WITH GRAVEL (SP): grayish brown (2.5Y 5/2), 55% fine to coarse grained sand, subangular to subrounded; 40% fine to coarse gravel up to 75mm, subangular to subrounded, meta-sedimentary, granitic/igneous and volcanic origins; 5% cobbles up to 165mm; poorly sorted; wet sample; contains quartz, feldspar and mica.	111		
112					112		
113				SAND WITH GRAVEL (SP): grayish brown (2.5Y 5/2), 65% fine to coarse grained sand, subangular to subrounded; 35% fine to coarse gravel up to 75mm, subangular to subrounded; trace cobbles up to 90mm; poorly sorted; wet sample; contains quartz, feldspar and mica, broken.	113		
114					114		
				CLAYEY GRAVEL WITH SAND (GC): very dark gray (5Y 3/1), 45% fine			

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WELL NUMBER **B-4/MW-2**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Lithologic Log

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
115				to coarse gravel up to 40mm, subrounded; 30% fine to coarse grained sand, subrounded; 25% clay, medium plasticity, low plasicity; poorly sorted; wet sample; contains quartz, feldspar and mica.	115		
				SAND (SP): dark gray (2.5Y 4/1), 90% fine to coarse grained sand, subrounded; 10% fine to coarse gravel up to 50mm, subrounded, meta-sedimentary origins; trace clay; poorly sorted; wet sample; contains quartz, feldspar and mica.			
116	Filter pack				116		
117	Well screen			GRAVEL WITH SAND (GP): dark gray (2.5Y 4/1), 55% fine to coarse gravel up to 50mm, subrounded, meta-sedimentary origins; 45% fine to coarse grained sand, subrounded; poorly sorted; wet sample; contains quartz, feldspar and mica.	117		
				SAND WITH GRAVEL (SP): dark grayish brown (2.5Y 4/2), 60% fine to coarse grained sand, subrounded; 40% fine to coarse gravel up to 75mm, subrounded, meta-sedimentary gravel; trace cobbles up to 90mm; trace clay, trace low plasticity clay balls; poorly sorted; contains quartz, feldspar and mica.			
118	Blank casing				118		
119					119		
120				SAND WITH GRAVEL (SP): dark grayish brown (2.5Y 4/2), 60% fine to coarse grained sand, subrounded; 40% fine to coarse gravel up to 75mm, subrounded, meta-sedimentary and granitic, some broken gravel; poorly sorted; contains quartz, feldspar and mica.	120		
121					121		
122					122		
123				GRAVEL WITH SAND (GP): dark grayish brown (2.5Y 4/2), 70% fine to coarse gravel up to 70mm, subrounded, meta-sedimentary; 30% fine to coarse grained sand, subrounded; poorly sorted; contains quartz, feldspar and mica.	123		
124					124		
125				GRAVEL WITH SAND (GP): grayish brown (2.5Y 5/2), 55% fine to coarse gravel up to 70mm, subrounded, meta-sedimentary; 45% fine to	125		

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BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Lithologic Log

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
				coarse grained sand, subrounded; poorly sorted; contains quartz, feldspar and mica.			
126	Filter pack				126		
127	Well screen with end cap				127		
128	Blank casing			GRAVEL WITH SAND (GP): grayish brown (2.5Y 5/2), 55% fine to coarse gravel up to 75mm, subrounded, meta-sedimentary; 40% fine to coarse grained sand, subrounded; 5% clay; trace cobbles up to 90mm; poorly sorted; contains quartz, feldspar and mica.	128		
129					129		
130				GRAVEL WITH SAND (GP): dark grayish brown (2.5Y 4/2), 55% fine to coarse gravel up to 75mm, subrounded; 45% fine to coarse grained sand, subrounded; 5% cobbles up to 90mm; poorly sorted; contains quartz, feldspar and mica.	130		
131					131		
132	Cement seal				132		
133				SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 55% fine to coarse grained sand, subrounded; 40% fine to coarse gravel up to 75mm, subrounded, meta-sedimentary and granitic origins; 5% cobbles up to 110mm; trace clay; poorly sorted; contains quartz, feldspar and mica.	133		
134					134		
135				GRAVEL WITH SAND (GP): dark gray (2.5Y 4/1), 75% fine to coarse gravel up to 45mm, subrounded; 25% fine to coarse grained sand, subrounded; poorly sorted; contains quartz, feldspar and mica.	135		
136				SAND WITH GRAVEL (SP): dark gray (2.5Y 4/1), 70% fine to coarse grained sand, subrounded; 30% fine to coarse gravel up to 40mm, subrounded, meta-sedimentary origins; poorly sorted; contains quartz,	136		

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WELL NUMBER **B-4/MW-2**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	Lithologic Log NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
				feldspar and mica.			
137					137		
				SAND WITH CLAY AND GRAVEL (SP-SC): dark gray (5Y 4/1), 50% fine to coarse grained sand, subrounded; 40% fine to coarse gravel up to 50mm, subrounded, meta-sedimentary origins; 10% clay; poorly sorted; contains quartz, feldspar and mica.			
138	Filter pack				138		
139	Blank casing				139		
140				GRAVEL WITH COBBLES (GP): olive gray (5Y 4/2), 50% fine to coarse gravel up to 75mm, subrounded, meta-sedimentary origins; 35% fine to coarse grained sand, subrounded; 5% clay; 10% cobbles up to 100mm; poorly sorted; wet sample; contains quartz, feldspar and mica.	140		
141	Well screen				141		
142				GRAVEL WITH SAND (GP): olive gray (5Y 4/2), 55% fine to coarse gravel up to 75mm, subrounded, meta-sedimentary origins; 40% fine to coarse grained sand, subrounded; 5% clay; trace cobbles up to 90mm; poorly sorted; wet sample; contains quartz, feldspar and mica.	142		
143				SAND (SP): light olive brown (2.5Y 5/4), 100% fine to coarse grained sand, subrounded, trace coarse sand; poorly sorted; wet sample; contains quartz, feldspar and mica.	143		
144					144		
145				SAND (SP): very dark gray (N3), 95% fine to coarse grained sand, subrounded, trace coarse sand; 5% clay; poorly sorted; wet sample; contains quartz, feldspar and mica.	145		
146					146		

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BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	Lithologic Log NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
147					147		
				SAND (SP): very dark gray (N3), 95% fine to coarse grained sand, subrounded, trace coarse sand; 5% clay; poorly sorted; wet sample; contains quartz, feldspar and mica.			
148	Filter pack				148		
149	Well screen				149		
150				SAND (SP): very dark gray (N3), 95% fine to medium grained sand, subrounded, trace coarse sand; 5% clay; poorly sorted; wet sample; contains quartz, feldspar and mica.	150		
151					151		
152					152		
				SAND (SP): very dark gray (N3), 95% fine to medium grained sand, subrounded, trace coarse sand; 5% clay; poorly sorted; wet sample; contains quartz, feldspar and mica.			
153					153		
154					154		
155				SAND (SP): dark gray (N4), 95% fine to coarse grained sand, subrounded, trace coarse sand; 5% clay; trace fine gravel up to 6mm, subrounded; poorly sorted; contains quartz, feldspar and mica.	155		
156					156		
157					157		

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WELL NUMBER **B-4/MW-2**

BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	Lithologic Log NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
158					158		
159	Filter pack			SAND (SP): dark gray (N4), 95% fine to coarse grained sand, subrounded, trace coarse sand; 5% clay; trace fine gravel up to 6mm, subrounded; poorly sorted; contains quartz, feldspar and mica.	159		
160	Well screen				160		
161					161		
162				SAND (SP): very dark gray (N3), 95% fine to coarse grained sand, subrounded, trace coarse sand; 5% clay; trace fine gravel up to 6mm, subrounded; poorly sorted; contains quartz, feldspar and mica.	162		
163					163		
164				NO SAMPLE.	164		
165				SAND (SP): very dark gray (N3), 95% fine to coarse grained sand, subrounded; 5% clay; poorly sorted; contains quartz, feldspar and mica.	165		
166	Blank casing with end cap				166		
167				CLAY (CL): (10Y 3/1), 100% clay, low plasticity, hard, dry and dense; trace silt.	167		
168				CLAY (CL): (10Y 5/1), 100% clay, low to medium plasticity, hard, dry, dense and moderately cemented; trace silt.	168		

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BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	Lithologic Log NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
169	Filter pack			CLAY (CL): very dark gray (N3), 100% clay, low to medium plasticity, moderately cemented from 169-170 and dense, hard, dry, some odor and some cemented fragments from 170-171; trace silt.	169		
170					170		
171	Backfill			SAND (SP): very dark gray (N3), 95% fine to coarse grained sand, subrounded; 5% clay; poorly sorted; contains quartz, feldspar and mica.	171		
172				SILT (ML): (10Y 2.5/1), 100% silt, hard, moist, dense and weakly lithified; trace clay.	172		
173				SILT (ML): (10Y 2.5/1), 100% silt, hard, moist, dense and weakly lithified; trace clay.	173		
174				SAND (SP): very dark gray (N3), 95% fine to coarse grained sand, subrounded; 5% clay; poorly sorted; contains quartz, feldspar and mica.	174		
175				SAND (SP): very dark gray (N3), 95% fine to coarse grained sand, subrounded; 5% clay; poorly sorted; contains quartz, feldspar and mica.	175		
176					176		
177				SAND (SP): very dark gray (N3), 95% fine to coarse grained sand, subrounded; 5% clay; poorly sorted; contains quartz, feldspar and mica.	177		
178				SILT (ML): (10Y 2.5/1), 95% silt, hard, moist, dense and weakly lithified;	178		

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BOREHOLE LITHOLOGIC LOG (continued)

CLIENT Municipal Water District of Orange County
PROJECT NUMBER 1250-04
LOCATION **Dana Point, California**

Depth bgs (feet)	(continued)	Zone Test	Graphic Log	Lithologic Log NOTE: Grain size distribution percentages are approximate. Material code (e.g. SP) reference Unified Soil Classification visual method. Color code (e.g. 10YR 5/2) reference Munsell Soil Color Charts.	Depth bgs (feet)	Sieve Sample Number	Drill Rate (ft/hr)
179				5% fine grained sand, subrounded, some layered fine pockets of sand; trace clay; contains quartz, feldspar and mica.	179		
180	Backfill				180		
181				SAND (SP): dark gray (N4), 95% fine to coarse grained sand, subrounded, trace coarse sand; 5% clay; poorly sorted; contains quartz, feldspar and mica.	181		
182					182		
183				SAND (SP): dark gray (N4), 95% fine to coarse grained sand, subrounded, trace coarse sand; 5% clay; poorly sorted; contains quartz, feldspar and mica.	183		
184					184		
185				SAND (SP): dark gray (N4), 95% fine to coarse grained sand, subrounded; 5% clay, very finely bedded silt/clay layers.; poorly sorted; contains quartz, feldspar and mica.	185		
186					186		
187					187		
188				Bottom of borehole at 188 feet.	188		

WELL CONSTRUCTION LOG MWDOC_BH-4_MW2.GPJ GEOSCIENCE.GDT 9/2/05

NINYO & MOORE 2004 AND 2007

J.B. LATHAM BORING LOGS

DATE DRILLED 11/5/04 BORING NO. B-1

GROUND ELEVATION 15' ± (MSL) SHEET 1 OF 3

METHOD OF DRILLING 8" Hollow-Stem Auger (Jet Drilling Co.)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY MKC LOGGED BY MKC REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0							ASPHALT CONCRETE:
						GP	Approximately 5.5 inches thick.
						SP/SM	BASE: Light brown, dry to damp, medium dense, sandy fine to coarse GRAVEL; approximately 5 inches thick.
							FILL: Brown, damp, loose to medium dense, fine to coarse SAND to silty fine to coarse SAND.
							Wet.
5			▽				@5': Groundwater encountered during drilling; saturated.
		7				SP	ALLUVIUM: Gray, saturated, loose, fine to medium poorly graded SAND; trace silt.
10		14					Medium dense; fine to coarse SAND.
15		16					Few fine gravel.
20							

Ninyo & Moore

BORING LOG

Fuel/Oil Container Pad - J.B. Latham Treatment Plant
Dana Point, California

PROJECT NO.	DATE	FIGURE
206037001	12/2004	A-1

DATE DRILLED 11/5/04 BORING NO. B-1

GROUND ELEVATION 15' ± (MSL) SHEET 2 OF 3

METHOD OF DRILLING 8" Hollow-Stem Auger (Jet Drilling Co.)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY MKC LOGGED BY MKC REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
20		47				SP	ALLUVIUM: (Continued) Gray, saturated, very dense, coarse SAND; trace fine gravel.
						CL	Gray, saturated, firm, silty CLAY.
25		5					
30		12					Stiff.
35		7					Firm; few fine sand.
40							

Ninyo & Moore

BORING LOG

Fuel/Oil Container Pad - J.B. Latham Treatment Plant
Dana Point, California

PROJECT NO.	DATE	FIGURE
206037001	12/2004	A-2

DATE DRILLED 11/5/04 BORING NO. B-1

GROUND ELEVATION 15' ± (MSL) SHEET 3 OF 3

METHOD OF DRILLING 8" Hollow-Stem Auger (Jet Drilling Co.)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY MKC LOGGED BY MKC REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
40		32				SM	ALLUVIUM: (Continued) Gray, saturated, dense, silty SAND.
45		13				SP-SM	Gray, saturated, medium dense, poorly graded to silty SAND.
50		55					Very dense; trace coarse gravel.
							Total Depth = 51.5 feet. Groundwater encountered during drilling at approximately 5 feet. Backfilled with bentonite-grout slurry and capped with asphalt concrete on 11/5/04.
55							
60							

Ninyo & Moore

BORING LOG

Fuel/Oil Container Pad - J.B. Latham Treatment Plant
Dana Point, California

PROJECT NO.	DATE	FIGURE
206037001	12/2004	A-3

DATE DRILLED 5/23/07 BORING NO. B-1

GROUND ELEVATION 9' ± (MSL) SHEET 1 OF 3

METHOD OF DRILLING 8" Hollow-Stem Auger (Baja Exploration)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY MKM LOGGED BY MKM REVIEWED BY JJB

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						SM	FILL: Brown, moist, loose, silty SAND; few roots; trace gravel.
5		6	11.3	114.3		SP	ALLUVIUM: Dark gray, moist, loose, poorly graded SAND with silt; trace gravel. @5': Groundwater encountered during drilling. Saturated. Scattered lenses of silty sand.
10		24					Dense.
15		33	15.7	112.3			Medium dense.
20							

Ninyo & Moore

BORING LOG

Power and Pumping Upgrades - J.B. Latham Treatment Plant
Dana Point, California

PROJECT NO.	DATE	FIGURE
207162001	7/07	A-1

DATE DRILLED 5/23/07 BORING NO. B-1

GROUND ELEVATION 9' ± (MSL) SHEET 2 OF 3

METHOD OF DRILLING 8" Hollow-Stem Auger (Baja Exploration)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY MKM LOGGED BY MKM REVIEWED BY JJB

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
20		22				SP-SM	ALLUVIUM: (Continued) Brown and gray mottled, saturated, dense, poorly graded coarse SAND with silt and gravel.
25		48					Dark gray; very dense.
30		62					
35		20					Scattered lenses of silty sand.
40							Gray.

Ninyo & Moore

BORING LOG

Power and Pumping Upgrades - J.B. Latham Treatment Plant
Dana Point, California

PROJECT NO.	DATE	FIGURE
207162001	7/07	A-2

DATE DRILLED 5/23/07 BORING NO. B-1

GROUND ELEVATION 9' ± (MSL) SHEET 3 OF 3

METHOD OF DRILLING 8" Hollow-Stem Auger (Baja Exploration)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY MKM LOGGED BY MKM REVIEWED BY JJB

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
40						SP-SM	ALLUVIUM: (Continued) Gray, saturated, very dense, poorly graded SAND with silt.
		91					
45		27					Dense.
50		60					Very dense.
							Total Depth = 51.5 feet. Groundwater encountered during drilling at approximately 5 feet. Backfilled with hydrated bentonite on 5/23/07. Note: Groundwater may rise to a level higher than that measured in borehole due to seasonal variations in precipitation and several other factors as discussed in the report.
55							
60							

Ninyo & Moore

BORING LOG

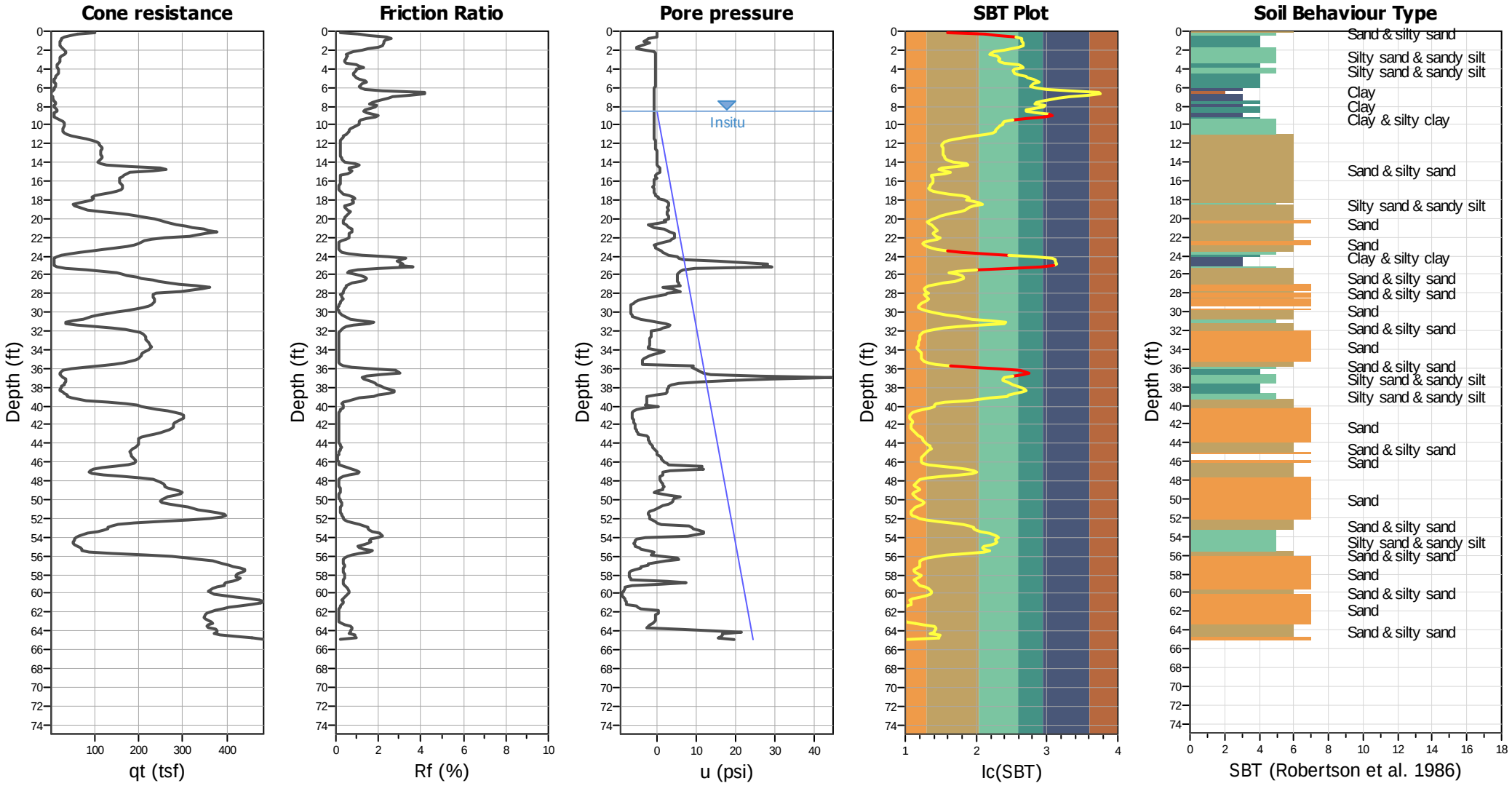
Power and Pumping Upgrades - J.B. Latham Treatment Plant
Dana Point, California

PROJECT NO.	DATE	FIGURE
207162001	7/07	A-3

GMU GEOTECHNICAL 2014

DEL OBISPO DEVELOPMENT CPT SOUNDINGS

CPT basic interpretation plots



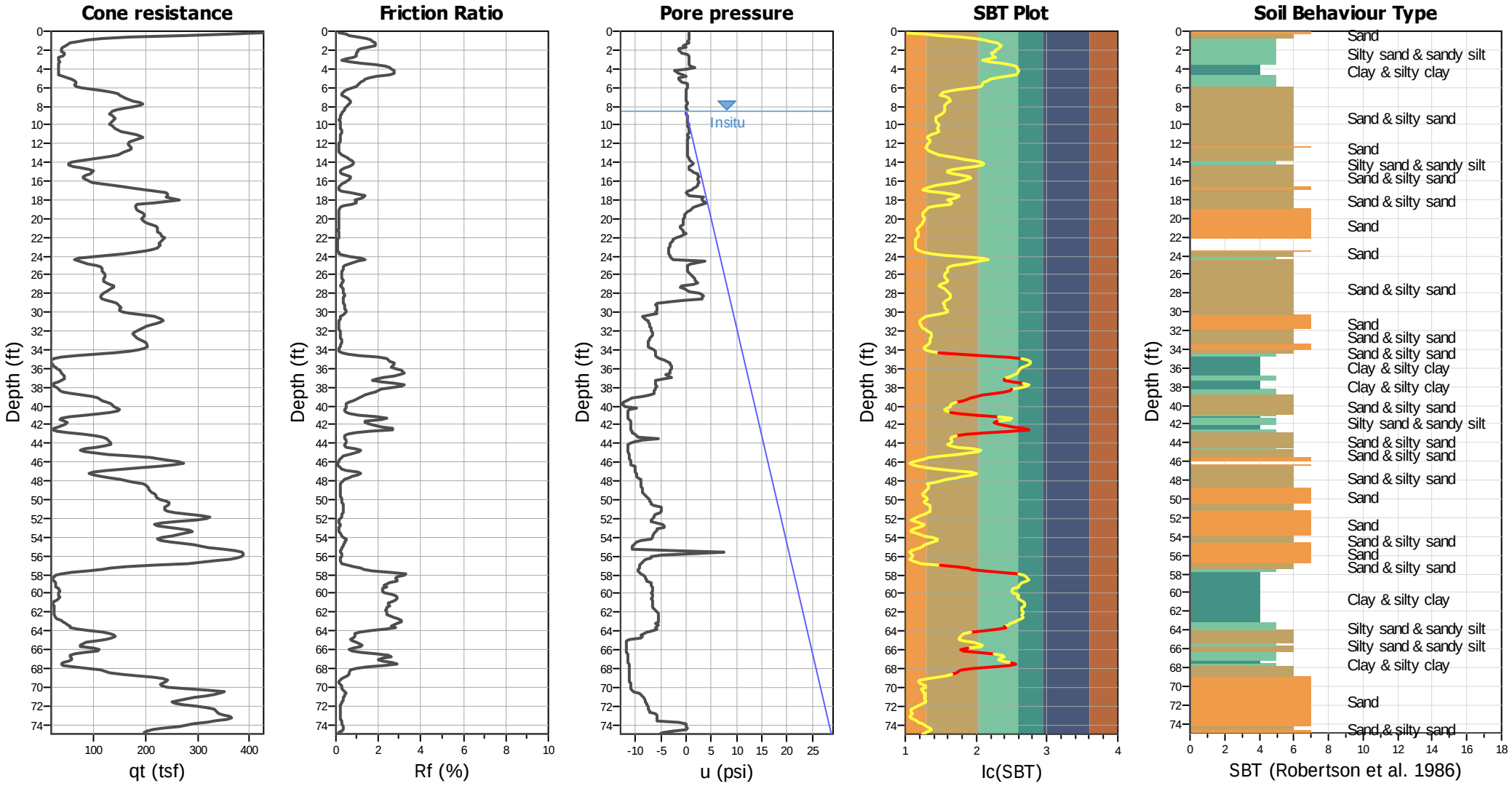
Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	7.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.45	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	8.50 ft	Fill height:	N/A	Limit depth:	N/A

SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

CPT basic interpretation plots



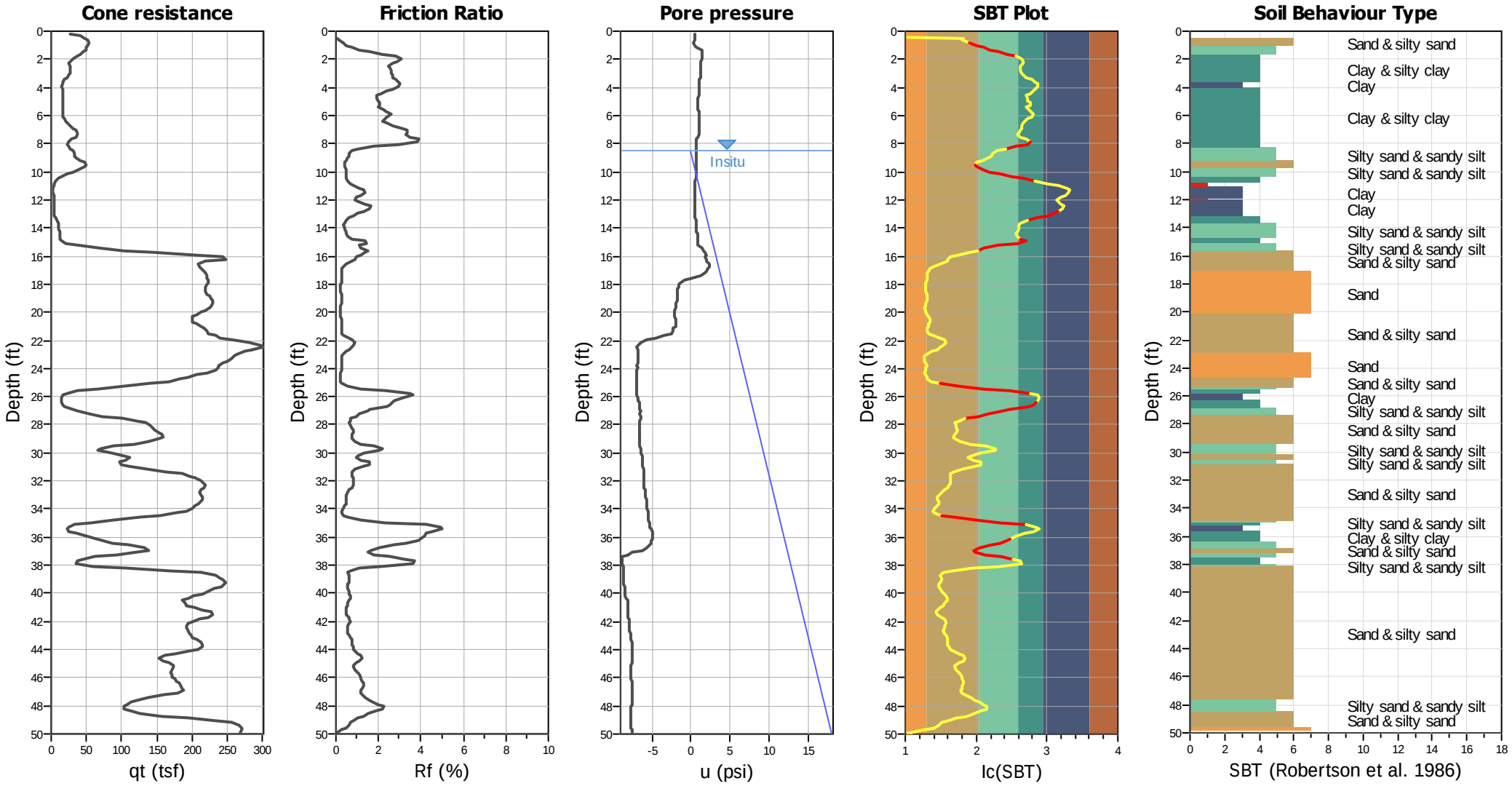
Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	7.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.45	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	8.50 ft	Fill height:	N/A	Limit depth:	N/A

SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

CPT basic interpretation plots



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	7.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.50	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.45	Use fill:	No	Limit depth applied:	Yes
Depth to water table (insitu):	8.50 ft	Fill height:	N/A	Limit depth:	50.00 ft

SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

APPENDIX B

COASTAL ENVIRONMENTS UPDATED COASTAL PROCESSES AND HYDRAULIC/HYDROLOGY STUDIES FOR DOHENY STATE BEACH DATED SEPTEMBER 11, 2014

UPDATED COASTAL PROCESSES AND HYDRAULIC/HYDROLOGY STUDIES FOR DOHENY STATE BEACH

TECHNICAL REPORT



for

South Coast Water District
31592 West Street
Laguna Beach, CA 92651

COASTAL ENVIRONMENTS
2166 Avenida de la Playa, Suite E
La Jolla, CA 92037

11 September 2014
CE Reference No. 14-15

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COASTAL PROCESSES AND HYDRAULIC/HYDROLOGY STUDIES FOR DOHENY STATE BEACH

1.0 INTRODUCTION

Doheny State Beach is situated in southern Orange County in the City of Dana Point, just south of Dana Point Harbor (Figure 1-1). The Doheny State Beach Park consists of 86 acres adjacent to the Pacific Coast Highway with frontage along 1.2 miles of the Pacific Ocean. San Juan Creek empties into the Pacific Ocean at Doheny State Beach (Figure 1-2).

As a part of an earlier plan in 2004 to construct a lifeguard headquarters, a study was deemed necessary to establish the risks of damage of the lifeguard headquarters building by coastal forces caused by wave or floods from San Juan Creek. This study was conducted by Coastal Environments (CE) in 2004 with the objective of assessing the following risks:

1. Reviewing the available oceanographic and coastal processes data for Doheny State Beach;
2. Conducting beach profile surveys in September 2004 at 10 ranges, both west and east of San Juan Creek;
3. Conducting an aerial survey of the beach on 7 September 2004 to evaluate possible errors as a result of estimating beach width from historical aerial photos;
4. Addressing the stability of the beach;
5. Describing the wave climate, tides, and sea level fluctuations in the area;
6. Determining the design waves and water levels for various return periods;
7. Conducting a runup analysis to determine the possibility of flooding by storm waves; and
8. Assessing the possibility of damage from San Juan Creek floods.

The purpose of this study is to update the previously conducted studies in order to address the impacts of sea level rise (SLR) on the beach width and profile, and estimate wave runup and overtopping and inundation of the beach or to the proposed desalination plant structures due to floods or tsunamis. The proposed plan expects to produce 15 mgd (million gallons per day) product water in phases. Phase 1 is 5 mgd. The proposed desalination plan schematics are shown in Figure 1-3.

For the reader's convenience and for completeness, we have included in this report some of the chapters from CE's previously conducted study in order to address coastal processes and hydraulic/hydrological studies at Doheny State Beach (CE, 2004). In the present report, these are Chapters 2 through 8. However, additional information was added to Chapter 4 and Chapter 5. These additions included extending the aerial photo set by adding additional photos from 2004 to the present and obtaining beach profile data at the east beach from 2001 to the present (Coastal Frontiers, Inc., 2014).

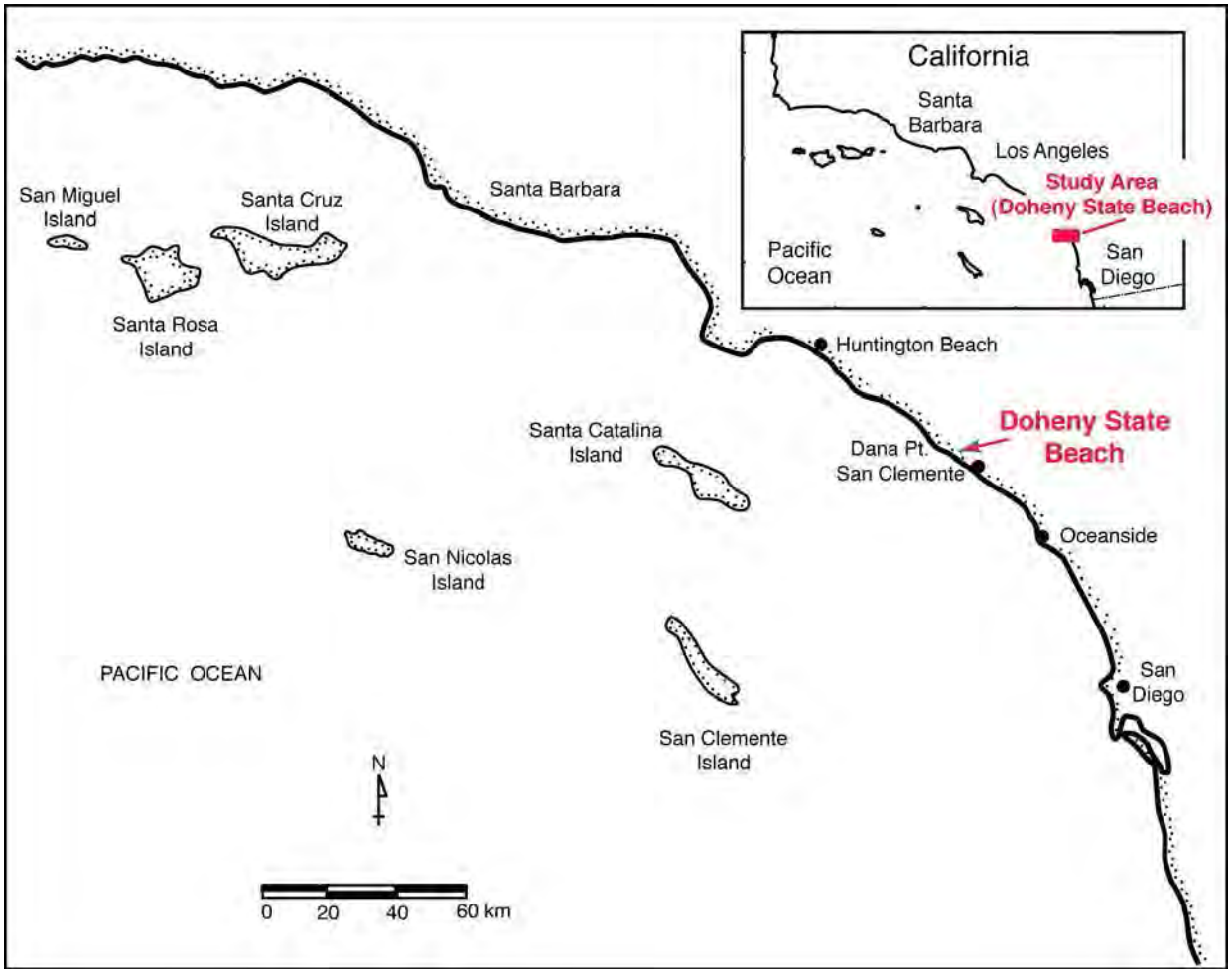


Figure 1-1. Location map of Doheny State Beach.

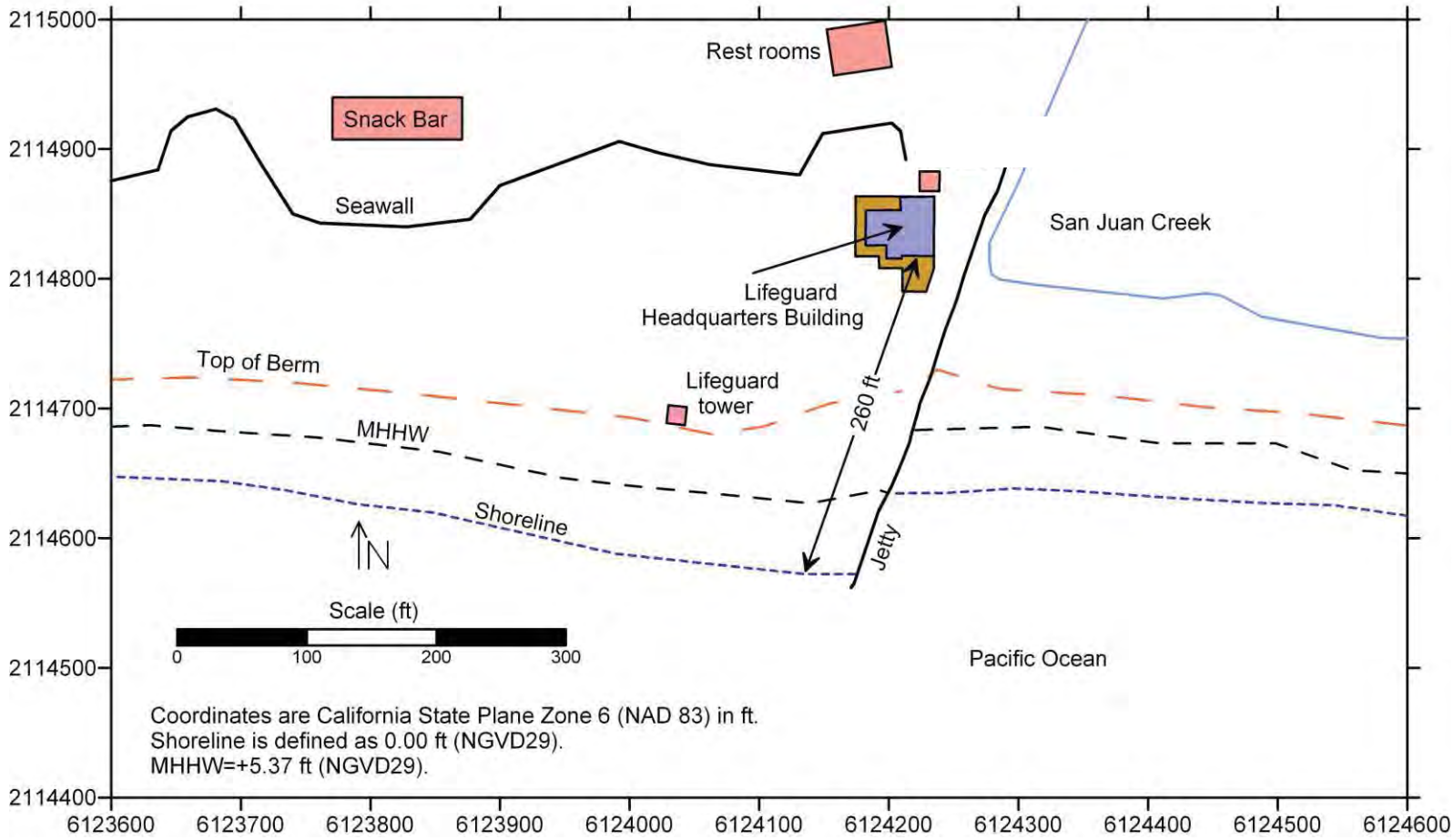


Figure 1-2. Map of Doheny State Beach showing the Beach west and east of San Juan Creek, and the shoreline.

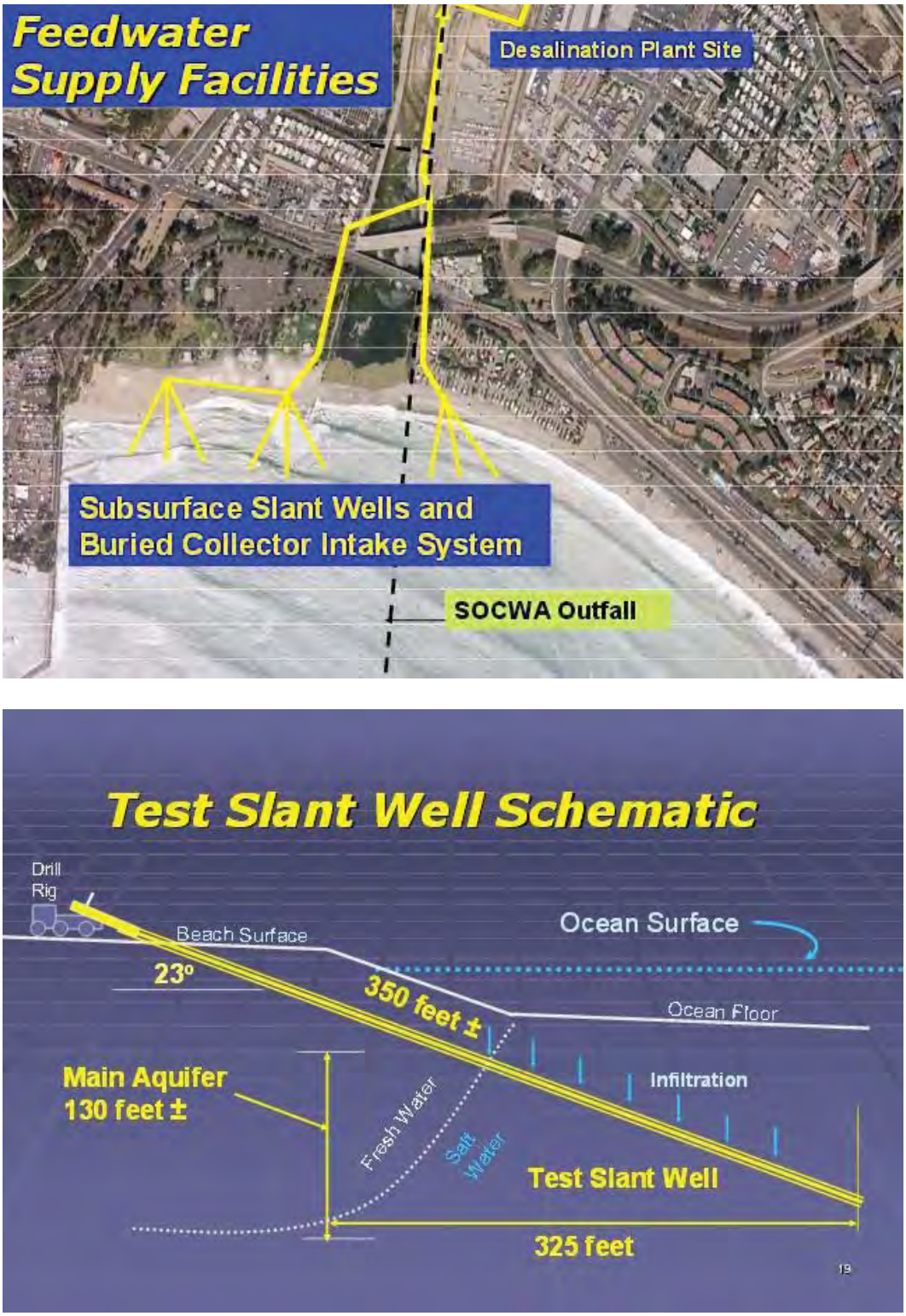


Figure 1-3. Schematic drawings for the proposed desalination plant at Doheny State Beach.

Flooding and inundation resulting from wave runup and overtopping are dependent upon wave conditions, water levels, and beach slope. Therefore, to meet the objectives of this study, this report includes:

1. An overview of the current projections for regional and global SLR for 2050 and 2100 (Chapter 9);
2. Estimation of the beach width response to SLR using Bruun's Rule (Chapter 10);
3. Analysis of wave runup and overtopping (Chapter 11);
4. Flow and water levels in the San Juan Creek Watershed (Chapter 12);
5. Tsunami inundation map for Dohney State Beach and the height of the waves estimated from historical observations (Chapter 13).

A summary of the study and its conclusions are presented in Chapter 14, followed by a list of references in Chapter 15. Appendices A through C contain photographs of Doheny State Beach (Appendix A) and aerial photographs of Doheny State Beach pre-harbor (Appendix B) and post-harbor (Appendix C).

2.0 SITE DESCRIPTION

Doheny State Beach (Figure 2-1) consists of two day-use areas (one west of San Juan Creek and one east of the creek), and one overnight campground area located just east of and adjacent to the creek. Approximately 1,400 feet of beach frontage, about 300 to 400 feet in width, provide 10 acres of sand west of the San Juan Creek jetty. The southern day-use area east of San Juan Creek consists of about 3,200 linear feet of public beach (California Department of Parks and Recreation, 2003) in front of the campground. A small creek known as North Creek is located in the southwestern part of Doheny Beach, just east of Dana Point Harbor. The shoreline in this vicinity includes areas of sand, cobble, rocky shore, and coastal bluff. Capistrano Beach County Park is located to the southeast.

San Juan Creek is a perennial creek that intersects the beach about midway across Doheny State Beach. The lower 2.6 miles of the creek were channelized circa the 1950s for flood control (USACOE, 1996).

Pacific Coast Highway (Highway 1) is located to the northeast of Doheny State Beach and crosses the creek via a bridge about 0.2 miles upstream of the ocean. At the mouth of San Juan Creek, a natural beach berm often blocks the creek from entering the ocean from late spring to late fall. The buildup of water occasionally breaks this berm (USACOE, 1997). A jetty was constructed at the west side of San Juan Creek to prevent erosion of the adjacent beach. This jetty is known as Thor's Hammer and was constructed of concrete and rebar. A regional bicycle path is located along the west side of San Juan Creek.

Doheny State Beach consists of 86 acres of state park area, which includes three visitor-use areas as mentioned above, in addition to a visitor center with aquariums and a simulated tide pool, park administrative offices, restrooms, a snack bar, showers, fire rings, volleyball courts, a main lifeguard tower, seasonal lifeguard towers, a maintenance area, and ample parking. A two-foot retaining wall, which extends approximately 15 feet below ground level, is located between the sandy beach and the park.

Flooding from the creek and/or from high tides occurs occasionally in the park. However, according to local lifeguards, flooding does not appear to impact the area west of San Juan Creek. The most recent flooding from high tides occurred east of the creek during June 2004. After this event, a large beach berm was built in front of the campground area to protect it from tides during the Fourth of July holiday.

The Southeast Regional Reclamation Authority (SERRA) operates a wastewater treatment plant on the west side of San Juan Creek about 0.5 miles from the park. The 57-inch ocean outfall extends underneath the park on the southeast side of the creek for about 6,000 feet into the ocean (California Department of Parks and Recreation, 2003).



Figure 2-1. Aerial photo of Doheny State Beach taken on 7 September 2004 by Coastal Environments.

The geology of the area is complex, dominated by periods of depression and uplift, mass wasting, and sediment deposition. The nearby Santa Ana Mountains are comprised of igneous and sedimentary rocks of Jurassic age or younger. Overlying these rocks are several thousand feet of sandstone, siltstone, and conglomerates of upper Cretaceous age. Sedimentary rocks of Tertiary age are located between the mountains and the Pacific Ocean. These rocks are about 20,000 feet thick and are composed of marine and non-marine sandstone, limestone, siltstone, shale, and conglomerates, overlain by Quaternary stream terrace deposits, stream channel, and landslide material (USACOE, 2002).

Several fault lines are located within the study area, including the Newport Inglewood/Rose Canyon fault, which lies about six miles offshore of the mouth of San Juan Creek. Also, the Cristianitos and Mission Viejo fault zones are located north and east of San Juan Capistrano, respectively. In addition, the potential for landslides is high along San Juan Creek.

3.0 HISTORY OF DOHENY STATE BEACH

Doheny State Beach is composed of two sections. The study area is in the western and eastern sections. The western area which lies between the east breakwater of Dana Point Harbor and the jetty on the east side of San Juan Creek (locally referred to as a groin). The original groin was constructed prior to construction of the Dana Point Harbor for the purpose of diverting river flow more directly into the ocean during floods. The jetty was repaired in 1967-68 after floods damaged it. The other section of the beach, the eastern portion of Doheny Beach, extends down coast about 4500 ft southeast from the mouth of San Juan Creek.

Prior to the construction of Dana Point Harbor, Doheny Beach extended west to the Dana Point headland. The beach was in an essentially natural state, situated at the northern end of the 60-mile long Oceanside Littoral Cell, which stretches to Point La Jolla. The south-facing beach was isolated and sheltered from the north by Dana Point. The Dana Point headland stabilized Doheny Beach by essentially preventing any sand transport alongshore to the west, while San Juan Creek provided sand during occasional floods. Figure 3-1 is an aerial photo taken in December 1952 showing the coastal reach from Salt Creek Beach just north of Dana Point (left side) to Doheny State Beach (center), the mouth of San Juan Creek (center right), and the San Clemente pier (right side).

Wiegel (1994) has described the history and development of Dana Point Harbor. The harbor was created by constructing two rubble-mound breakwaters between 1966 and 1968. By 1970, the major features of the harbor were essentially complete, as shown in Figure 3-2. The harbor eliminated the majority of Doheny Beach west of San Juan Creek. However, the breakwaters enhanced protection from waves approaching from the north and northwest for the remaining beach segments southeast of the harbor, especially for the 1,400-foot long study area between the east breakwater and the mouth of San Juan Creek.

Sand nourishment at Doheny Beach has occurred from different sources over time (Wiegel, 1994; Shaw, 1980). Based on the beach width data presented in Section 4.0, the width of the beach in the study area was about 160 ft. In 1964, 94,000 yd^3 of sand from San Juan Creek were placed in the west side of the river mouth. About 690,000 yd^3 of sand were placed on the eastern part of the beach from old terrace deposits in Camp Pendleton in 1966-67. In October-November 1969, about 212,000 yd^3 were placed on the beach from San Juan Creek flood control restoration dredging. In 1970, approximately 125,000 cubic yards of dredged material were placed offshore of the beach in an attempt to enhance surfing.

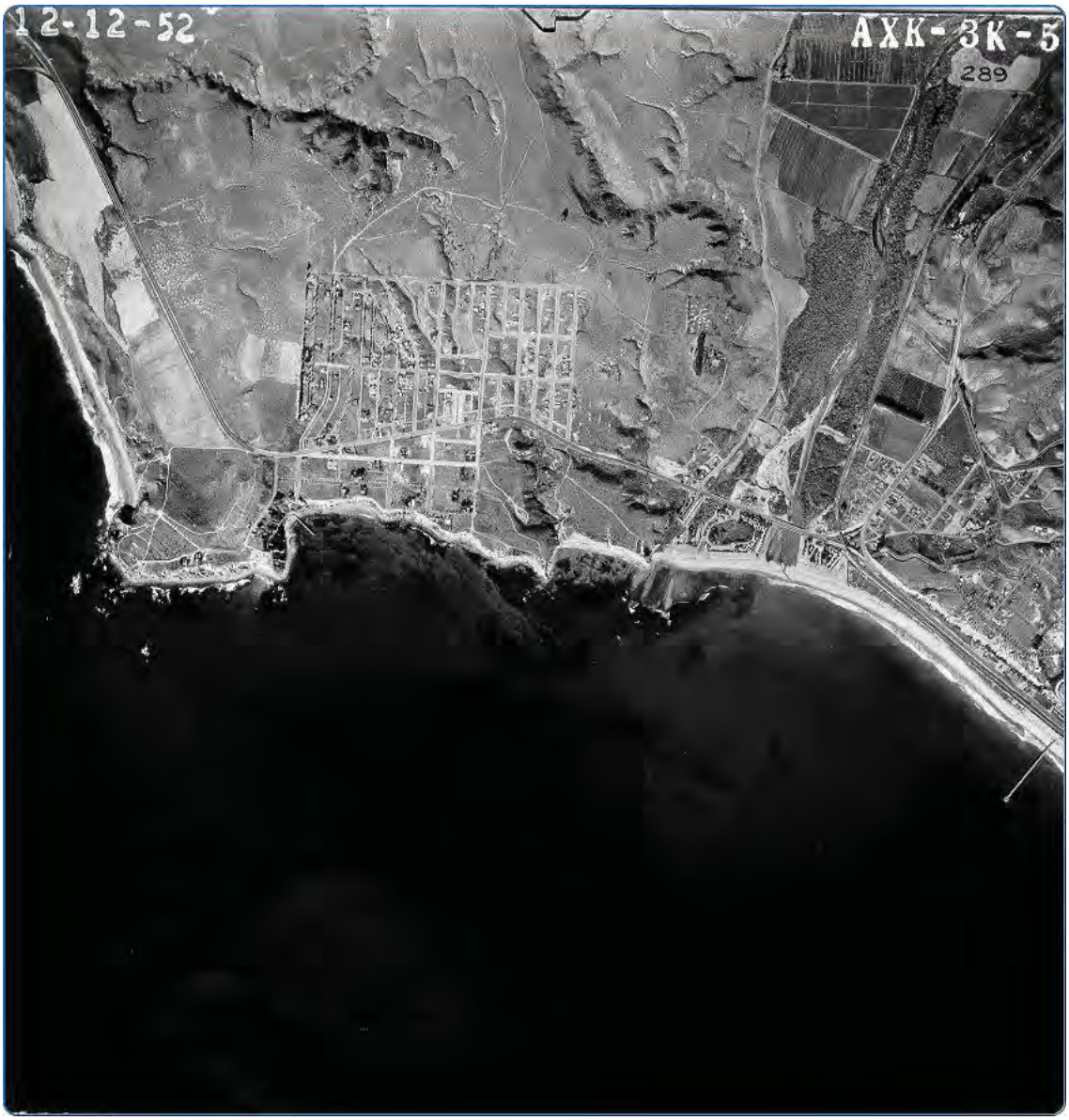


Figure 3-1. Aerial photo showing Doheny State Beach on 12 December 1952 prior to construction of Dana Point Harbor.



Figure 3-2. Aerial photo showing Dana Point Harbor on 30 July 1970 after all major construction was essentially complete.

4.0 BEACH CONFIGURATION AND SHORELINE STABILITY

4.1 DATA

Beach configuration and shoreline change and stability were quantified and assessed in a previous study carried out by Coastal Environments (2004) in three ways: (1) by conducting beach profile surveys in September 2004 (Section 4.1.1), (2) by obtaining aerial photographs (Section 4.1.2), and (3) by gathering and analyzing historical aerial photos (Section 4.1.3). Beach sand thickness information was also collected as part of the survey conducted by Coastal Environments in 2004 (CE, 2004).

In this study, we obtained additional aerial photographs primarily to cover the missing data from 2004 to present. Interesting aerial photos prior to 2004 were also added to the existing data base. These newly aerial photos were analyzed using a similar procedure to the one used during the 2004 study (CE, 2004).

Beach profiles from 2001 to 2007 at range DB-1850 were obtained from Coastal Frontiers, Inc. as a courtesy for our project. These data were used in this study to represent the eastern part for Doheny State Beach and was valuable to estimate the closure depth at the beach.

4.1.1 Beach Profiles

Beach profiles were measured on 1 and 8 September 2004 on 10 range lines using a laser surveying transit (total station) to determine the current beach configuration. Figure 4-1 is a plan-view map showing the locations of these ranges. Nine new range lines were occupied (R1-R9), as well as one historical range (DB1890), which was first established by the U.S. Army Corps of Engineers (USACOE) (and was surveyed once) in 1984. Historically, few profile measurements have been made in the area west of San Juan Creek in the beach segment adjacent to the east breakwater of Dana Point Harbor.

Of the 10 beach profile range lines examined in this study (Figure 4-1), five are located in the study area west of San Juan Creek (DB1890, R1-R4), three are situated in front of and adjacent to the creek mouth (R5-R7), and two are located in the east (R8-R9). The range lines are oriented approximately perpendicular to the shoreline, and profile data extend from the seawall at the back of the beach to a depth of -12 ft, NGVD. The collected beach profile data are shown in Figures 4-2 through 4-4. Figure 4-2 shows the profile data taken at Ranges DB1890 and R1 to R4 west of San Juan Creek. Figure 4-3 shows the data from Ranges R5 to R7 at the river mouth, and Figure 4-4 shows data from east of San Juan Creek at Ranges R8 and R9. The beach berm height at all ranges was approximately 10-12 ft (NGVD), except at Ranges R7 through R9. At the latter three ranges, park rangers had moved sand from the beach face and back of the berm to the front of the berm to protect the camping area from flooding during high tides. The result was dune-like features 17-18 ft high. Doheny State Beach is relatively steep, and the beach face (foreshore) slope, seaward of the beach berm, is relatively uniform along the study area, with a slope of 1:15. Offshore beyond the 4 ft water depth, the beach is more gently sloped at 1:100.

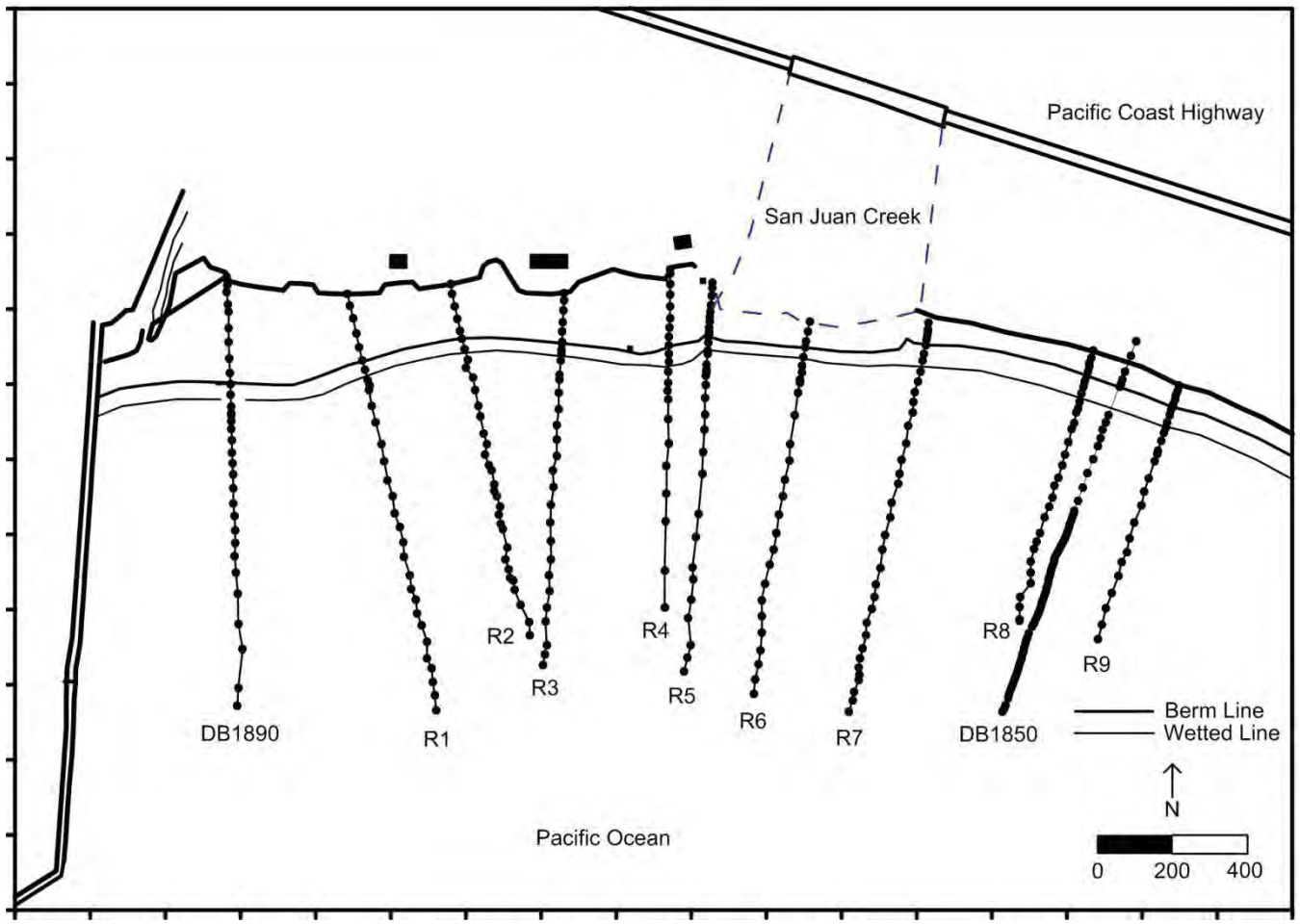


Figure 4-1. Locations of beach profiles at Doheny State Beach (surveys conducted on 1 and 8 September 2004).

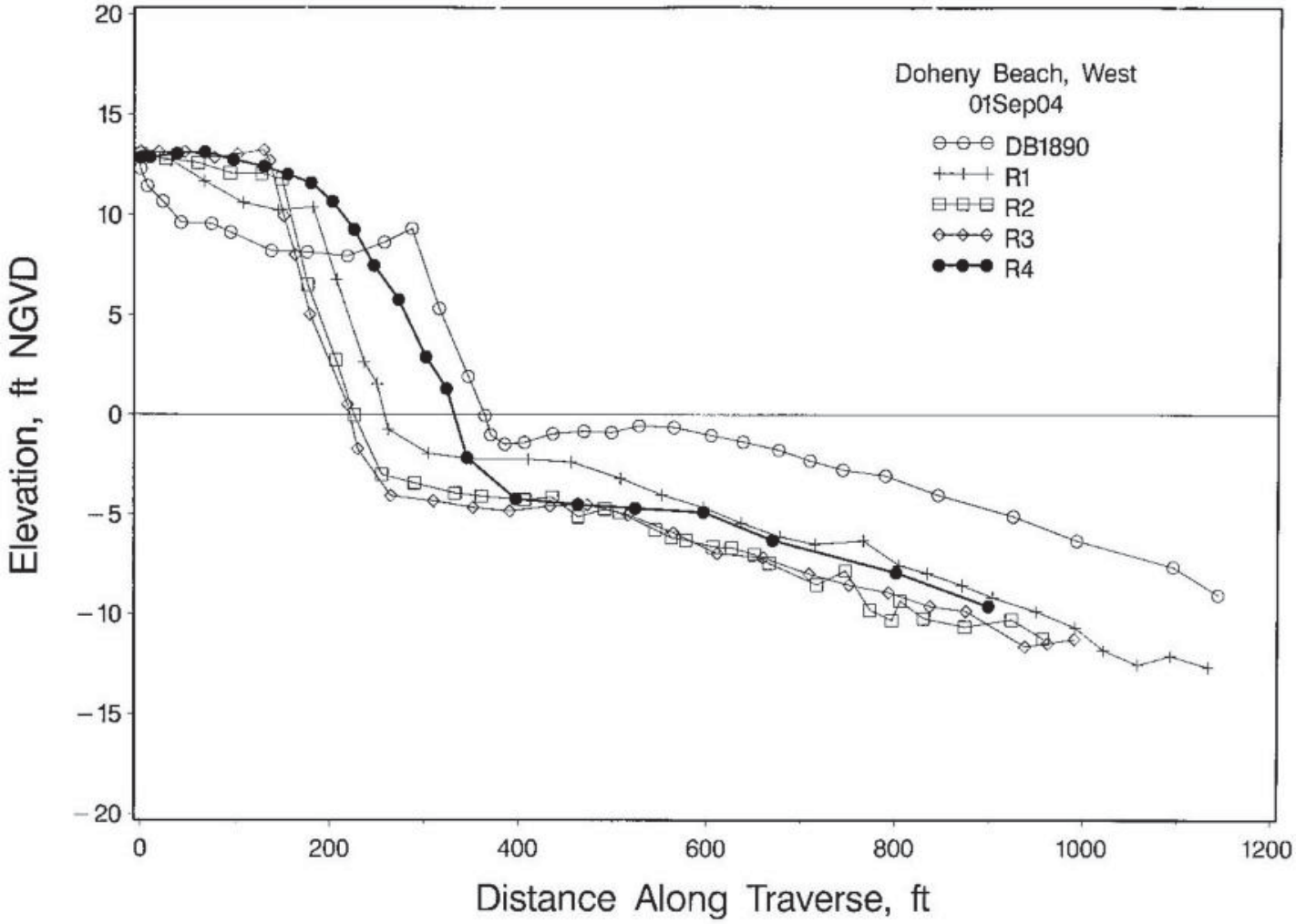


Figure 4-2. Beach profiles west of San Juan Creek.

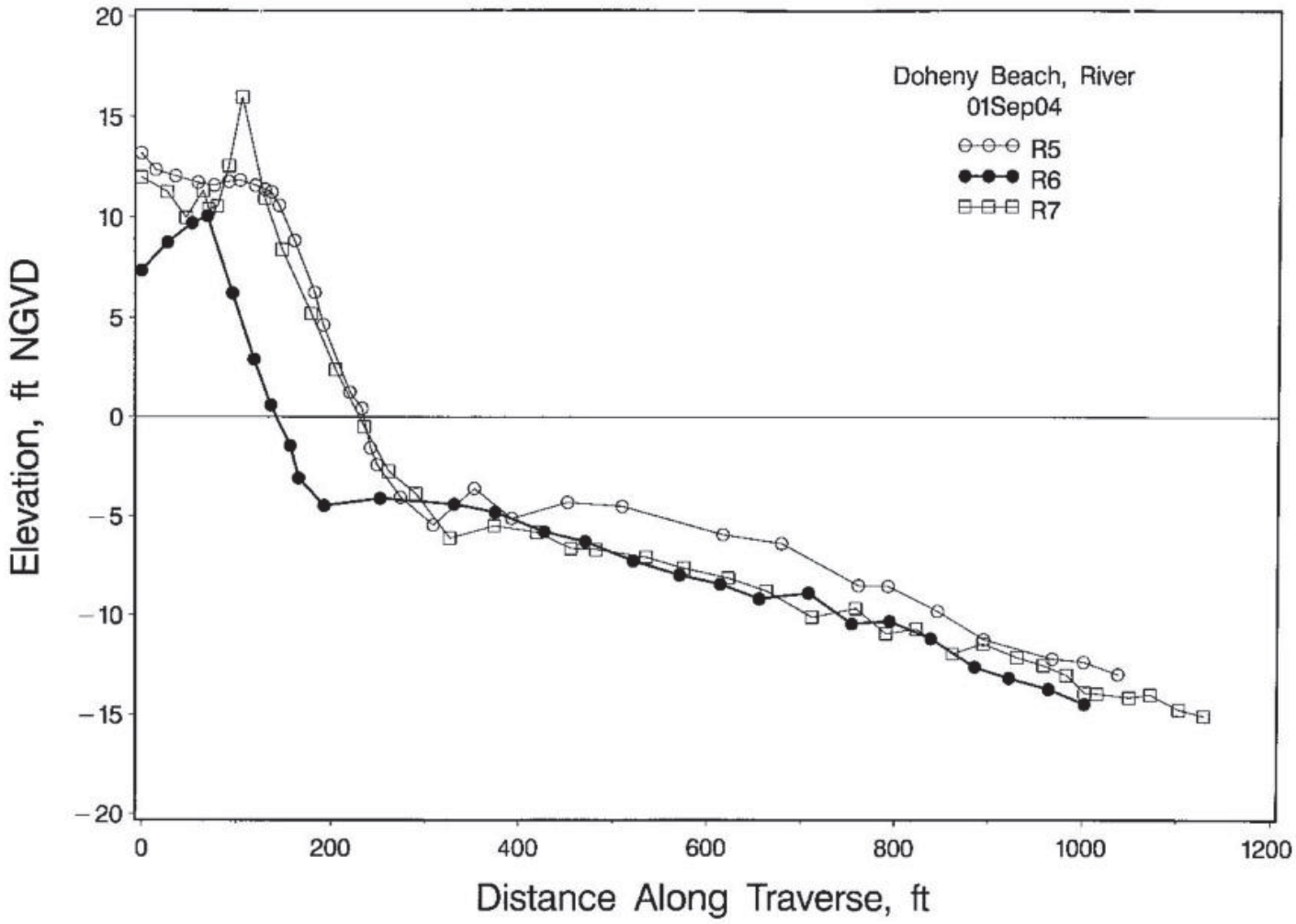


Figure 4-3. Beach profiles adjacent to San Juan Creek river mouth.

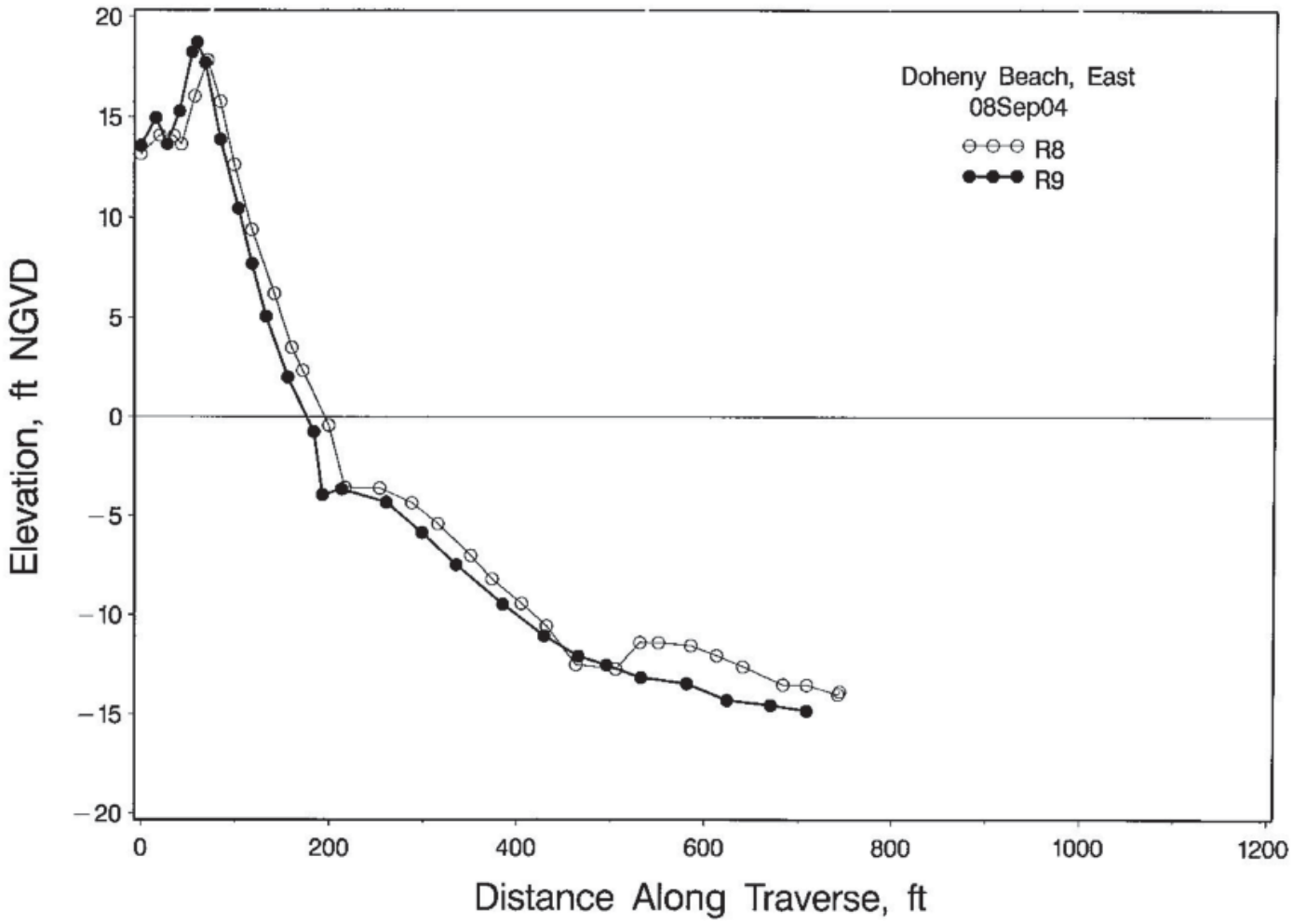


Figure 4-4. Beach profiles east of San Juan Creek.

Beach profile data (Figures 4-5a and 4-5b) east of San Juan Creek were obtained from Coastal Frontiers, Inc. (2014).

The data gathered were used to prepare the nearshore bathymetry for the project area and are shown in Figure 4-6.

4.1.2 Recent Aerial Photographs

An aerial photograph survey conducted on 7 September 2004 produced a detailed image of the western and eastern portions of Doheny State Beach (Figure 4-7). The survey was conducted by NEOS Limited of La Jolla, CA. The survey was undertaken with an Ultra-Lite aircraft and a digital video camera. During the survey, the aircraft flew at an altitude of 1,000 ft (305 meters). Images obtained from this survey have an image resolution of 0.85 ft (25 cm).

4.1.3 Historical Aerial Photographs

Aerial photos were analyzed to determine the history of beach width and shoreline change in the study area. Aerial photo coverage spans the time from before the construction of Dana Point Harbor, including photos taken in 1929, 1939, 1947, 1952, and 1964, through final construction in 1970, to photos taken for this project in September 2004. For each photo, we determined the distance between a back beach reference point (e.g., seawall) and the wetted sand line. In all, 37 photos were analyzed. Of these, 34 were taken after construction of Dana Point Harbor, and three were taken before construction. Of special interest are the photos taken around the time of the major storms of 1980 and 1983, when the beaches retreated because of storm wave attack, but were simultaneously nourished with sand from flood flows in San Juan Creek.

The wetted sand line, bridges, creek banks, and other features in black from 2 April 1990 were overlain onto every photograph, after each image was rectified. We made certain that the headquarters tower in each photo was covered by the traced plot to ensure high accuracy. For each photo, the distance between the south end of the headquarters tower to the wetted line was measured. A correction of 37 ft was applied to give the distance to the shoreline as defined by 0 ft, NGVD. This distance was estimated by multiplying the elevation of Mean Higher High Water (5.37 ft, NGVD) by the beach face slope (1:7), which is approximately 37 ft. Appendix B shows selected aerial survey photographs.

4.1.4 Sand Thickness

Sand thickness at Doheny Beach, as measured from the sand surface to the depth of the cobble bed, was established at Range R6 on September 8, 2004. The sand layer thickness was found to be about 1 ft or less, which is relatively thin. Figure 4-8 shows the sand thickness overlying the cobble bed at Range R6.

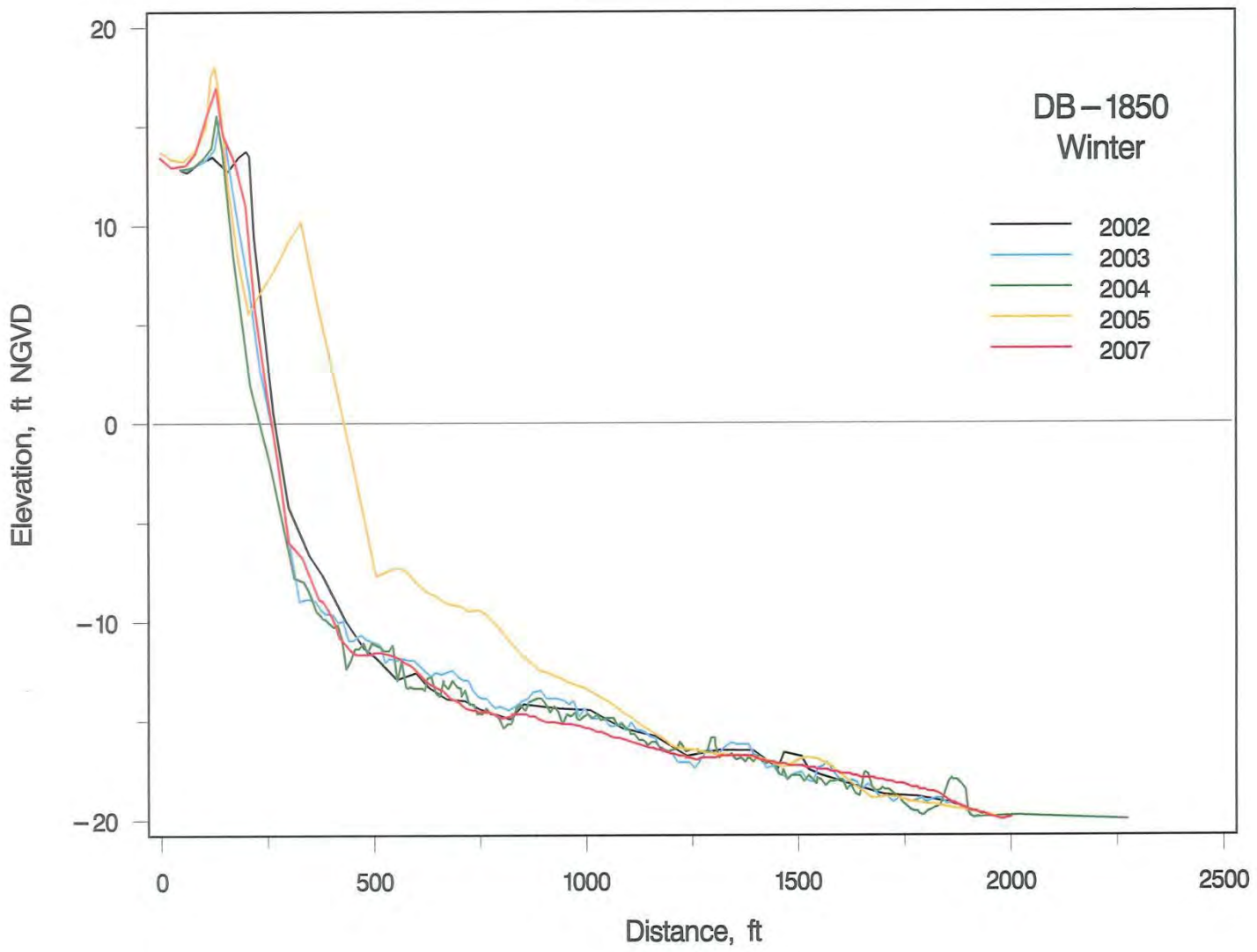


Figure 4-5a. Beach profiles east of San Juan Creek from 2002 to 2007 during winter season. Data from Coastal Frontiers, Inc. (2014).

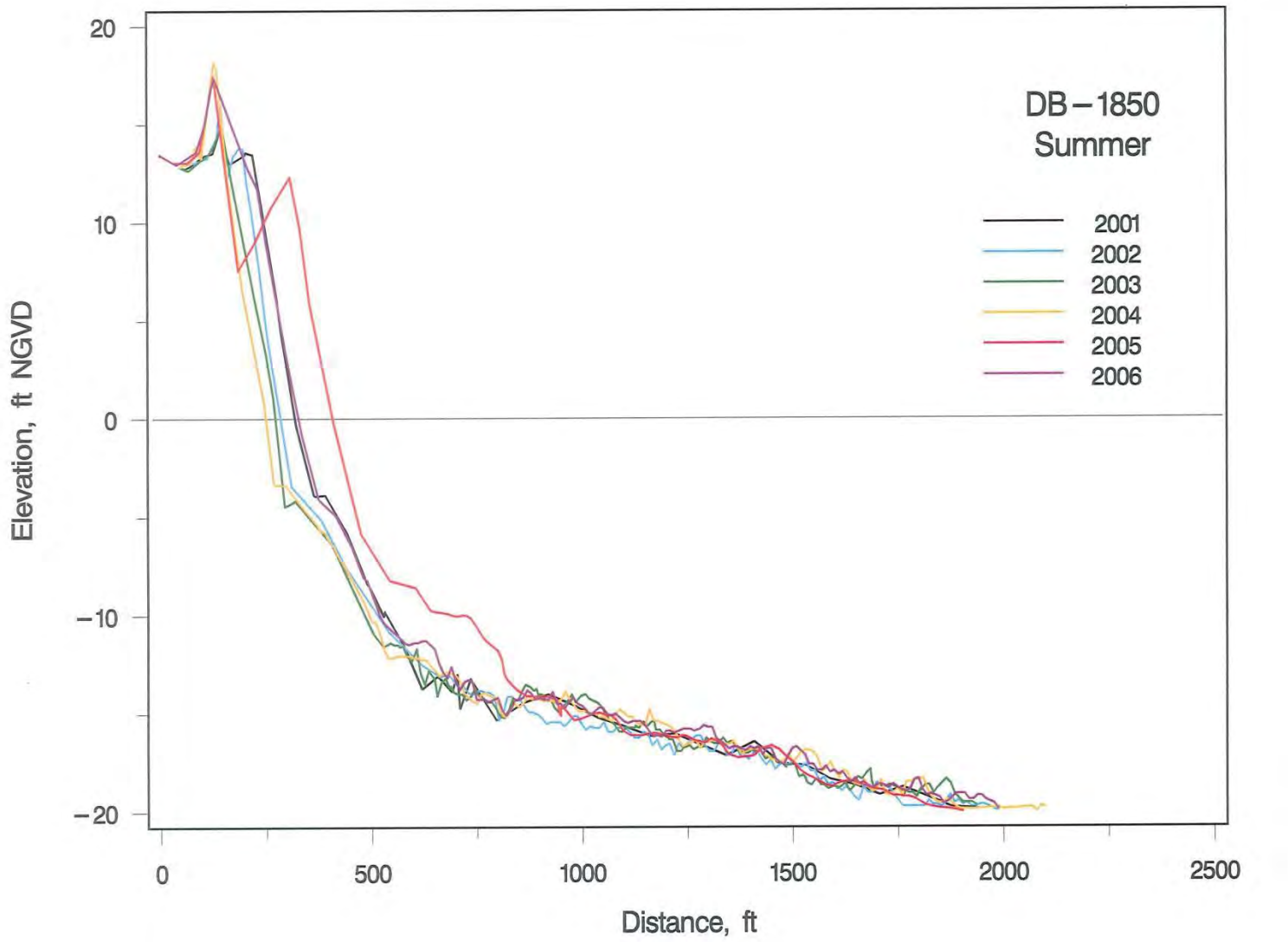


Figure 4-5b. Beach profiles east of San Juan Creek from 2001 to 2006 during summer season. Data from Coastal Frontiers, Inc. (2014).

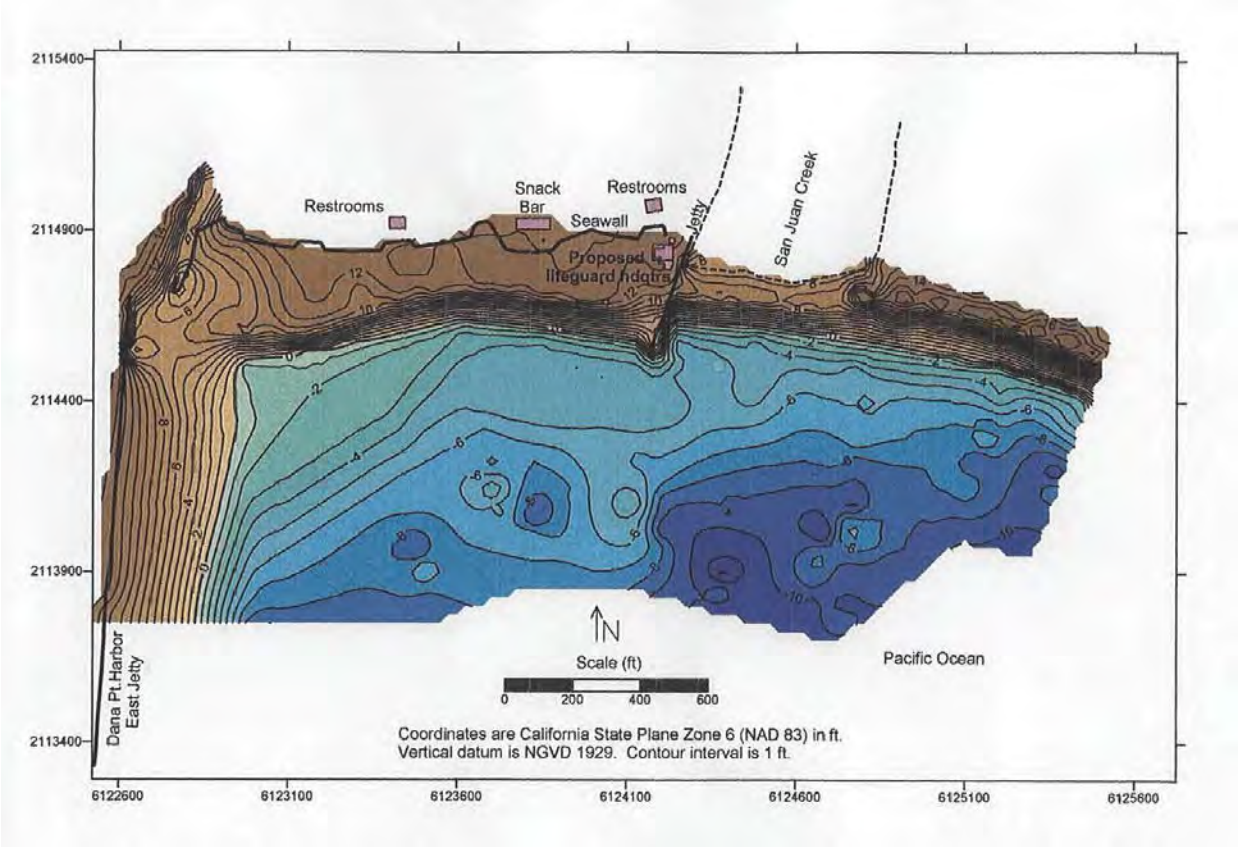


Figure 4-6. Nearshore bathymetry at Doheny State Beach, as contoured from beach profile data collected on 1 and 8 September 2004.



Figure 4-7. Image of west Doheny State Beach obtained from an aerial survey on 7 September 2004.

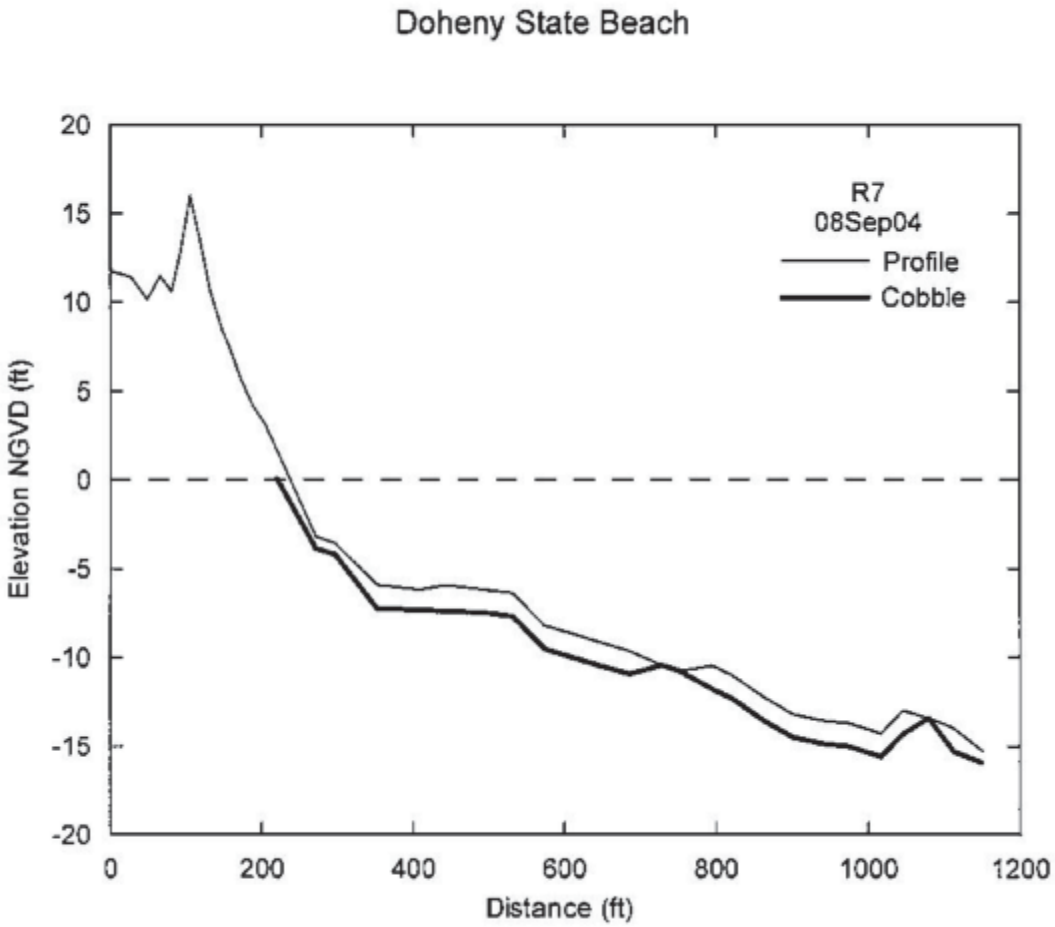


Figure 4-8. Sand thickness overlying cobble bed at Range R6.

4.2 BEACH WIDTH IN 2004

Beach width is herein defined as the distance from a fixed point at the back of the beach (in this case, from the seawall for profiles west of the creek, and from the campground fence for ranges east of the creek) to wherever the beach profile intersects the National Geodetic Vertical Datum (NGVD) reference plane. Beach width is a fundamental and frequently measured characteristic, describing the size of the exposed, subaerial portion of a beach. It is a quantity closely related to beach sand volume, the fluctuation of which is probably the single best indicator of beach stability. Since only a limited number of beach profiles were available for the present study, it was not possible to construct the history of beach sand volume changes. However, historical beach widths were readily measurable from the numerous aerial photos, as well as from the profiles measured as part of this project. These provide a sound basis for assessing the stability of the beach in the western portion of the Doheny State Beach project area, between Dana Point Harbor and San Juan Creek.

Table 4-1 provides the beach width data from the September 2004 beach profile survey. The average beach width was 280 ft west of San Juan Creek and 186 ft east of the creek. Since these data were collected in September before any substantial wave action from the Pacific Ocean had impacted the beach, it is reasonable to assume that they represent seasonal maximum beach width conditions for 2004. This is especially true of the west end of the beach (DB1890), since the area normally accretes sand during the summer months. During this time, south swells allow sand to be transported toward the northwest. The east end of the west segment (R4) could be expected to accrete during the moderate northwest swells characteristic of the winter months. The pattern of beach width revealed by the data illustrates the positive stabilizing effects of the jetty and the harbor's east breakwater.

Accumulation of sand and cobbles has produced a fillet on the west end of Doheny Beach adjacent to the harbor's east breakwater, which causes local wave divergence at range R4 and convergence at ranges R1-R3 (Figure 4-9). The result is an overall reduction in wave energy at range R4. Furthermore, the presence of the groin at San Juan Creek adds additional protection to the beach near range R4.

A comparison of the beach width estimated from the beach profiles and the beach width derived from the aerial survey of 7 September 2004 for range R4 shows agreement within 3% (10 feet). This agreement between the two methods allows for increased confidence in the accuracy of the aerial survey method for estimating beach widths.

Table 4-1. Beach widths at Doheny State Beach on 1-8 September 2002.

Range Line	Segment	Beach Width (ft)	
		Beach Width	Survey Date
DB1890	West	364.0	1 Sep 04
R1	West	258.0	1 Sep 04
R2	West	225.0	1 Sep 04
R3	West	221.0	1 Sep 04
R4	West	331.0	1 Sep 04
R5	Creek	235.0	1 Sep 04
R6	Creek	143.0	8 Sep 04
R7	Creek	230.0	8 Sep 04
R8	East	195.0	8 Sep 04
R9	East	176.0	8 Sep 04
Average [a] (west)		279.8	
Average [b] (east)		185.5	

[a] Average for ranges west of San Juan Creek (DB1890, R1, R2, R3 and R4)
[b] Average for ranges east of San Juan Creek (R8 and R9)

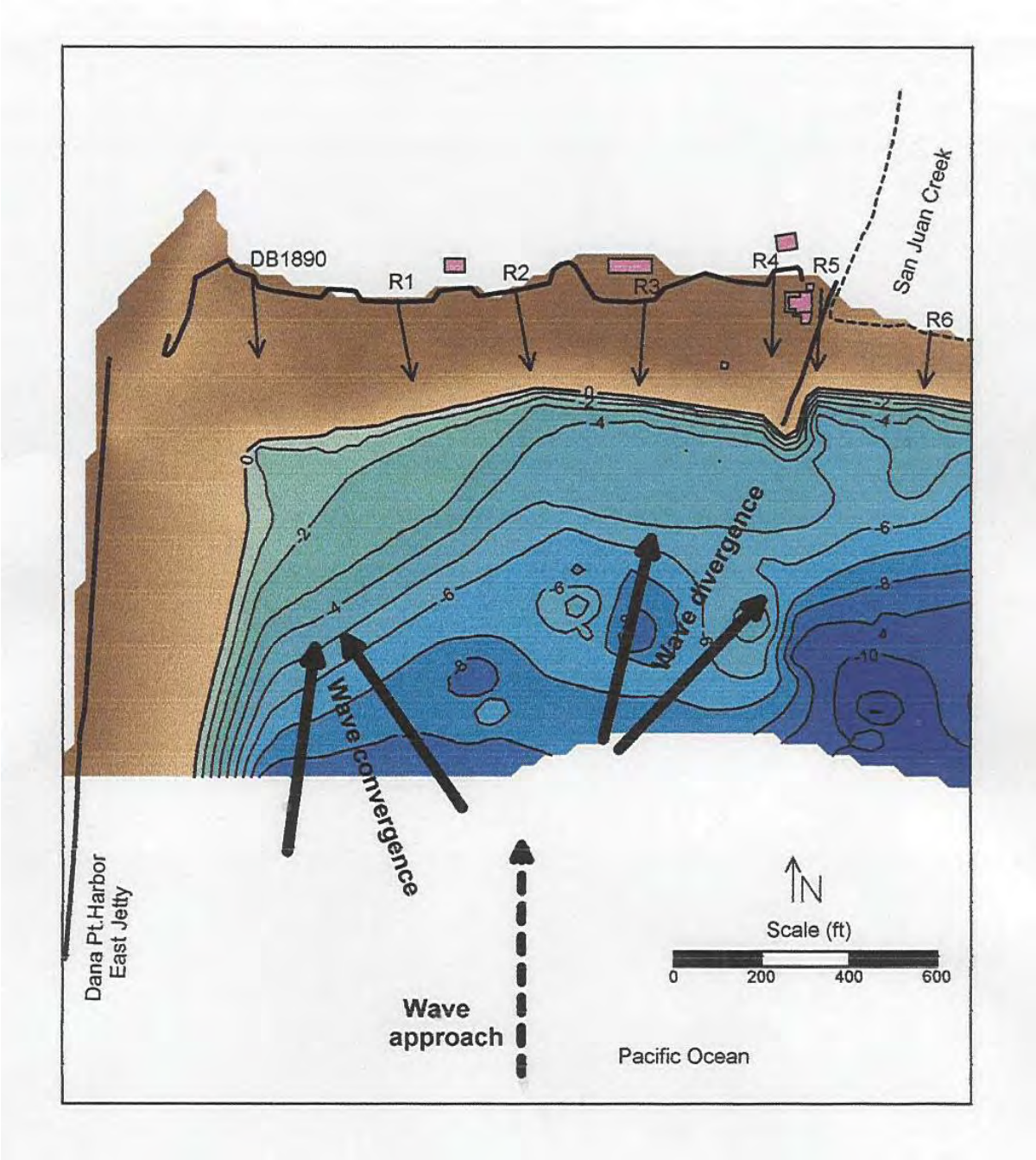


Figure 4-9. Wave convergence and divergence at west Doheny State Beach.

4.3 BEACH WIDTH HISTORY

Beach width history at Doheny Beach was analyzed primarily by examining aerial photographs. The emphasis of this study is on the width and stability of the beach within the project area, at the west end of Doheny Beach between the groin and the east harbor breakwater. Summaries of beach width information extracted from aerial photographs before Dana Point Harbor construction are given in Tables 4-2 and 4-3. Few beach profile surveys have been conducted in this area in the past. For example, Range DB1890 had only been surveyed once, in December 1984. For comparison, the profile was overlain onto the September 2004 survey at DB1890, and the result is shown in Figure 4-10. The comparison suggests that this area of the beach, just east of the Dana Point breakwater, has eroded about 40 ft over a 20-year period.

Figure 4-11 and 4-12 show the chronological history of beach width at west Doheny Beach from 1964 to the present at range R4. This range is located at the end of the west beach. The images were rectified to accurately reproduce vertical map-like images that reflect true ground distances.

The most obvious feature revealed in Figure 4-11 is the increase in beach width after construction of the harbor, as shown by comparing the width in 1964 (237 ft) with the average width between 1980 and today (418 ft). After 1980, beach width varied from a maximum of about 550 ft on 18 September 1980 to a minimum of about 331 ft in September 2004, a period of 24 years. Substantial decreases in beach width occurred during years of large and persistent wave activity, such as the El Niño winter of 1982-83, when 10 large wave storms occurred, and in January 1988. On the other hand, large increases in beach width were clearly related to significant flood events, such as those of 1980, 1983, 1993, 1995 and 1998.

Other potential sources of sand during dry weather periods include sand transported southward around Dana Point, sand passing westward around the jetty, and sand moving onshore. Several photos show the presence of a sand spit in front of west Doheny Beach (see Appendix B). Since 1970, none of the material dredged from Dana Point Harbor or nearby locations has been deposited on Doheny Beach. Therefore, the observed fluctuations of beach width were not influenced by beach nourishment but were solely due to the “natural” supply of sand.

A study was conducted by Elwany (1998) at Harbor Beach, which is located just south of Oceanside Harbor, between the south harbor breakwater and the north jetty of the San Luis Rey River. West Doheny Beach is similarly bordered by the Dana Point Harbor east breakwater and the jetty on the west side of the San Juan Creek mouth. Harbor Beach is oriented to the southwest, and Doheny Beach is oriented to the south. The Harbor Beach study showed that the beach remained stable between 1960 and 2000. Beach width has varied from a minimum of about 300 ft to a maximum of about 600 ft during this time period. The beach accreted during the floods of 1969, 1978, 1980, 1993, and 1998, and eroded during the 1982-83 storm wave cluster and the storm waves of January 1998. Although Harbor Beach has undergone large changes in beach width, it is stable in the sense that beach width has remained at or above 300 ft since 1960.

Table 4-2. Beach widths along Transect R4 as measured from aerial photographs before harbor construction in 1964.

Date	Measurements[a] (ft)	Beach Width[b] (ft)	Season
1929	190	227	Unknown
10 Oct 1939	175	212	Summer
3 March 1964	200	237	Winter
Average	**188**	**225**	

[a] Raw measurement from air photo of distance from seawall to wetted bound.
[b] Includes 37 ft adjustment from average wetted bound to NGVD shoreline.

Table 4-3. Beach widths along Transects R4 and R8 as measured from aerial photographs after 1964.

Date	R4-Beach Width[a] (ft)	R8-Beach Width[a] (ft)	Season
01Oct39	204	177	Fall
01Aug47	202	172	Summer
08Jan58	205	187	Winter
29Nov62	174	81	Fall
12Jun63	158	25	Spring
01Jul75	379	250	Summer
01Feb77	378	218	Winter
18Sep80	517		Summer
30-Dec-80	639	619	Fall
22Feb83	462		Winter
09Mar83	443	352	Winter
25Mar83	436	350	Winter
03May83	399	315	Spring
17May83	445	437	Spring
28Jul83	479	429	Summer
18Sep83	438	654	Winter
06Oct83	439	395	Winter
02Nov83	482	491	Fall
11Nov83	429	382	Fall
06Dec83	459	379	Fall
13Jan86	416	358	Winter
19Mar86	391		Winter
21Jan87	320		Winter
24Jan88	320		Winter
30Jan89	391		Winter
15Mar90	391		Winter
03Apr90	429	294	Spring
15Jan91	403		Winter
02Dec91	407	281	Fall
08Jan92	336		Winter
05Mar93	352		Winter
1Jun94	425	231	Spring
12Feb94	399		Winter
26Mar95	431		Winter
12Jan96	450		Winter
19Feb97	478		Winter
01Nov97	426	326	Fall
10Mar98	450		Winter
05Jan99	450		Winter

Table 4-3. Beach widths along Transects R4 and R8 as measured from aerial photographs after 1964 (continued).

Date	R4-Beach Width[a] (ft)	R8-Beach Width[a] (ft)	Season
02Feb00	395		Winter
15Apr01	426	269	Winter
15Jun02	337	205	Spring
21Jan04	401	247	Winter
07Sep04	331		Summer
7Jun05	449	354	Spring
1Mar07	391	204	Winter
22Jun09	365	212	Spring
28Mar10	449	194	Winter
1May10	379	145	Spring
18Jan11	465	143	Winter
19May12	391	225	Spring

[a] Includes 37-ft adjustment from average wetted bound to NGVD shoreline.

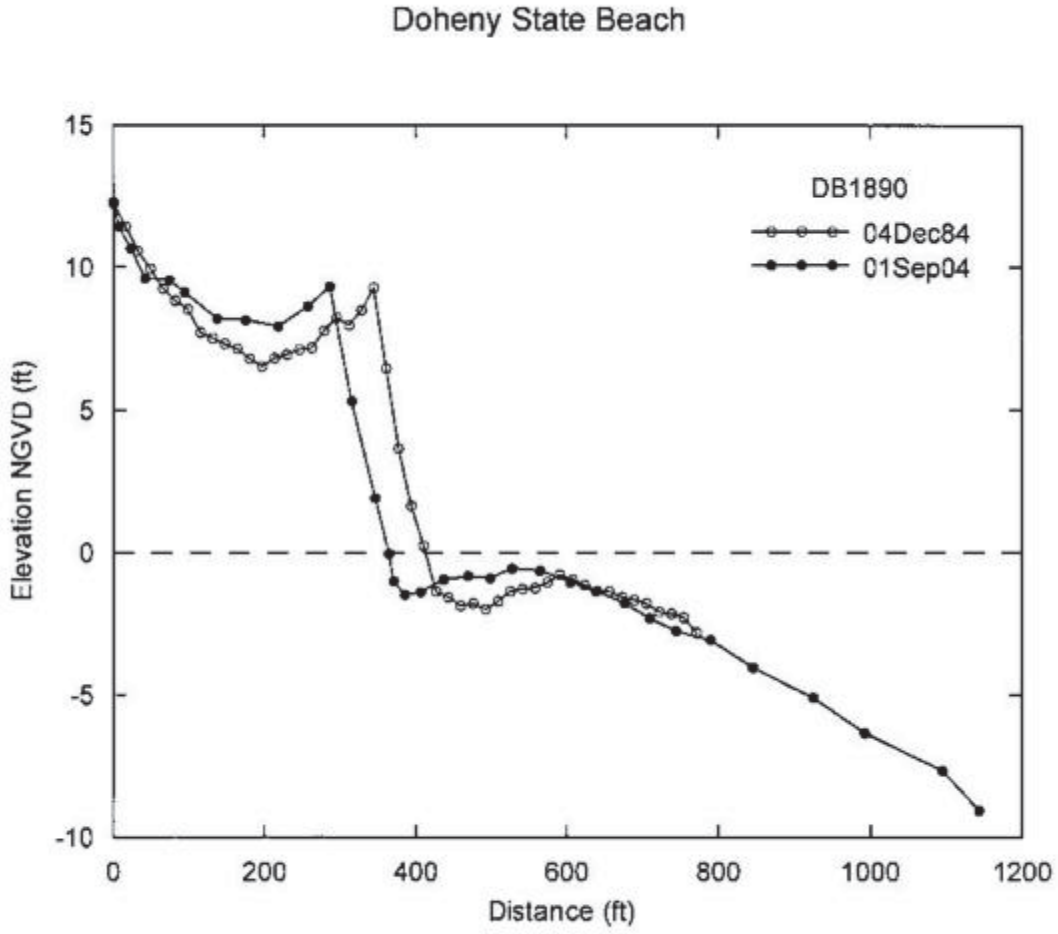


Figure 4-10. Comparison of profiles at DB1890 surveyed on 4 December 1984 and 1 September 2004 (USACOE, 1984).

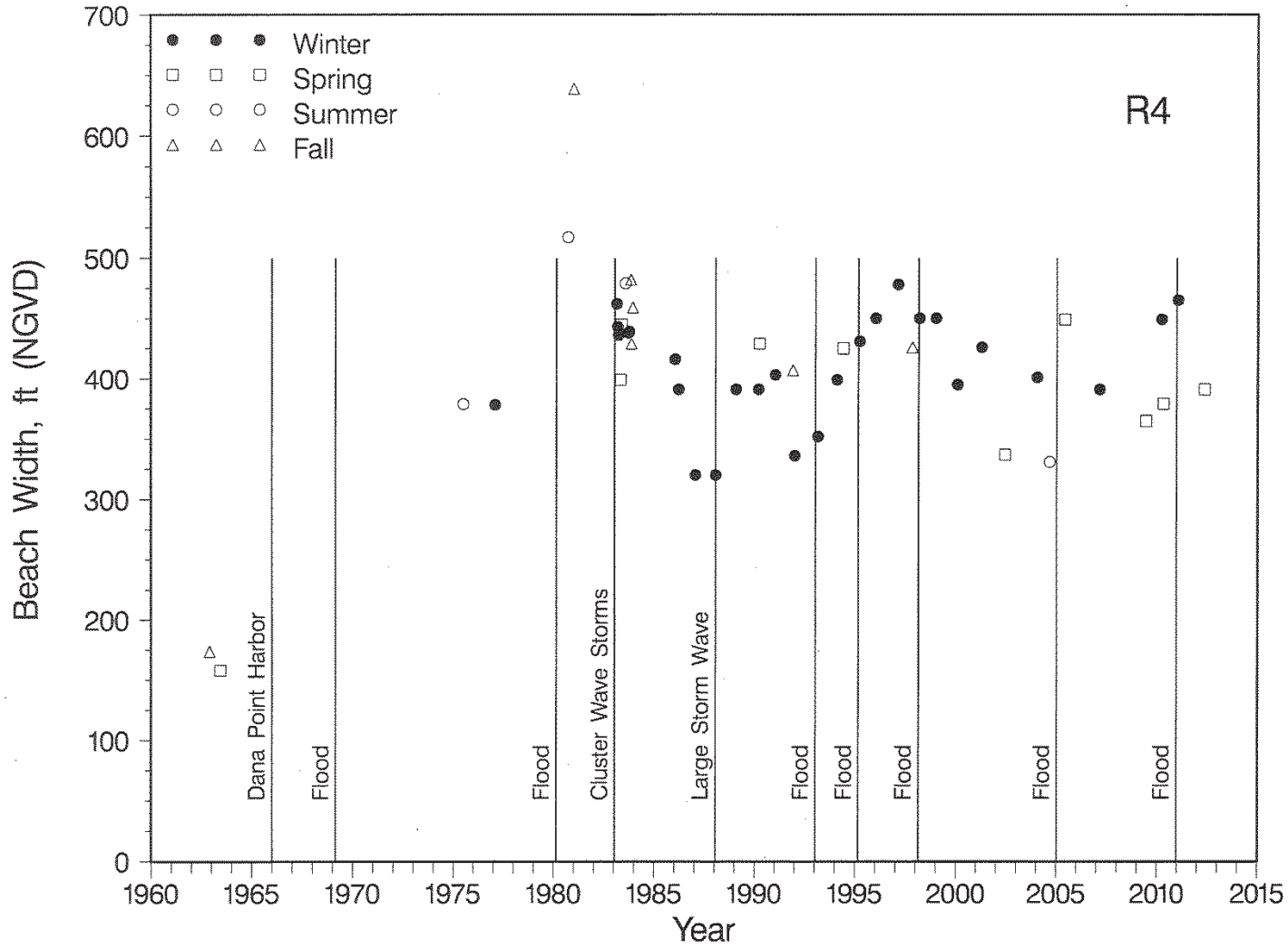


Figure 4-11. History of beach width at Range R4 at west Doheny State Beach between 1980 and the present.

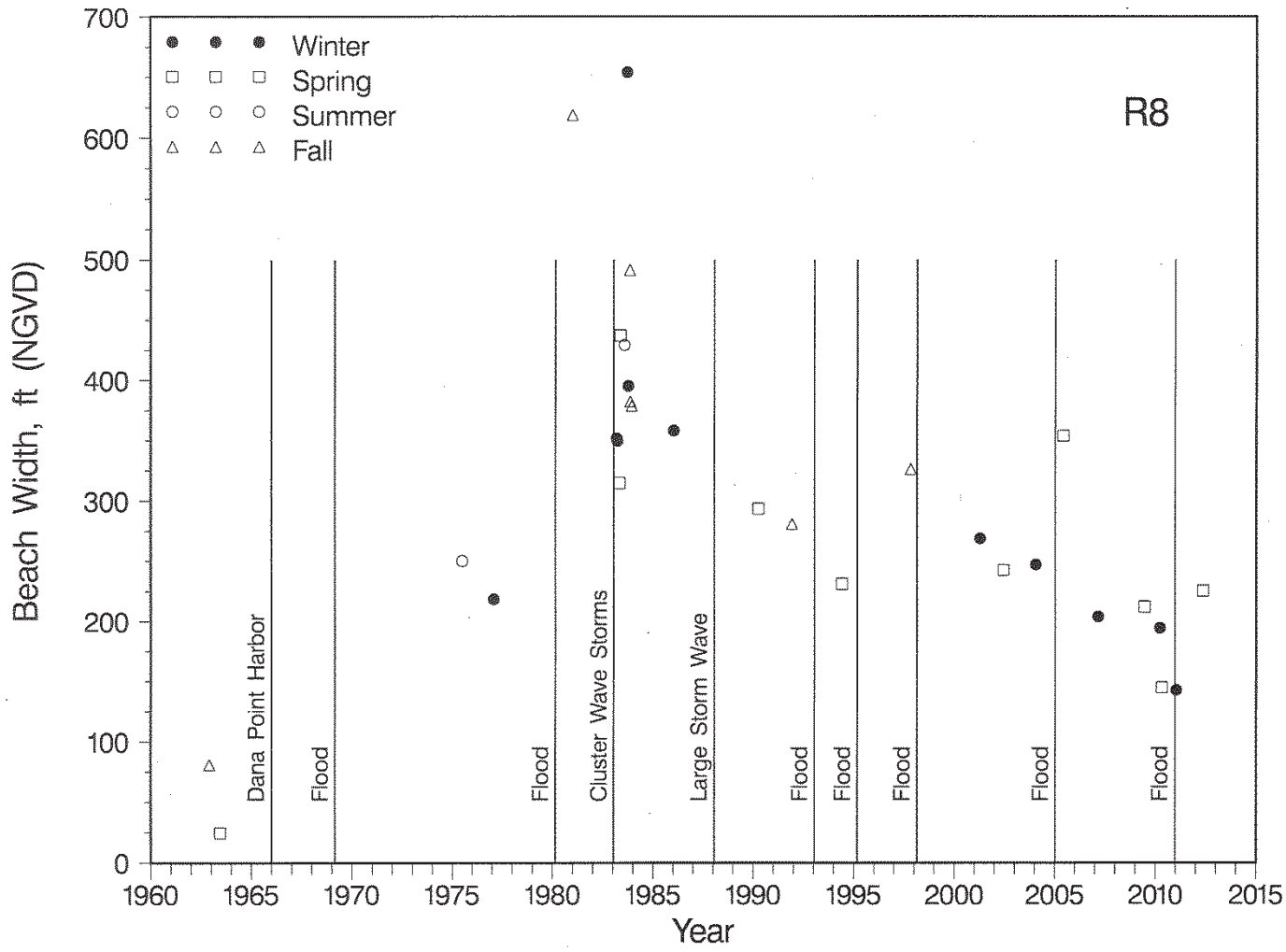


Figure 4-12. History of beach width at Range R8 at west Doheny State Beach between 1980 and the present.

4.4 EROSION AND ACCRETION PATTERNS

Long-term beach width changes are herein defined as those that occur over a period of at least one year and encompass fluctuations associated with the variability of inter-annual wave climate and episodic contributions of sand to west Doheny Beach from flooding of San Juan Creek.

Elwany et al. (1998) discussed the influence of wet and dry periods on the stability of coastal lagoon inlets. Inlet flushing by flood events was found to dominate the pattern of inlet closure over periods longer than a year or two. In an analogous way, river flooding occasionally provides large amounts of sand that widen west Doheny Beach.

Figure 4-9 shows that west Doheny Beach increases in width after a single flood event. This suggests that during extended wet time periods, west Doheny Beach will be wider than during dry time periods. During dry time periods, river flows and sand supply decrease dramatically, leading to decreased beach width. A pattern is formed: San Juan Creek supplies sand to Doheny Beach, after which waves progressively erode it until the next flood event occurs.

It should be pointed out that Thor's Hammer, the jetty west of San Juan Creek, plays an important part in the stability of west Doheny Beach. A study conducted by Elwany et al. (2003) to determine the effects of the San Dieguito River outlet on adjacent properties indicated that river flows erode adjacent beaches as they flow out. Under some circumstances, these beaches are severely eroded, such that they require some time to recover. Thor's Hammer trains the river flow into the ocean and prevents eroding of the beach to the west.

West Doheny State Beach undergoes cycles (Figure 4-11). It fluctuates between minimum and maximum configurations over time due to several factors described previously. The maximum beach width observed at West Doheny Beach between 1980 and 2014 was 517 ft after the 1980 floods. The minimum beach width observed during the same time period was 320 ft, following the 17 January 1988 wave storms. In 1997, beach width was 478 ft, attaining a recent local maximum, before retreating during the dry period between summer 1998 and the present. While west Doheny Beach underwent large fluctuations in beach width, during the last 25 years, the beach has never been less than 320 ft wide. Compared to San Diego area beaches, this is wider than average. The average beach width in Southern California is 150 ft. In the sense that the beach appears to fluctuate between consistent upper and lower limits, one could consider it to be in a stable but dynamic state.

East Doheny State Beach width fluctuated from 619 ft to 143 ft during the period from 1980 to present. The east Doheny State Beach responses to floods from San Juan Creek and the sediment loads carried by these floods as shown in Figure 4-12.

5.0 WAVES

Waves provide the largest source of energy to the coast of California and are responsible for sand transport and beach erosion as well as coastal flooding and damage. This section reviews the relevant properties of waves at Doheny State Beach as an introduction to the design wave and runup analysis which follows.

5.1 WAVE CLIMATE OVERVIEW

Ocean waves in Southern California fall into three main categories (USACOE, 1986):

1. Northern Hemisphere Swell: Waves generated in the Northern Hemisphere that propagate into Southern California waters,
2. Southern Hemisphere Swell: Similar waves generated south of the equator, and
3. Local Seas: Relatively short-period waves generated within the Southern California Bight.

Southern California is sheltered from deep-ocean waves by numerous offshore islands and shoals (Figure 5-1), thus greatly complicating the coastal wave climate (Pawka, 1982 and 1983). Due to the location of Doheny State Beach within the Southern California Bight, only waves from certain directions reach its shores. This is due to the sheltering effect of various offshore islands, including Santa Rosa, Santa Catalina, and San Clemente. The largest windows from which waves can reach the shoreline at Doheny State Beach are from the south at an angle of between 155°- 221° and 241°-252° (from true north). The predominant winter wave direction is largely blocked, and only waves with an approach angle of 272° to 283° reach Doheny State Beach (Figure 5-1).

The wave climate varies over the years. For example, wave events tended to be moderate between the mid-1940s and the mid-1970s when La Niña (cool water temperature periods of low wave energy and low rainfall) conditions were typical. The principal wave energy from the winter Aleutian low-pressure systems did not track far enough south to reach Southern California. Summer swells were intermittent and came from distant Southern Hemisphere storms. The wave climate changed over the next 20 years from 1978 to 1998 with the onset of El Niño (periods of local warm water and corresponding large storms and high rainfall) weather conditions. There was an increase in the number and intensity of extreme wave events. High-energy winter waves approached the coastline from the west or southwest, and the shorter-period summer waves were from hurricanes off Central America.

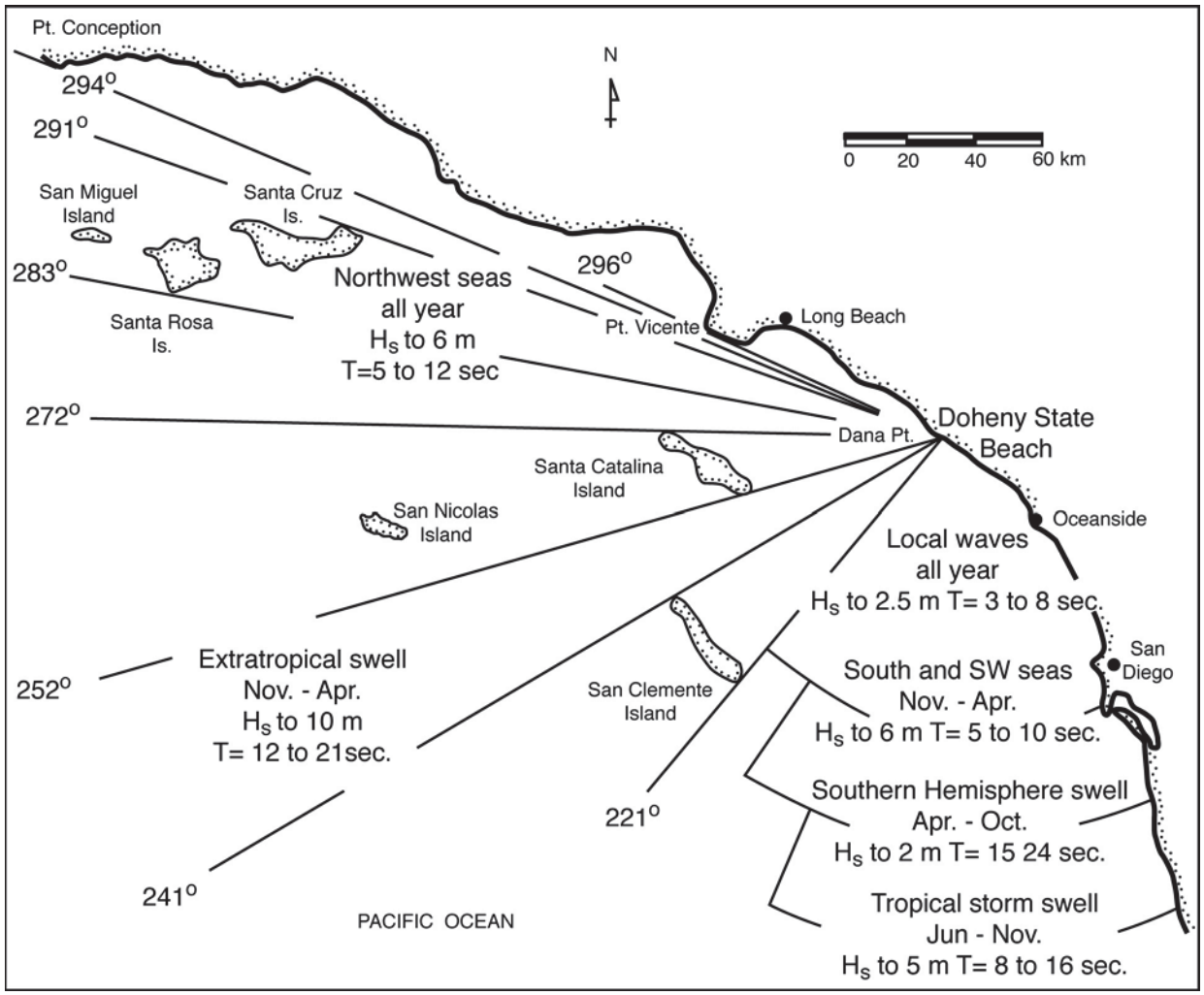


Figure 5-1. Wave exposure at Doheny State Beach illustrating island-shadowing effects.

5.2 WAVE CHARACTERISTICS

5.2.1 Available Wave Data

Measured wave data are unavailable measurements in the immediate vicinity of Doheny Beach. However, a directional wave measurement taken at Dana point at 370 m water depth is available between July 2000 and present (Station 096 at http://cdip.ucsd.edu) and Oceanside Beach between 1978 and 1994 are available. Huntington Beach and Doheny Beach share similar exposures to deep-ocean waves. The wave data for Oceanside Beach were collected by the Coastal Data Information Program (CDIP, 1992). Figure 5-2 shows the CDIP wave stations along the Southern California coast and indicates which stations are operational, which are non-operational, and which are de-commissioned. Table 5-1 provides a summary of the measured wave data. In this table, data are from nearshore and deepwater sources. Buoys, wave riders, and *Sxy* wave arrays provide directional information about measured wave conditions.

5.2.2 Spectral Refraction

Without the benefit of long-term wave measurements in the immediate vicinity of Doheny Beach, wave conditions must be estimated from a combination of deepwater wave hindcasts, regional wave measurements, and shallow-water wave models.

The transformation of deep-ocean directional wave spectra to Doheny Beach was performed using a spectral wave-refraction model (Longuet-Higgins, 1957; LeMehaute and Wang, 1982; O'Reilly and Guza, 1991). The model accounts for island blocking, wave refraction, and wave shoaling. The spectral model is linear and is used to derive transformation coefficient matrices between the deepwater wave spectrum and the shallow and/or sheltered location. At each wave frequency, *f,* the spectral refraction model is typically used to derive one energy transformation coefficient matrix,

$$C_E\,(f,\,\theta_o\,), \tag{5-1}$$

and transformation coefficient matrices for the four lowest-order directional moments of the nearshore wave spectrum:

$$\begin{aligned} &C_{E\cos\theta}\,(f,\,\theta_o),\\ &C_{E\sin\theta}\,(f,\,\theta_o),\\ &C_{E\cos 2\theta}\,(f,\,\theta_o),\\ &C_{E\sin 2\theta}\,(f,\,\theta_o), \end{aligned} \tag{5-2}$$

where, θ_o, is the deepwater direction and θ is the nearshore direction. Table 5-2 shows the wave energy matrix (Eq. 5-1) at 10m (33 ft) depth at Doheny Beach.

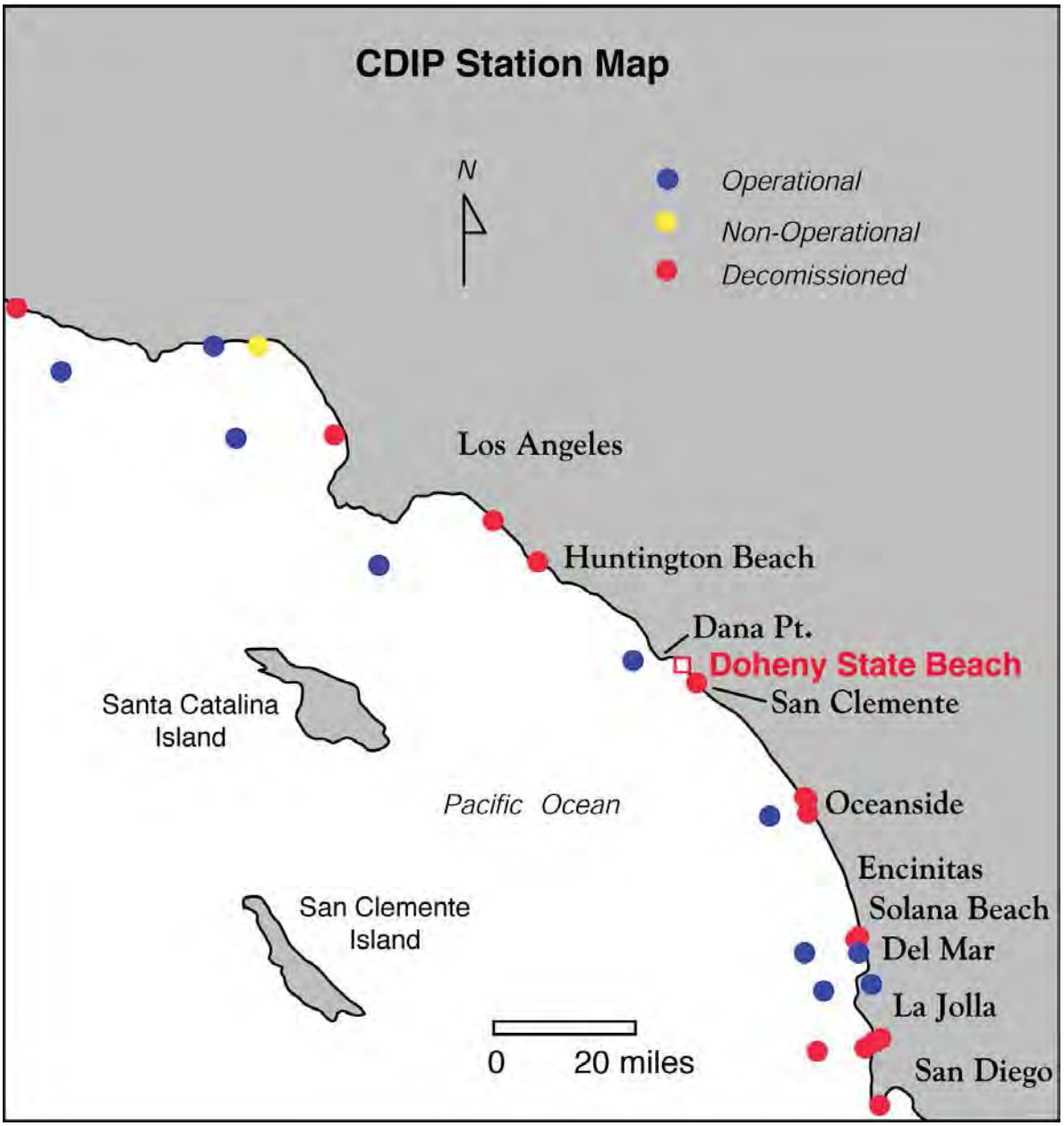


Figure 5-2. Location of CDIP wave stations along Southern California coast.

Table 5-1. Measured wave data summary (from USACOE, 1988).

Data Source	Years of Record	Data Gaps	Location		Water Depth (feet)	Sampling Interval
			Latitude	Longitude		
NOAA DATA BUOY - Buoy ID # 46024	4/82 - 10/85	11/83 - 5/84	32° 50'	119° 10'	2460	0.67 second 20 min. avg.
Dana Point	7/2000-9/1/14+	None	33° 45'	117° 76'	370	0.5 hr.
MISSION BAY – Waverider	2/81 - 3/87	1/1/82 - 5/18/82, 5/11/83 - 12/7/84, 2/25/84 - 12/16/84, 1/30/86 - 2/9/86	32° 44.8'	117° 22.3'	630	6 hr.
BEGG ROCK – Waverider	10/82 - 3/87	7/15/83 - 7/28/83	33° 24.4'	119° 40.1'	361	6 hr.
SCRIPPS PIER - Unidirectional Wave Gauge	4/77 - 2/87	5/77, 3/78 - 1/79, 11/30/83 - 3/5/84, 2/5/86 - 3/24/86, 2/86 - 5/86	32° 52'	117° 15.4'	26	6 hr.
MISSION BAY ENTRANCE - S_{xy} Array	8/78 - 3/87	2/79 - 7/80, 3/1/83 - 2/4/85	32° 45.4'	117° 15.7'	32.8	6 hr.
DEL MAR - S_{xy} Array	7/83 - 3/87	None	32° 57.4'	117° 16.7'	35	6 hr.
OCEANSIDE BEACH - S_{xy} Array	12/78 - 3/87	12/5/80 - 12/15/80, 1/18/81 - 3/28/81, 3/28/81 - 7/12/83	33° 11.4'	117° 23.4'	30	6 hr.
SAN CLEMENTE - S_{xy} Array	7/83 - 3/87	None	33° 24.9'	117° 37.8'	33.5	6 hr.
SHIPBOARD OBSERVATIONS	1949 - 1986		32.5° to 33.5°	118.5° to 120°	Varies	Varies

Table 5-2. Wave energy transformation coefficient matrix, C (f,θ) (Eq. 5-3), for swell frequencies at 33 ft (10 m) depth at Doheny Beach. Columns show wave frequency (0.01Hz frequency bands); rows show deepwater wave direction (5° direction bands).

(θ_o)(f)	0	0.05	0.06	0.07	0.08	0.09	0.1	0.11	0.12Hz
155°	0.01	0	0.03	0	0	0.02	0.04	0.06	0.12
160	0.01	0.02	0.1	0.03	0.02	0.03	0.06	0.08	0.07
165	0.03	0.02	1.06	0.17	0.38	0.63	0.57	0.61	0.67
170	0.07	0.05	1.62	0.99	0.53	0.6	0.69	0.7	0.68
175	0.15	0.06	1.37	1.25	0.84	0.78	0.75	0.74	0.77
180	0.25	0.12	0.62	1.71	0.88	0.74	0.78	0.83	0.81
185	0.39	0.21	0.86	1.34	1.09	0.79	0.73	0.76	0.79
190	0.47	0.28	1.09	0.72	1.35	1.04	0.84	0.79	0.76
195	0.15	0.18	0.49	1.08	0.74	0.99	0.95	0.85	0.84
200	0.39	0.34	0.28	1.04	1.46	0.86	0.91	0.9	0.86
205	0.71	0.62	0.46	0.43	0.62	1.17	1.05	0.96	0.9
210	1.43	1.06	0.89	0.68	0.61	0.67	0.75	0.79	0.83
215	2.34	2.28	2.09	1.79	1.47	1.19	1.06	0.98	0.92
220	0.94	0.58	0.49	0.49	0.59	0.69	0.69	0.72	0.69
225	0.08	0.06	0.03	0.08	0.12	0.09	0.06	0.04	0.03
230	0.06	0.04	0.03	0.08	0.08	0.06	0.04	0.01	0.01
235	0.03	0.04	0.04	0.12	0.07	0.08	0.07	0.04	0.03
240	0.03	0.05	0.06	0.08	0.09	0.08	0.09	0.09	0.09
245	0.05	0.12	0.29	0.3	0.55	0.68	0.68	0.74	0.74
250	0.07	0.17	0.32	0.61	0.89	1.16	1.05	0.9	0.85
255	0.15	0.27	0.14	0.18	0.72	0.5	0.29	0.24	0.23
260	0.2	0.12	0.06	0.18	0.13	0.04	0.02	0.01	0.01
265	0.2	0.18	0.03	0.03	0.05	0.02	0.01	0.01	0
270	0.09	0.12	0.04	0.03	0.12	0.04	0.04	0.03	0.03
275	0.07	0.22	0.14	0.53	0.49	0.37	0.39	0.36	0.38
280	0.07	0.19	0.13	1.02	0.46	0.35	0.3	0.32	0.31
285	0.05	0.1	0.03	0.15	0.09	0.03	0.02	0.02	0.01
290	0.03	0.08	0.02	0.2	0.01	0	0	0.02	0
295	0.02	0.04	0.01	0.01	0	0	0	0	0
300	0.01	0.02	0	0	0	0	0	0	0
305	0.01	0.01	0	0	0	0	0	0	0
310	0	0.01	0	0	0	0	0	0	0
315	0	0	0	0	0	0	0	0	0
320	0	0	0	0	0	0	0	0	0
325	0	0	0	0	0	0	0	0	0
330	0	0	0	0	0	0	0	0	0
335	0	0	0	0	0	0	0	0	0

The transformation coefficients are in turn used to estimate the nearshore wave frequency spectrum:

$$S(f) = \Sigma_{\theta o}\, S_o\,(f,\theta_o) \times C_E(f,\theta_o) \tag{5-3}$$

and the two lowest-order nearshore directional moments at each frequency:

$$\begin{aligned} \textstyle\int_\theta S\,(f,\theta) \times cos\,(\theta\,) &= \Sigma_{\theta o}\, S_o\,(f,\,\theta_o) \times C_{Ecos\,\theta}\,(f,\theta_o), \\ \textstyle\int_\theta S\,(f,\theta) \times sin\,(\theta\,) &= \Sigma_{\theta o}\, S_o\,(f,\theta_o) \times C_{Esin\,\theta}\,(f,\theta_o), \end{aligned} \tag{5-4}$$

The two nearshore directional moments derived in Equation 5-4 can be converted to the more commonly used directional Fourier coefficients by normalizing with the wave energy:

$$\begin{aligned} a_1(f) &= \{ \textstyle\int_\theta S\,(f,\theta\,) \times cos(\theta\,) = \Sigma_{\theta o}\, S_o(f,\theta_o) \times C_{Ecos\theta}\,(f,\theta_o)\,\} \,/\, S(f), \\ b_1(f) &= \{ \textstyle\int_\theta S\,(f,\theta\,) \times sin(\theta\,) = \Sigma_{\theta o}\, S_o(f,\theta_o) \times C_{Esin\theta}\,\,(f,\theta_o)\,\} \,/\, S(f), \end{aligned} \tag{5-5}$$

The frequency spectrum (Equation 5-3) and the directional Fourier coefficients (Equation 5-5) are the same wave parameters measured by directional buoys and pressure-velocity (PUV) sensors.

The directional Fourier coefficients can be used to estimate the mean wave direction and directional spread at each wave frequency,

$$\begin{aligned} &\text{mean direction} && \theta_m = tan^{-1}\,[\,b_1 / a_1\,], \\ &\text{spread} && \sigma = [\,1 - m_1\,]^{1/2} \\ &\text{with} && m_1 = (a_1^2 + b_1^2)^{1/2} \end{aligned} \tag{5-6}$$

Finally, the energy transformation coefficient matrix (Equation 5-1) can be used to further derive the relative total energy ratios, E/E_o, or wave heights, H/H_o, of the shallow-water wave spectrum at Doheny Beach, $S(f)$, for a specified deep-ocean frequency directional wave spectrum, $S_o\,(f,\,\theta_o)$:

$$H / H_o = (E / E_o)^{1/2} = \Sigma_f\, S(f) \,/\, \Sigma_f \Sigma_\theta\, S_o(f,\theta\,) \tag{5-7}$$

Where $S(f)$ is estimated from $S_o\,(f,\,\theta_o)$ using Eq. 5-3.

The spectral-refraction model results can also be presented as sheltering coefficients over a range of possible peak wave periods, or frequencies, and peak deep-ocean wave directions. Table 5-2 shows the relative wave energy coefficients for Doheny Beach. These are for narrow, rectangular "bins" of the incident deepwater wave spectra ($0.01Hz$, $5°$) of uniform wave energy density. Deepwater wave spectra of any shape can be transformed to wave energy at Doheny Beach using these coefficients. Additional coefficients are obtained from the model to transform offshore wave spectra to directional moments, equivalent to those measured by buoys and pressure-current meters, in order to also estimate the mean wave direction and spread of the Doheny Beach wave spectra.

5.2.3 Wave Exposure at Doheny Beach

To provide a general overview of the Doheny Beach wave exposure to all plausible deepwater wave events, simulated deepwater wave spectra are transformed to Doheny Beach. The three major types of wave events are simulated: extra-tropical (North Pacific winter), tropical (Mexican summer), and Southern Hemisphere (south swell) storms.

In order to account for the spectral nature of these storm events, each is given a frequency and directional distribution as proposed by Goda (1985). The frequency spectrum is a simplified version of the JONSWAP spectrum given by Hasselmann et al. (1973). Its shape is defined by the significant wave height, peak period, and a peak enhancement factor, Γ. Larger values of Γ result in a narrow peak in the frequency spectrum, and are representative of well-dispersed waves arriving from a distant storm.

The directional distribution of wave energy at each frequency is a modified version of that described by Mitsuyasu et al. (1975). In this case, the spectral shape is specified by the significant wave height, peak frequency, peak direction, and a spreading parameter, s_{max}. Larger spreading parameters represent narrower directional distributions and more distant wave sources.

The values of Γ and s_{max} used to represent each of the three primary types of wave event are presented in Table 5-3.

In order to get an overall view of the sheltering and shallow-water effects at a given site, or wave exposure, offshore wave spectra for each type of event were transformed to the Doheny site for all plausible combinations of offshore peak direction and peak wave period. The resulting relative wave heights (H/H_o; Eq. 5-7) and mean wave directions at Doheny (θ_m, Eq. 5-6) were then contoured as a function of the type of wave event, its peak period, and its peak deepwater wave direction (Figures 5-3 through 5-5).

The computed coefficients listed in Table 5-2 were used to transfer the deep water directional wave measurements to 10 m water depth at Doheny State Beach. Deep water wave data were from the Huntington Beach wave buoy for the period between 1992 to June 2000 and from the Dana Point wave buoy from July 2000 to 2014. Figure 5-6 shows significant wave height (Hs) and the peak wave period. Figure 5-7 shows deep water wave rose for wave directions (degrees) and height (m). Figure 5-8 shows the distribution of the observed/real wave periods shown in Figure 5-6 (bottom).

Table 5-3. JONSWAP frequency width parameter, Γ, and directional width parameter, S_{max}, used to define two-dimensional wave spectra for energetic wave events that affect Southern California.

Event Type	Γ, Frequency Width Parameter	S_{max}, Directional Width Parameter
North Pacific (swell)	8	75
North Pacific (seas)	4	10
Tropical Storms	5	22
Southern Swell	10	1,000

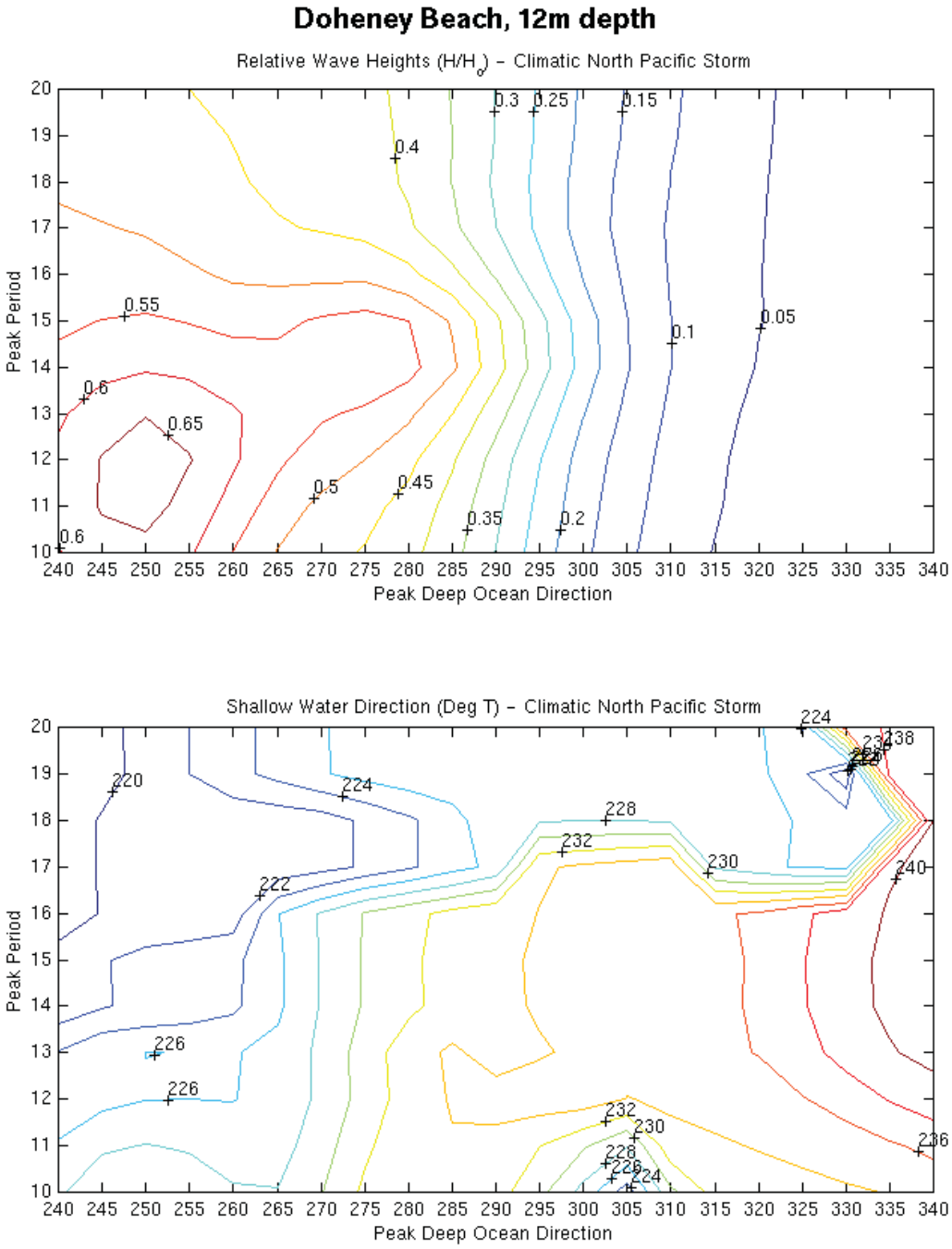


Figure 5-3. Wave exposure contour plots for North Pacific storms. Greatest exposure is for 11-12s waves arriving from WSW (250°). These waves would have a mean direction of 226° at the Doheny Beach 33 ft (10 m) site.

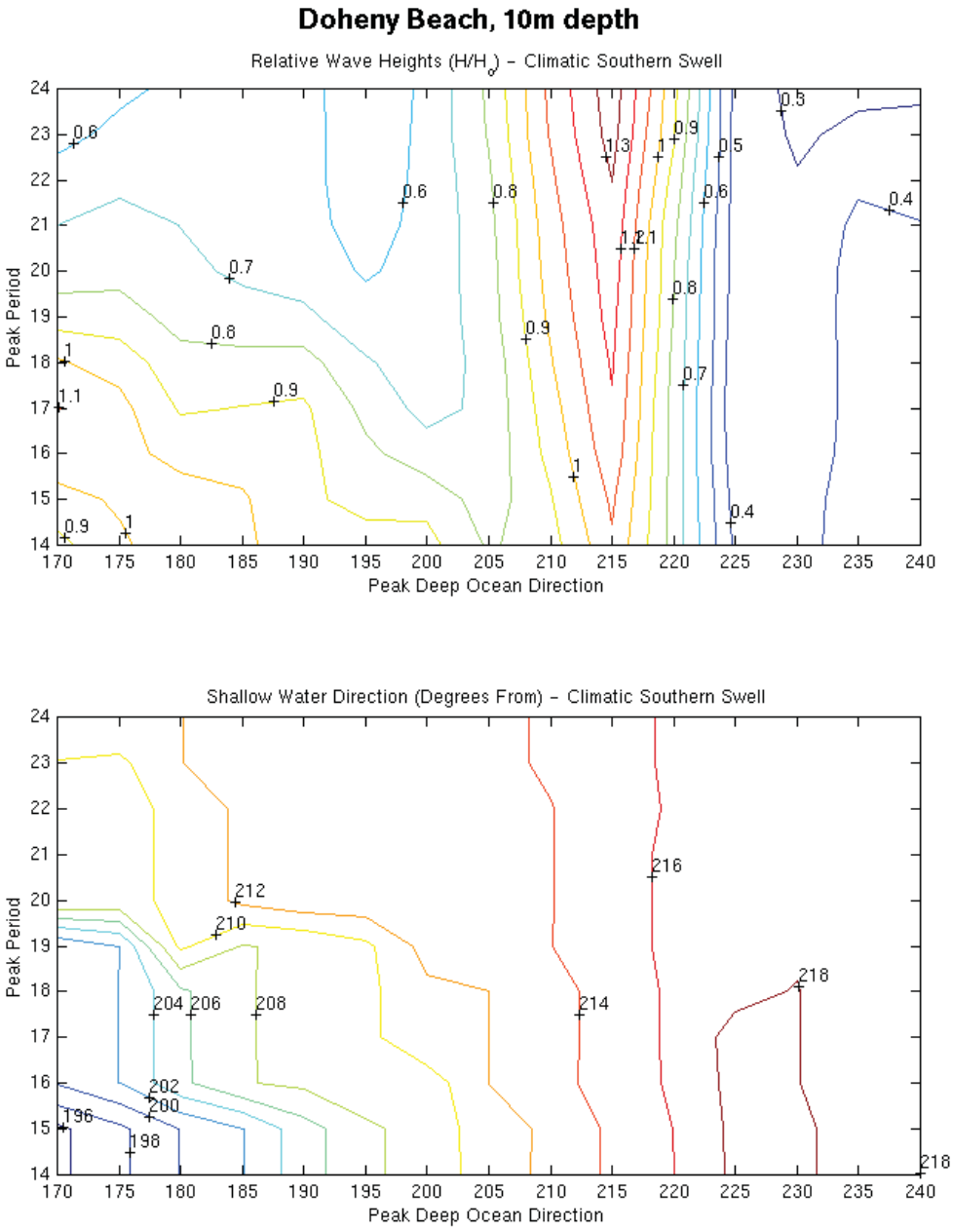


Figure 5-4. Wave exposure contour plots for tropical storms. Greatest exposure is for 14-16s waves arriving from SSW (195°). These waves would have a mean direction of 206° at the Doheny Beach 33 ft (10 m) site.

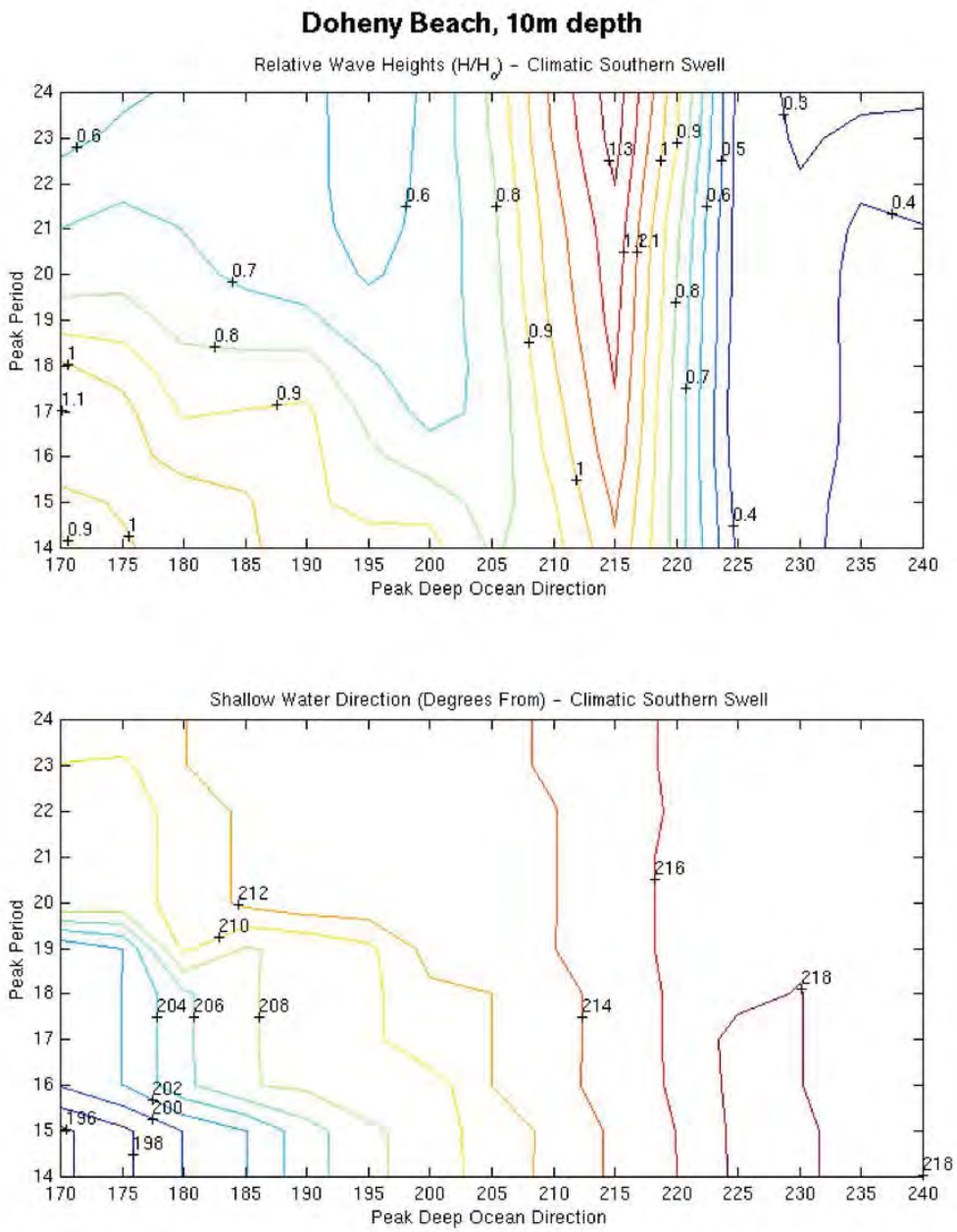


Figure 5-5. Wave exposure contour plots for Southern Hemisphere swell. Greatest exposure is for 20+s waves arriving from SW (215°). These waves would have a mean direction of 216° at the Doheny Beach 33 ft (10 m) site.

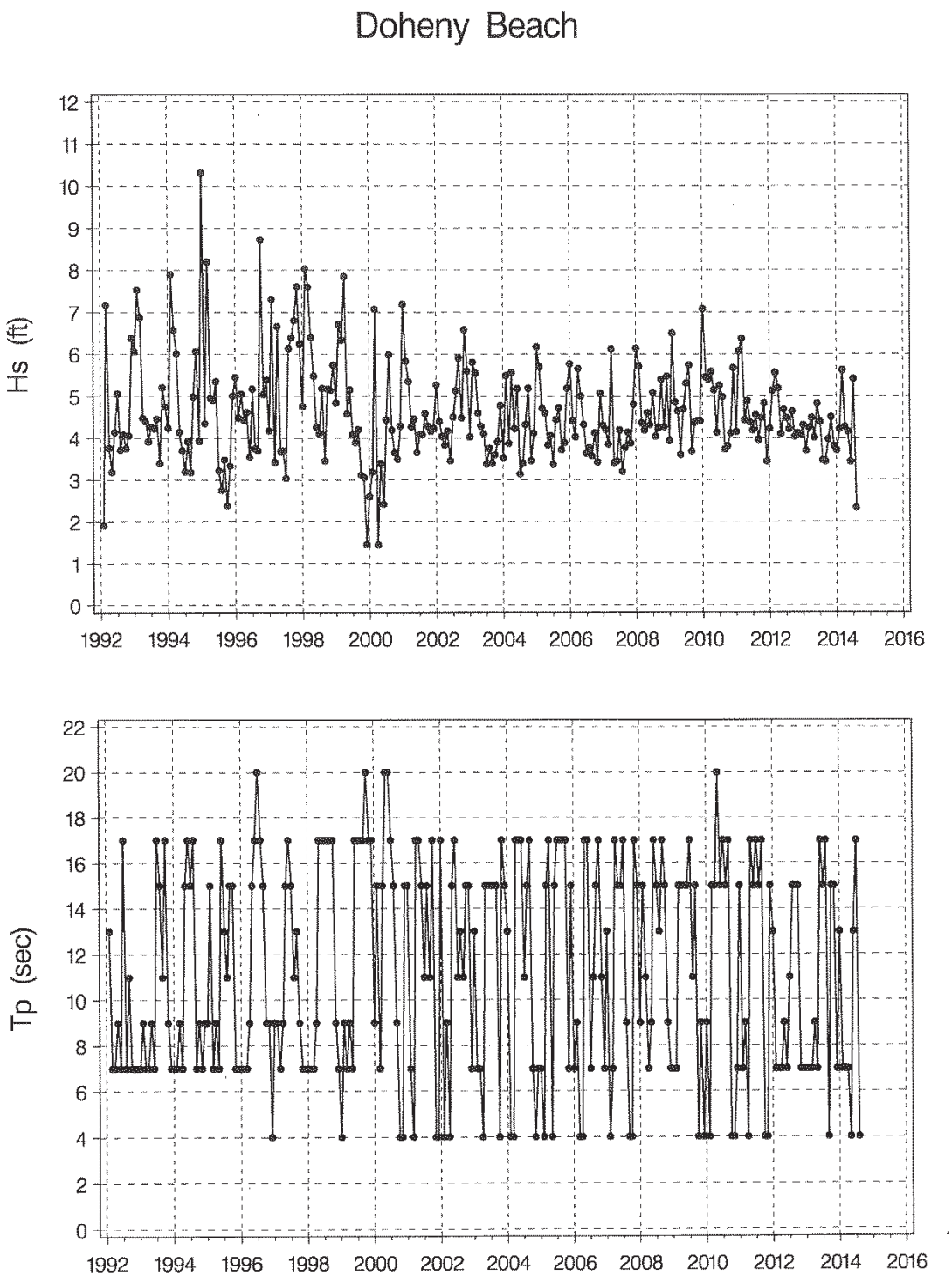


Figure 5-6. Maximum monthly wave height (ft) from 1992 to present (top). Wave periods (secs) for these high waves are presented below (bottom). Computed from Huntington Beach and Dana Point wave Buoys at 10 m water depth.

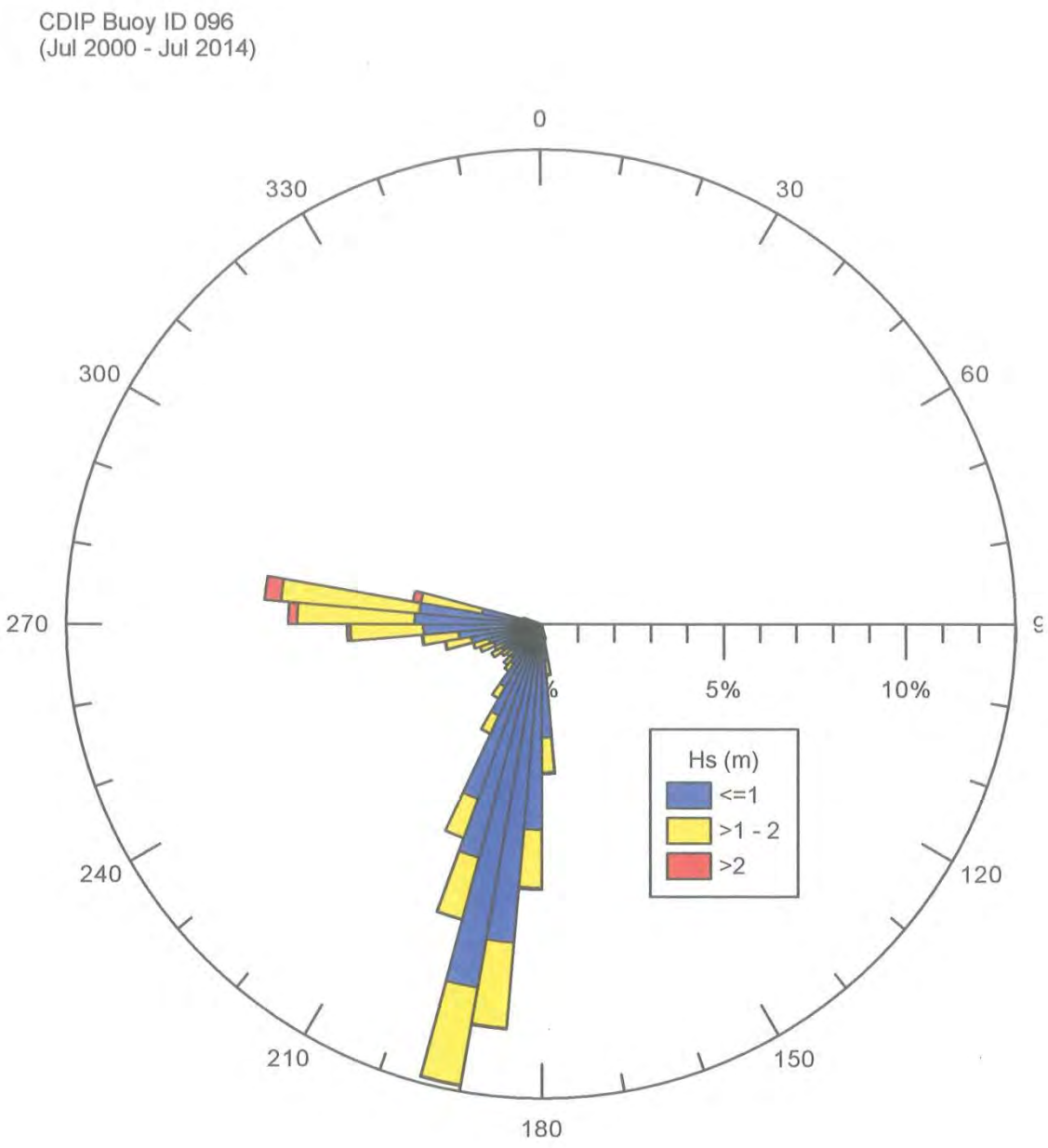


Figure 5-7. Deep water wave rose for wave directions (degrees) and height (m).

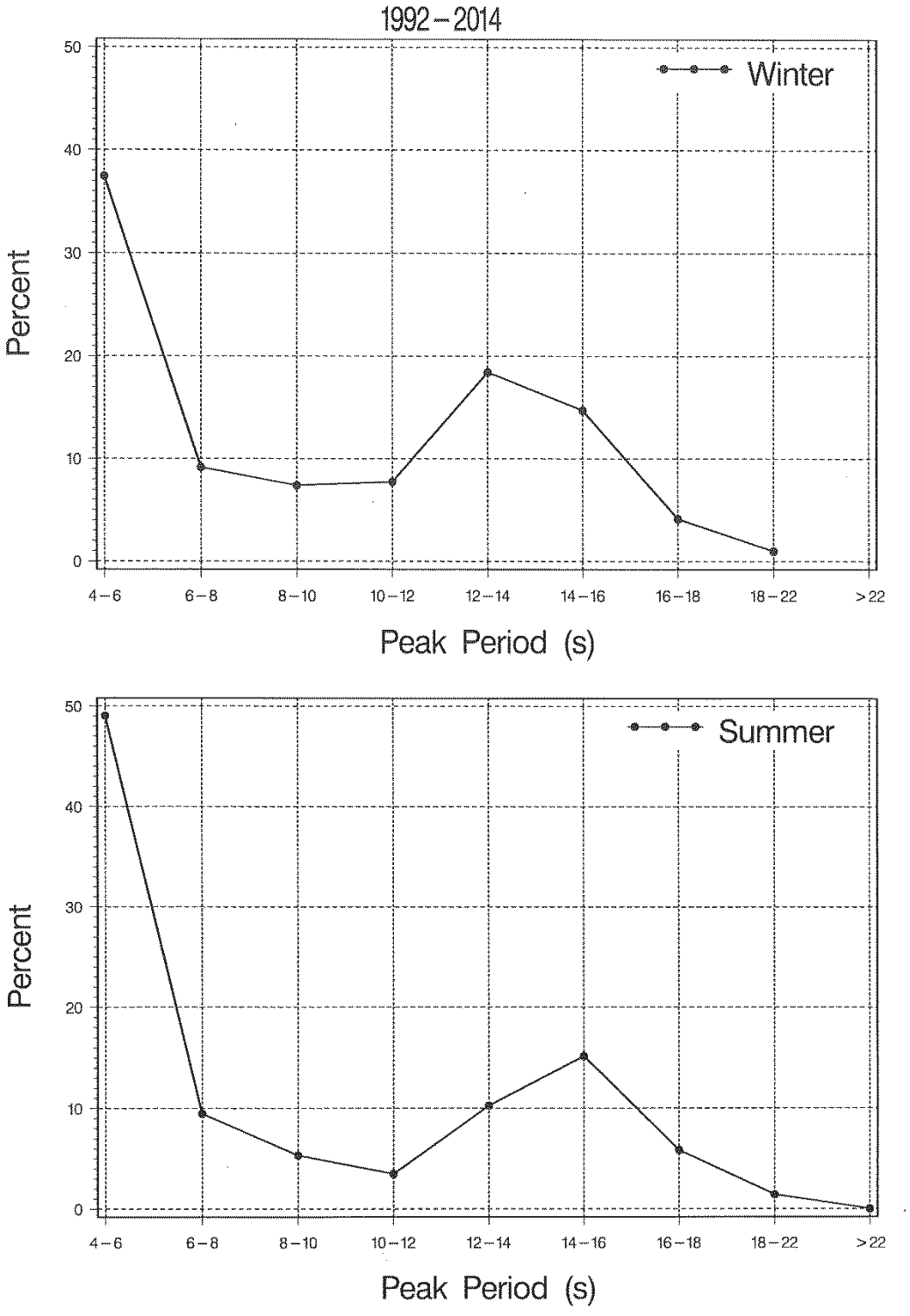


Figure 5-8. Distribution of the observed/real wave periods shown in Figure 5-6 (bottom).

6.0 TIDES AND SEA LEVEL

The tide refers to the change of ocean water level caused by the astronomical forces of the moon and sun. Tidal fluctuations are superimposed upon sea level. Tides along the California coast are mixed, with two high and two low tides of unequal amplitude occurring each day. Seasonal sea level, as determined from monthly mean values, tends to be highest in the fall and lowest in the spring, with differences of about 0.5 ft.

Tidal elevations are referenced to Mean Lower Low Water (MLLW), which is defined as the elevation of the lowest water level reading of each day averaged over a specified 19-year interval, currently 1960-1978 (National IDA Datum Epoch). In this study area, the maximum tidal range is about 9 ft (from 7.2 ft above MLLW to 1.8 ft below MLLW).

Storm surges are increases in water level above the tide that result from the effects of lower atmospheric pressure and higher winds during storms. The storm-surge component of sea level is a maximum of 1 ft along the Southern California coast. Together, tides, storm surges, and sea level changes determine design water levels. The design water level is important for beach processes and engineering, since it determines how high and how far shoreward the effects of breaking waves can reach. For example, if sea levels are unusually high because of the high tides, storms, and elevated sea levels that are associated with El Niño conditions, as occurred during the winters of 1982-83 and 1997-98, large waves can be far more effective in causing flooding, structural damage, beach erosion, and cliff failure than under normal conditions.

Evidence indicates that sea level is rising with respect to land at an accelerating rate due to global warming. The widely accepted value for global SLR over the past century is 0.6-0.7 ft (Revelle, 1983). The Scripps Pier tide gauge, which has been in continuous operation since 1924, shows a mean rate of sea level increase of about 0.7 ft/100 years. Local warming or cooling resulting from offshore shifts in water masses can alter the average sea level by .006 to .008 ft/year (Everts Coastal, 1997) based on 20th century data. A doubling of the rate of SLR is within most scenarios of SLR for the 21st century (Everts Coastal, 1997).

NOAA (National Oceanographic and Atmospheric Administration) tidal stations are located at the Newport Harbor entrance (Station 9410580) and at San Clemente (33° 25' 117° 37'). Tidal datums at the Newport Harbor entrance and at Scripps Pier, La Jolla, in San Diego County (Station 9410230) are included in Table 6-1. Note that there are no significant differences between the two tide stations. Because of greater accessibility, the data from Scripps Pier were utilized to describe the design water level elevations.

Histograms of sea level data for winter and summer seasons at La Jolla are shown in Figure 6-1. Figure 6-2 shows the cumulative distribution of sea level data at La Jolla. It should be noted that 95% of the time, sea level elevation is less than 3.3 ft, NGVD. Figure 6-3 shows the joint probability distribution between significant wave height and tide level. This figure shows that significant wave events may occur at any tidal elevation. This is because astronomic tides are independent of wave storms or weather systems.

Table 6-1. Tidal datums at Newport Harbor and Scripps Pier.

Datum	Elevation (ft) Newport Harbor	Elevation (ft) Scripps Pier	Difference (ft)
Mean Higher High Water	5.39	5.37	0.02
Mean High Water	4.65	4.62	0.03
Mean Tidal Level	2.79	2.77	0.02
NGVD29 [a]	2.71	2.56	0.06
Mean Low Water	0.93	0.93	0
NAVD88 [b]	0.37	0.45	0.08
Mean Lower Low Water	0	0	0

[a] National Geodetic Vertical Datum, 1929
[b] North American Vertical Datum, 1988

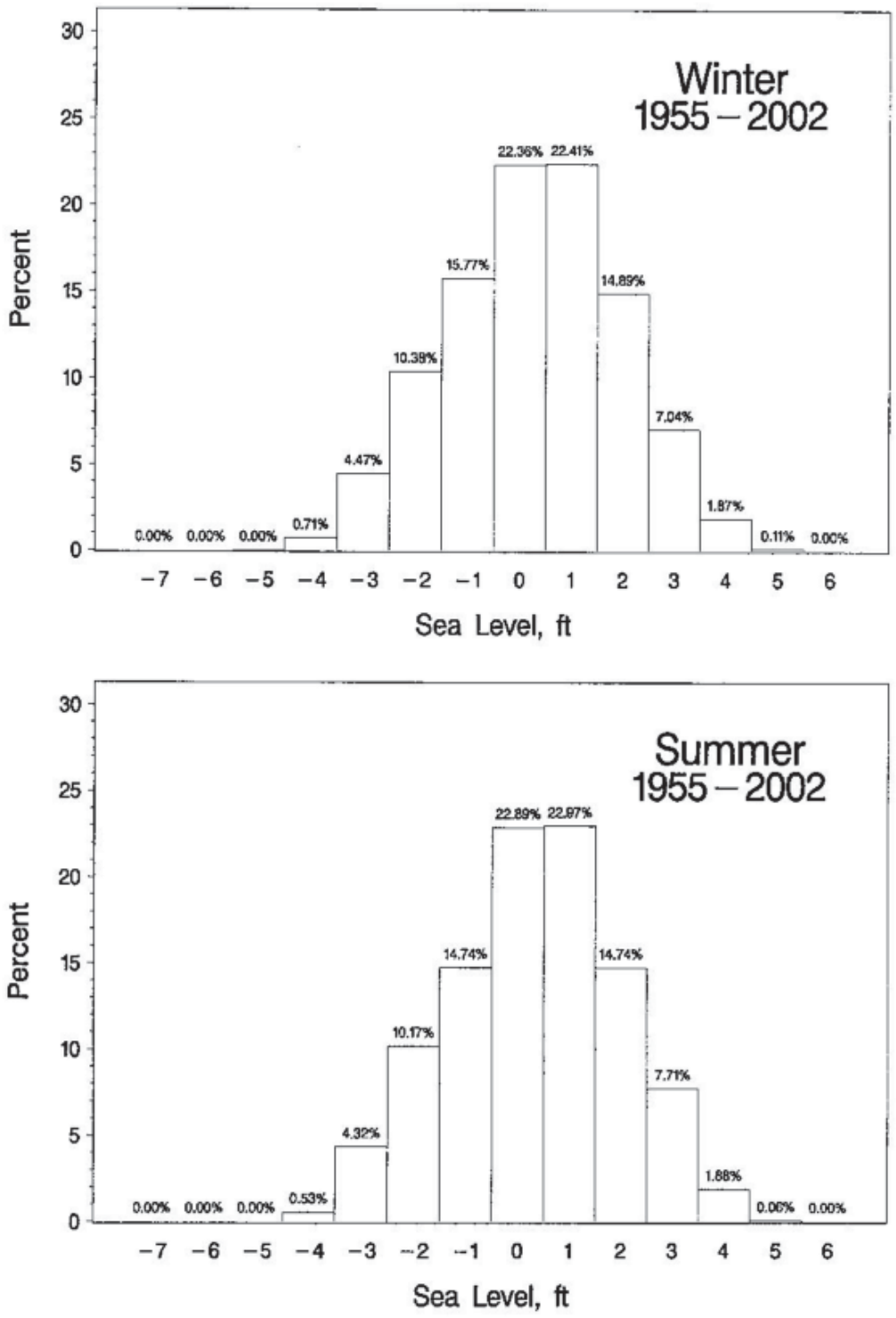


Figure 6-1. Histogram of tide height for winter (top) and summer (bottom) seasons between 1955 and 2002 with respect to NGVD 1929.

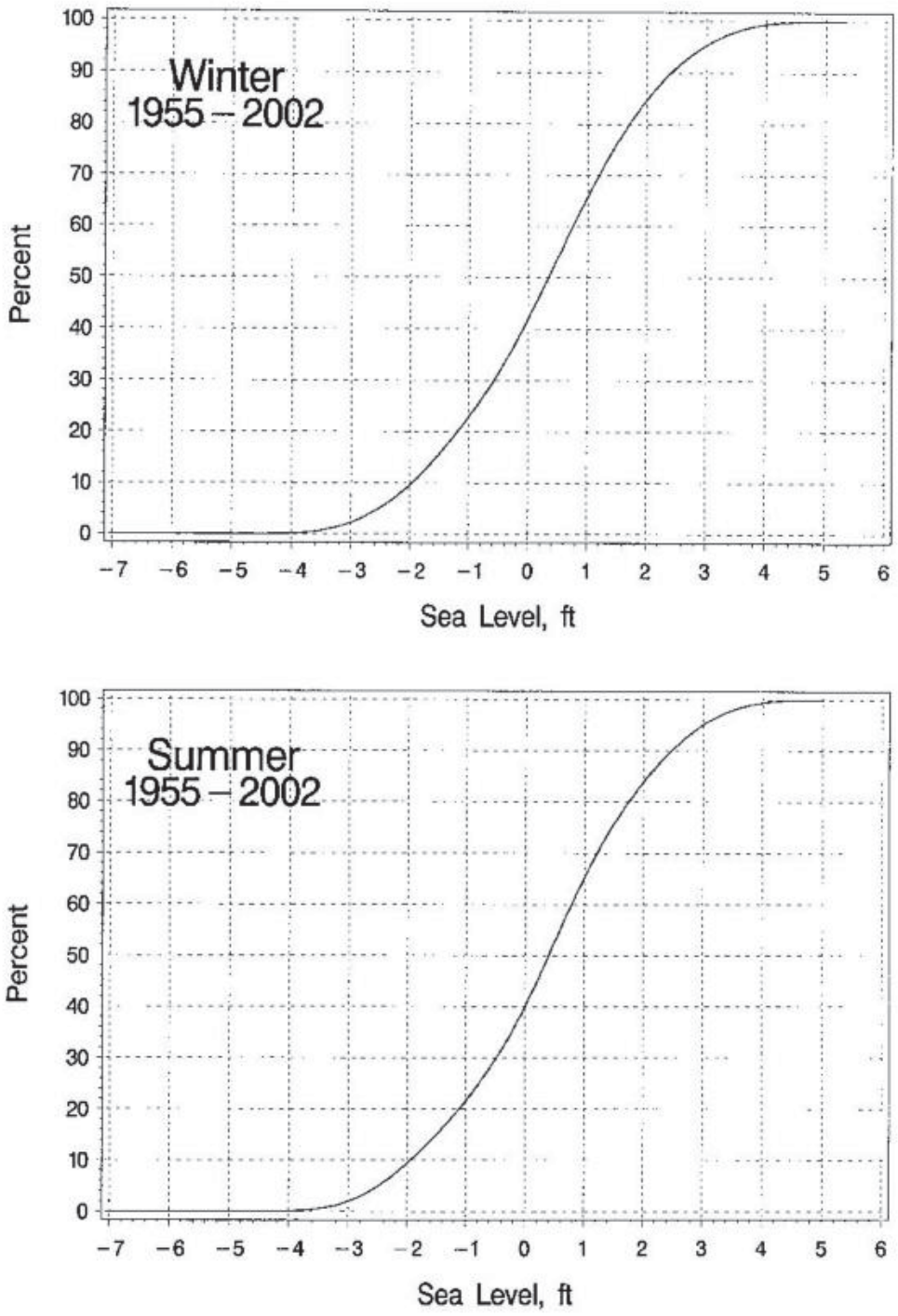


Figure 6-2. Cumulative percentage of tide heights for winter (top) and summer (bottom) seasons from 1955-200 with respect to NGVD 1929.

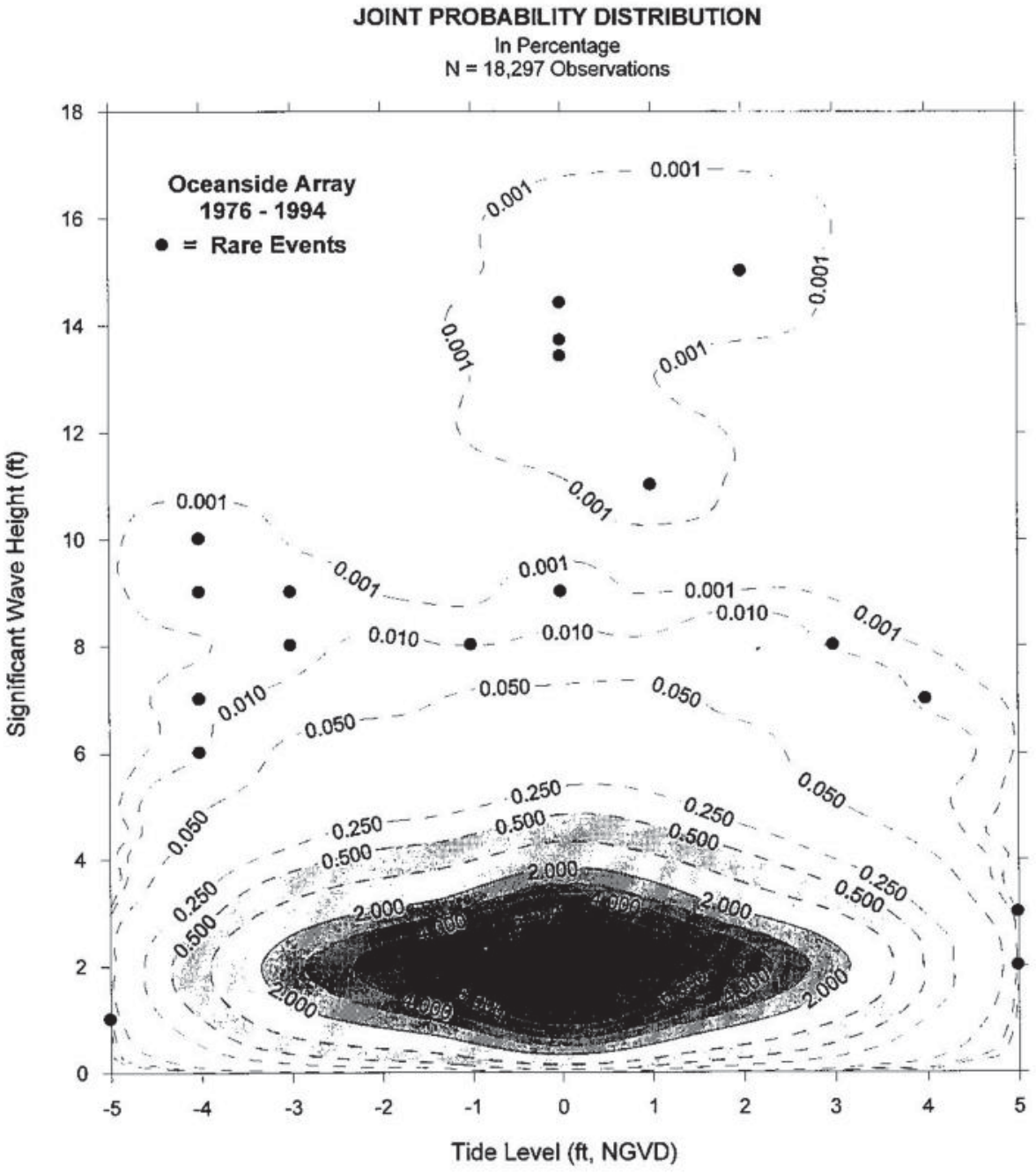


Figure 6-3. Joint probability distribution between significant wave height and sea level. Tidal values are with respect to NGVD 1929.

7.0 COASTAL SEDIMENTS AND LITTORAL TRANSPORT

A littoral cell is defined as a geographic area with a complete cycle of littoral sand sources, transport paths, and sinks (Inman and Frautschy, 1965). The Oceanside Littoral Cell extends approximately 53 miles from Dana Point to Point La Jolla and the Scripps-La Jolla Submarine Canyon System (Figure 7-1). The headland at Dana Point to the north and the submarine canyon at La Jolla to the south define the boundaries of the Oceanside Littoral Cell. These boundaries are considered as complete littoral barriers, where no littoral sediment is exchanged between the two adjacent littoral cells. The main sources of sand in the Oceanside Littoral Cell include river discharge, cliff erosion, and to a smaller extent, artificial beach nourishment (Section 7.2). The sink of the Oceanside Littoral Cell is the La Jolla Submarine Canyon. Sand may also be lost offshore along the littoral cell during storms. This littoral cell can be divided into two main segments or sub-cells, one extending from Dana Point to Oceanside Harbor, and the other extending from Oceanside Harbor to Point La Jolla. Doheny State Beach is located at the northern, updrift end of the Oceanside Littoral Cell. Since the 1930s, the amount of sediment entering the system has decreased because of the damming and stabilizing of affiliated rivers (Inman, 1985).

7.1 SEDIMENT SOURCES

7.1.1 Rivers

Despite damming and stabilization, rivers along the Oceanside Littoral Cell contribute some sediment to the littoral cell during periods of high rainfall and runoff. The USACOE (1987) estimated that the average total sediment yield of all the major rivers in the Oceanside Littoral Cell was about 159,000 yd^3/yr.

Table 7-1 shows the range of estimated volumes of littoral sediments supplied by the major rivers in the Oceanside Littoral Cell (Zampol et al., 1997). The total range of sediment volume entering the cell is estimated at 67,240 to 167,840 yd^3/yr. The volume of sediment entering the littoral cell from river sources is greater north of Oceanside Harbor than south of it, as seen in Table 7-1.

7.1.2 Cliffs

Since the beaches within the Oceanside Littoral Cell are relatively narrow, the elevated water level and increased wave action produced by storms commonly reach the base of the sea cliffs, which may result in severe erosion. Cliff erosion may also increase during rainfall because of landslides. Estimates of cliff erosion rates and total yield of sandy sediments were presented by the USACOE (1991, Table 9-6). These estimates are highly variable and depend greatly on the location of the cliffs. Estimates of total sandy sediment yield over a 79-year period for the cliffs north of Oceanside Harbor at Camp Pendleton and the cliffs at Torrey Pines State Beach are 23.6×10^6 yd^3 and 4.4×10^6 yd^3, respectively. This represents an overall sediment contribution rate of approximately 354,430 yd^3/yr from the cliffs to the beaches within the Oceanside Littoral Cell.

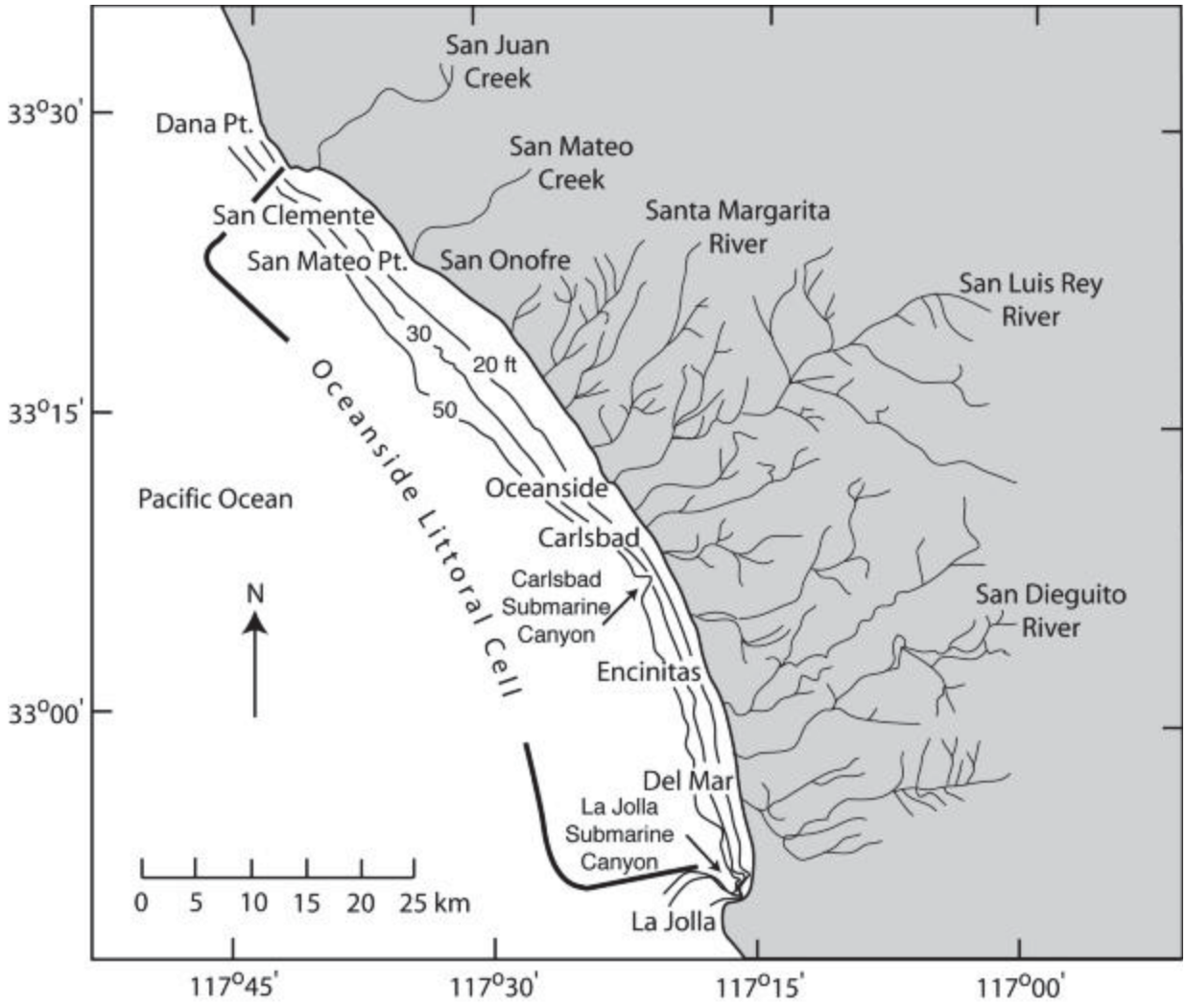


Figure 7-1. Location of Oceanside Littoral Cell, modified from Inman et al. (1983).

Table 7-1. Estimated river coarse sediment yield in the Oceanside Littoral Cell (yd^3/yr).

River/Stream	DNOD[1] (1977)	Brownlie[2] & Taylor (1981)	Inman[3] & Jenkins 1983)	Simmons,[4] Li & Assoc. (1988)	Range of Estimates
San Juan Creek	47,000 /56,000[5]	---	---	34,000	34,000-56,000
San Mateo Creek	32,000	---	---	8,100	8,100-32,000
San Onofre Creek	5,000	---	---	1,800	1,800-5,000
Las Flores Creek	4,000	---	---	2,700	2,700-4,000
Aliso Canyon Creek	---	---	---	900	900
Santa Margarita River	15,000	7,000	9,000	19,000	7,000-19,000
Oceanside Harbor					
San Luis Rey River	351,000	18,000	22,000	10,800	10,800-18,000 (351,000)[6]
Loma Alta Creek[7]	14,000[7]	---	---	940	940
Buena Vista Creek[7]		---	---	0	0
Agua Hedionda Creek[7]		---	---	0	0-14,000[7]
San Marcos Creek[7]		---	---	0	---
Encinitas Creek[7]		---	---	0	---
Escondido Creek	14,000	---	---	0	0-14,000
La Orilla Creek	---	---	---	0	0
San Dieguito River	4,000	1,500	2,000	1,000	1,000-4,000
Carmel Valley Creek[8]	---	---	---	0	---
Los Peñasquitos Creek[8]	---	---	---	0	---
Carroll Canyon Creek[8]	---	---	---	0	---
			Total Range		**67,240-167,840**

[1] Present sediment production.
[2] Period of maximum control, or total period of record, if less.
[3] Values calculated using the data of Brownlie & Taylor (1981) and assumed to be sand-to-suspended- load ratios of Inman & Jenkins (1983).
[4] Present condition.
[5] USGS estimate of sediment discharge reported in DNOD (1977).
[6] Extreme value.
[7] San Marcos Group of DNOD (1977) assumed to include Loma Vista Creek to Encinitas Creek.
[8] DNOD (1977) sediment estimates from these creeks were not directly given (see Table 2 and footnote 5).

7.1.3 Placement of Sand

In addition, sand has been placed on Doheny State Beach from dredging of the San Juan Creek (as discussed in Chapter 3). Sand has also been brought in from other areas. For example, sand from old terrace deposits at Camp Pendleton was placed on the subject beach in 1966 (estimated at 690,000 cubic yards). About 212,000 cubic yards were added in November of 1969. In 1970, about 125,000 cubic yards of dredged material were placed offshore in an attempt to enhance surfing conditions (Wiegel, 1994).

7.2 LONGSHORE TRANSPORT AT SAN CLEMENTE AND DANA POINT

The principal mechanism for transporting beach sand along the shore is the longshore or littoral drift of sand in the surf zone (Inman and Frautschy, 1965; Inman et al., 1968; Komar and Inman, 1970). The longshore transport moves sand suspended by the turbulence of breaking waves and carries it along the shore by the longshore current produced by breaking waves approaching the shore obliquely.

The Seymour and Higgins formula (1978) relates the longshore sediment transport rate in the surf zone to the component of radiation stress in the longshore direction (S_{xy}) and significant wave height (H_s) at the array. This involves two assumptions: (1) that the shoreline contours are straight and parallel, so that S_{xy} is conserved between the array and the breakpoint (Longuet-Higgins, 1970); and (2) that the depth at breaking (h_b) can be approximated by 1.65 times H_s at the array (Griswold, 1964). The relation used in the present study is:

$$Q_\ell = (3.843 \times 10^6)\, S_{xy}(H_s)^{0.5} \tag{7-1}$$

where Q_ℓ is the "at rest" volume transport rate of sand in yd^3/yr, S_{xy} and H_s at the array are expressed in ft^2, respectively, and the proportionality coefficient, 3.843×10^6, has units $yd^3/(yr \times ft^{2.5})$.

In metric units, the equation above can be written as:

$$Q_\ell = 980\, S_{xy}(H_s)^{0.5} \tag{7-2}$$

where Q_ℓ is the "at rest" volume transport rate of sand in m^3/yr, S_{xy} and H_s at the array are expressed in their CDIP reported units of cm^2 and cm, respectively, and the proportionality coefficient of 980 has units $m^3/(yr \times cm^{2.5})$.

Figure 7-2 shows a plot of monthly averaged daily longshore transport potential calculated from directional wave measurements made at San Clemente, San Onofre, and Oceanside. The data from San Clemente are represented by a dashed line, while the data from Oceanside are represented by a solid line. San Onofre is located 2,000 ft south of San Mateo Point between Oceanside and San Clemente. Directional wave data from San Clemente and Oceanside were routinely collected by the CDIP at Scripps Institution of Oceanography (1992) at 11 m water depth. Wave data from San Onofre were collected by EcoSystems Management Associates, Inc. (Reitzel et al. 1988) using the "S4" directional wave meter at 10m water depth. Wave height data begins in 1981, but directional measurements only cover the period from April 1985 to December 1986.

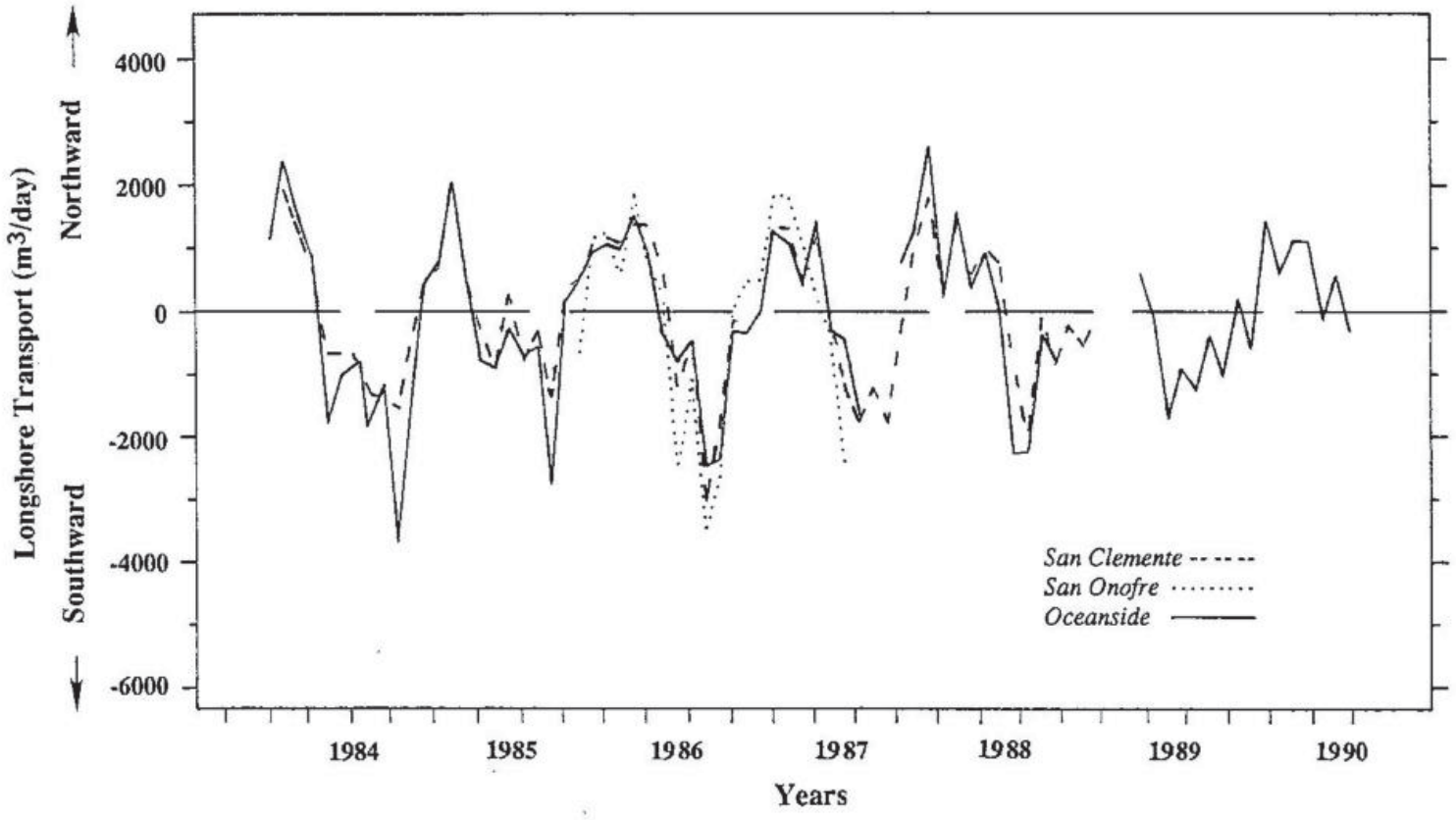


Figure 7-2. Longshore transport potential (m^3/day) at San Clemente, San Onofre, and Oceanside from 1983 through 1989 (calculated from directional wave measurements).

Over the five-year period from 1983 to 1988 when simultaneous data were recorded, there was good qualitative agreement between the transport rates at San Clemente and Oceanside. The dotted line in Figure 7-2 shows the directional measurements at San Onofre. There is also good agreement of magnitude and phase with the results reported for Oceanside and San Clemente.

Elwany et al. (1999) calculated longshore sediment transport at Oceanside from 1978 to 1994. They estimated the longshore transport to the north per year to be +320,600 yd^3/yr and transport to the south per year to be -371,600 yd^3/yr. The net transport per year was -51,000 yd^3/yr (to the south). These numbers are estimates of longshore transport for the cities of San Clemente and Dana Point.

7.3 SEDIMENT BUDGET FOR SAN CLEMENTE AND DANA POINT

In this section, we will compute the sediment budget in order to determine whether the section of the coast between San Mateo Point to the south and Dana Point to the north is in balance (i.e., there is no significant erosion or accretion). The method is simple; it is based upon calculating the volume of sediment input and the volume of sediment output. The difference between these two quantities will provide the following: 1) the volume of sand gained or lost; 2) information for calculating the long-term average of shoreline/beach width changes in the study area; and 3) the ability to calculate offshore sand losses, based upon knowledge of shoreline changes derived from historical sources.

Table 7-2 summarizes the sediment budget for the northern subcell of the Oceanside Littoral Cell. For this table, it was assumed that the cross-shore transport was small (5,000 yd^3/yr) since the offshore portion of the beach profile in this area is, in general, gently sloped. In Table 7-2,

Q_a = Beach nourishment (from Newport Bay channel dredging)
Q_y = Longshore transport
Q_x = Cross-shore transport
Q_b = Bluff sediment yield
Q_r = Stream sediment yield

Table 7-2 shows net losses of sand of about -50,000 yd^3/yr during a dry period and -3,000 yd^3/yr (-620 m^3/yr) during a wet period. Based upon Table 7-2, this reach of the coast will be stable during wet time periods, and the beach will erode slightly during dry time periods. Since Doheny State Beach is located at the end of the littoral cell and protected from north-northwest waves, the shoreline at Doheny is likely to undergo only small changes during dry time periods and to be stable during wet time periods. However, it is important to note that although the beach will retreat during large storm events, it is likely to recover quickly.

Table 7-2. San Clemente to San Mateo littoral subcell sediment budget.

Sediment Sources	Dry Period		Wet Period	
	Input yd^3 (m^3)	Output yd^3 (m^3)	Input yd^3 (m^3)	Output yd^3 (m^3)
Q_a	0	0	0	0
Q_y	320,000	-371,000	320,000	-371,000
Q_x	0	-5,000	0	-5,000
Q_b	0	0	0	0
Q_r	0	0	59,000	
Sediment total yd^3 (m^3)	320,000	-376,000	379,000	-376,000
Net yd^3/yr	-56,000 (erosion)		3,000 (accretion)	

Q_a = Beach nourishment (from Newport Bay channel dredging)
Q_y = Longshore transport
Q_x = Cross-shore transport
Q_b = Bluff sediment yield
Q_r = Stream sediment yield

8.0 DESIGN WAVE STORMS AND WATER LEVEL

8.1 EXTREMAL WAVE STATISTICS

In order to characterize the extremal wave conditions offshore of Doheny State Beach, significant wave heights with 2-, 5-, 10-, 25-, 50- and 100-year return periods were estimated at a 36 ft water depth.

Pacific Weather Analysis (PWA) hindcasts for the Coast of California Storm and Tidal Wave Study, San Diego Region (USACOE, 1988), were used as sources of deepwater wave information. In addition, a hindcast of the January 17-18, 1988 "Storm of the Century" (O'Reilly, 1989), which occurred after the publication of the PWA hindcasts, was added to the PWA list of storms. The PWA hindcasts provide deepwater significant wave height, peak period, and peak deepwater wave direction for the sea and swell components of the peak storm conditions. These parameters were used to estimate two-dimensional deepwater wave spectra and transferred to Doheny using the method described above. The shallow wave heights, peak periods, and mean directions at peak periods, derived from each transformed spectra, are listed in Tables 8-1 through 8-3.

8.2 DESIGN WAVE CONDITIONS

The methodology used to calculate the extreme heights and return periods is that suggested by Goda (1988) and modified slightly by Wyland and Thornton (1991). The transformed PWA hindcasts at each shallow water site represent a so-called partial-duration time series. The data sets were "censored" by keeping the largest 2/3 of the heights. The data were then iteratively fit to Weibull (Type III) distributions with a range of Weibull K values to find the best overall Weibull distribution fit at the Doheny site (K=1.0). The resulting extremal analysis curve is shown in Figure 8-1.

Design wave height and period at Doheny Beach are given in Table 8-4. For each of these design wave heights, we selected the wave storm period from Tables 8-1, 8-2, and 8-3. The maximum observed from these three wave categories was assigned to the design wave. Table 8-5 gives a comparison between estimated significant wave height (Hs) at various locations along the coast of Southern California including Doheny State Beach for 2-, 5-, 10-, 25-, 50-, and 100-year return periods.

8.3 DESIGN WATER LEVEL

Data from the tide gauge located at Scripps Pier were used to estimate water level design parameters for various return periods (USACOE, 1988). Figure 8-2 shows the extreme sea level predictions for various return periods. The tide gauge is located near the shore, and therefore, the data are considered to include any effects of wave setup, wind setup, and storm surges, as well as astronomical tides. The predicted sea level elevation for a 100-year return period is 5.2 ft, NGVD (7.7 ft MLLW). The design water levels were also presented in tabular form (Table 8-6). In this study, two design water levels were considered in the runup analysis: 3.3 ft and 5.2 ft. These values were selected because the actual water levels are less than 3.3 ft, NGVD, about 95% of the time, and a water level of 5.2 ft represents the 100-year water level.

Table 8-1. Deepwater and Doheny State Beach wave characteristics for the largest North Pacific winter storms from 1958-88.

Storm Date		Offshore Hs	Tp	Dp	Shallow Hs	Tp	Dp
1/27/58	Sea	9.0	9.5	280.	3.6	9.1	236.
1/27/58	Swell	15.2	13.5	270.	7.7	14.3	238.
	Combined				8.5	14.3	
4/5/58	Sea	7.4	8.5	280.	2.9	8.3	237.
4/5/58	Swell	20.0	17.5	293.	4.7	16.7	237.
	Combined				5.5	16.7	
2/10/60	Sea	10.0	11.5	290.	3.6	11.1	236.
2/10/60	Swell	15.3	18.5	294.	3.9	20.0	234.
	Combined				5.3	20.0	
2/11/63	Sea	11.3	10.5	150.	5.8	10.0	194.
2/11/63	Swell	15.9	14.5	269.	8.1	14.3	237.
	Combined				9.9	14.3	
2/7/69	Sea	6.2	8.5	280.	2.4	8.3	237.
2/7/69	Swell	14.3	14.5	284.	7.2	14.3	241.
	Combined				7.6	14.3	
12/7/69	Swell	14.4	20.5	276.	5.7	20.0	229.
	Combined				5.7	20.0	
1/16/78	Sea	5.1	7.5	290.	1.7	7.7	242.
1/16/78	Swell	16.6	16.5	284.	5.3	16.7	237.
	Combined				5.6	16.7	
2/20/80	Sea	3.0	9.5	220.	2.2	9.1	210.
2/20/80	Swell	15.3	13.5	255.	8.6	12.5	231.
	Combined				8.9	12.5	
1/23/81	Swell	15.4	17.5	265.	5.9	16.7	230.
	Combined				5.9	16.7	
1/29/81	Sea	4.1	6.5	210.	3.1	6.7	205.
1/29/81	Swell	21.1	15.5	269.	9.5	14.3	236.
	Combined				10.0	14.3	
12/1/82	Sea	10.3	12.5	290.	3.8	12.5	235.
12/1/82	Swell	17.6	14.5	293.	6.2	14.3	241.
	Combined				7.3	14.3	
1/27/83	Sea	7.3	8.5	160.	4.4	8.3	193.
1/27/83	Swell	19.7	20.5	283.	7.0	20.0	230.
	Combined				8.2	20.0	
2/13/83	Sea	3.5	5.5	330.	0.4	5.6	250.
2/13/83	Swell	16.7	16.5	275.	6.0	16.7	236.
	Combined				6.0	16.7	
3/2/83	Sea	7.7	11.5	160.	4.6	11.1	197.
3/2/83	Swell	22.3	18.5	263.	9.2	20.0	229.
	Combined				10.3	20.0	
1/17/88	Swell	33.0	17.0	270.	11.9	16.7	233.
	Combined				11.9	16.7	

Table 8-2. Deepwater and Doheny State Beach wave characteristics for the largest tropical storms from 1958-88.

Storm Date		Offshore Hs	Tp	Dp	Shallow Hs	Tp	Dp
9/10/67	Sea	7.4	11.5	184.	6.1	11.1	199.
	Combined				6.1	11.1	
8/29/68	Sea	5.6	11.5	195.	4.8	11.1	203.
	Combined				4.8	11.1	
7/17/69	Sea	2.3	8.5	180.	1.8	8.3	194.
	Combined				1.8	8.3	
8/8/69	Sea	7.8	12.5	153.	3.8	12.5	195.
	Combined				3.8	12.5	
7/24/70	Sea	3.1	9.5	188.	2.6	9.1	198.
	Combined				2.6	9.1	
9/6/70	Sea	5.5	10.5	155.	2.9	10.0	191.
	Combined				2.9	10.0	
8/1/71	Sea	4.4	10.5	178.	3.4	10.0	196.
	Combined				3.4	10.0	
9/4/71	Sea	6.7	10.5	166.	4.4	10.0	193.
	Combined				4.4	10.0	
8/22/72	Sea	7.7	8.5	178.	5.9	8.3	193.
	Combined				5.9	8.3	
8/25/72	Sea	7.4	12.5	160.	4.4	12.5	196.
	Combined				4.4	12.5	
8/26/72	Sea	5.4	8.5	180.	4.2	8.3	194.
	Combined				4.2	8.3	
8/29/72	Sea	12.7	17.5	156.	7.4	16.7	201.
	Combined				7.4	16.7	
8/30/72	Sea	8.2	13.5	174.	6.4	14.3	200.
	Combined				6.4	14.3	
9/5/72	Sea	6.7	12.5	194.	5.9	12.5	203.
	Combined				5.9	12.5	
7/26/73	Sea	7.0	12.5	156.	3.7	12.5	195.
	Combined				3.7	12.5	
7/29/73	Sea	3.0	8.5	184.	2.4	8.3	195.
	Combined				2.4	8.3	
7/21/74	Sea	4.6	9.5	159.	2.7	9.1	190.
	Combined				2.7	9.1	
10/12/74	Sea	4.6	9.5	180.	3.6	9.1	195.
	Combined				3.6	9.1	
7/7/75	Sea	7.0	12.5	153.	3.4	12.5	195.
	Combined				3.4	12.5	
7/15/75	Sea	5.4	11.5	180.	4.3	11.1	198.
	Combined				4.3	11.1	

Table 8-2. Deepwater and Doheny State Beach wave characteristics for the largest tropical storms from 1958-88 (continued).

Storm Date		Offshore Hs	Tp	Dp	Shallow Hs	Tp	Dp
8/27/75	Sea	4.1	9.5	180.	3.2	9.1	195.
	Combined				3.2	9.1	
8/12/76	Sea	4.9	10.5	153.	2.4	10.0	191.
	Combined				2.4	10.0	
8/14/76	Sea	3.5	10.5	180.	2.8	10.0	197.
	Combined				2.8	10.0	
9/25/77	Sea	3.8	10.5	206.	3.2	10.0	205.
	Combined				3.2	10.0	
10/8/77	Sea	5.1	9.5	153.	2.5	9.1	189.
	Combined		2.5	9.1			
7/28/78	Sea	7.9	12.5	156.	4.2	12.5	195.
	Combined				4.2	12.5	
9/5/78	Sea	8.7	12.5	155.	4.5	12.5	195.
	Combined				4.5	12.5	
9/5/78	Sea	4.3	10.5	178.	3.3	10.0	196.
	Combined				3.3	10.0	
7/23/79	Sea	5.6	11.5	174.	4.2	11.1	197.
	Combined				4.2	11.1	
8/7/80	Sea	5.1	9.5	167.	3.4	9.1	192.
	Combined				3.4	9.1	
7/5/81	Sea	6.6	10.5	167.	4.4	10.0	194.
	Combined				4.4	10.0	
9/18/82	Sea	4.0	9.5	188.	3.3	9.1	198.
	Combined				3.3	9.1	
9/24/82	Sea	11.1	15.5	158.	6.8	16.7	200.
	Combined				6.8	16.7	
9/19/83	Sea	7.1	11.5	158.	4.0	11.1	194.
	Combined				4.0	11.1	
10/7/83	Sea	4.9	11.5	178.	3.8	11.1	198.
	Combined				3.8	11.1	
8/11/84	Sea	8.6	11.5	161.	5.2	11.1	194.
	Combined				5.2	11.1	
8/12/84	Sea	6.0	10.5	186.	4.9	10.0	199.
	Combined				4.9	10.0	
9/10/84	Sea	7.3	10.5	155.	3.8	10.0	191.
	Combined				3.8	10.0	
8/29/85	Sea	6.7	10.5	160.	3.9	10.0	192.
	Combined				3.9	10.0	
8/27/86	Sea	7.8	12.5	153.	3.8	12.5	195.
	Combined				3.8	12.5	
8/28/86	Sea	3.2	9.5	174.	2.4	9.1	194.
	Combined				2.4	9.1	

Table 8-3. Deepwater and Doheny State Beach wave characteristics for the largest southern swell from 1958-88.

Storm Date		Offshore Hs	Tp	Dp	Shallow Hs	Tp	Dp
5/15/66	Swell	4.1	16.5	210.	4.1	16.7	213.
	Combined				4.1	16.7	
10/6/67	Swell	3.7	15.5	204.	2.9	14.3	209.
	Combined				2.9	14.3	
8/19/68	Swell	9.3	22.5	199.	6.0	25.0	210.
	Combined				6.0	25.0	
9/12/70	Swell	3.8	17.5	198.	2.6	16.7	208.
	Combined				2.6	16.7	
5/8/71	Swell	7.4	19.5	192.	4.5	20.0	208.
	Combined				4.5	20.0	
6/7/72	Swell	3.8	18.5	217.	4.4	20.0	215.
	Combined				4.4	20.0	
7/13/73	Swell	6.2	18.5	190.	4.9	16.7	207.
	Combined				4.9	16.7	
10/9/74	Swell	4.5	15.5	199.	3.8	14.3	208.
	Combined				3.8	14.3	
5/15/75	Swell	4.8	18.5	215.	6.0	20.0	215.
	Combined				6.0	20.0	
9/25/75	Swell	4.5	18.5	203.	3.3	20.0	211.
	Combined				3.3	20.0	
6/24/76	Swell	4.7	19.5	212.	5.9	20.0	214.
	Combined				5.9	20.0	
6/10/77	Swell	4.8	18.5	199.	3.2	20.0	209.
Combined					3.2	20.0	
5/25/77	Swell	4.5	19.5	220.	3.8	20.0	216.
	Combined				3.8	20.0	
9/12/78	Swell	3.9	16.5	196.	2.9	16.7	208.
	Combined				2.9	16.7	
6/2/79	Swell	5.5	19.5	197.	3.2	20.0	210.
	Combined				3.2	20.0	
6/12/79	Swell	5.5	20.5	221.	3.9	20.0	217.
	Combined				3.9	20.0	
6/27/81	Swell	4.7	18.5	185.	3.7	16.7	205.
	Combined				3.7	16.7	
7/3/81	Swell	6.3	19.5	213.	8.3	20.0	215.
	Combined				8.3	20.0	
10/13/81	Swell	4.3	16.5	202.	3.0	16.7	210.
	Combined				3.0	16.7	

Table 8-3. Deepwater and Doheny State Beach wave characteristics for the largest southern swell from 1958-88 (continued).

Storm Date		Offshore Hs	Tp	Dp	Shallow Hs	Tp	Dp
9/27/82	Swell	4.2	16.5	196.	3.1	16.7	208.
	Combined				3.1	16.7	
5/25/83	Swell	4.1	17.5	187.	3.8	16.7	206.
	Combined				3.8	16.7	
8/8/83	Swell	5.4	19.5	204.	4.2	20.0	212.
	Combined				4.2	20.0	
8/23/84	Swell	3.7	17.5	198.	2.5	16.7	208.
	Combined				2.5	16.7	
10/5/85	Swell	6.3	17.5	221.	4.3	16.7	216.
	Combined				4.3	16.7	
8/28/86	Swell	5.3	18.5	193.	4.0	16.7	207.
	Combined				4.0	16.7	

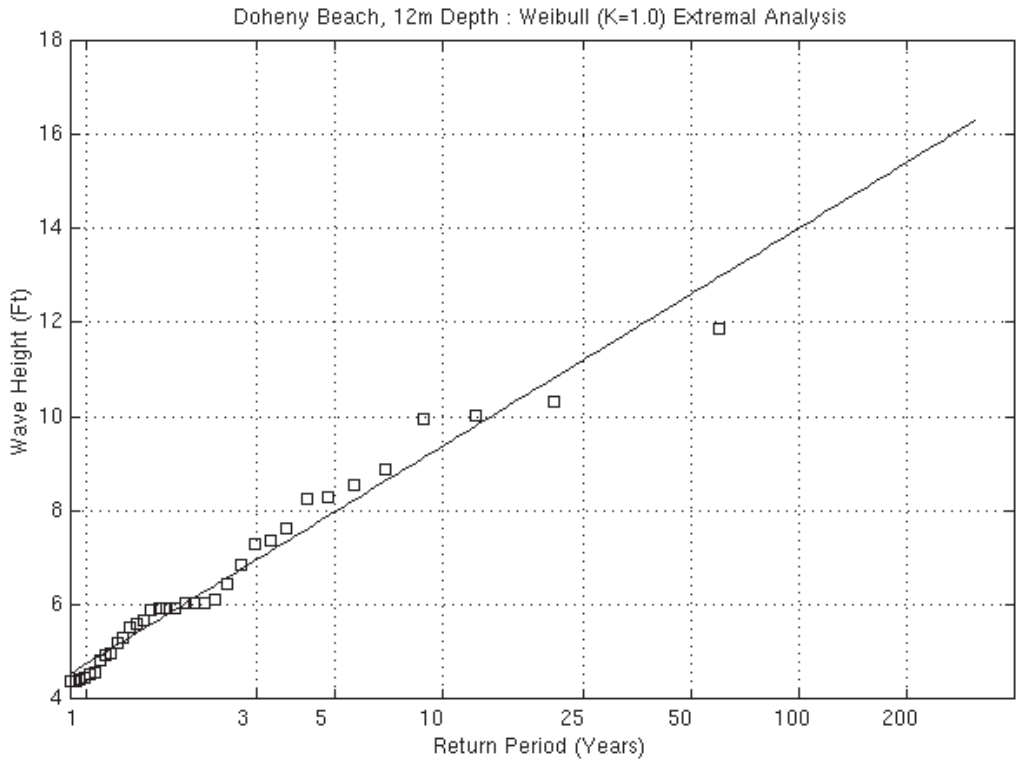


Figure 8-1. Extremal wave heights for the Doheny State Beach 33 ft (10m) site.

Table 8-4. Design wave characteristics at Doheny State Beach.

Storm Period Return Year	Design Waves (ft)	Period (sec)			
		North Pacific Winter	Tropical Storms	South Swell	Max
2 (typical)	6	16.7 (1/23/81)	12 (9/10/67)	20 (5/15/75)	20
5	8	20.0 (1/27/83)	--[a]	20 (7/31/81)	20
10	9.5	20.0 (3/2/83)	--[a]	--[a]	20
25	11.2	17[a]	--[a]	--[a]	17
50	12.5	16.7 (1/17/88)	--[a]	--[a]	16.7
100	14	17[a]	--[a]	--[a]	17

[a] No match assumed.

Table 8-5. Design significant wave heights (ft) for various return periods at various locations.

Location	Water Depth, ft	Return Periods (yrs)				
		5	10	25	50	100
Scripps Pier[a]	26	9.3	10.5	12.1	13.2	14.3
Mission Bay Entrance[a]	33	14	16	18.8	20.7	22.7
Del Mar[a]	35	13	14.5	16.5	18	19.4
Oceanside[b]	30	10.1	11.5	13.4	14.7	16.1
San Clemente[a]	34	11	12.3	14.3	15.8	17
Doheny State Beach[d]	35	8	9.5	11.2	12.5	14
Crystal Cove[c]	33	10.2	11.6	13.3	14.6	15.8
Huntington Beach[c]	33	10.2	11.5	13.2	14.2	15.4

[a] Computed by R. Guza and L. E. Borgman (USACOE 1988)
[b] Computed by Coastal Environments (1999)
[c] Computed by Coastal Environments (2002)
[d] Computed by Coastal Environments (this study)

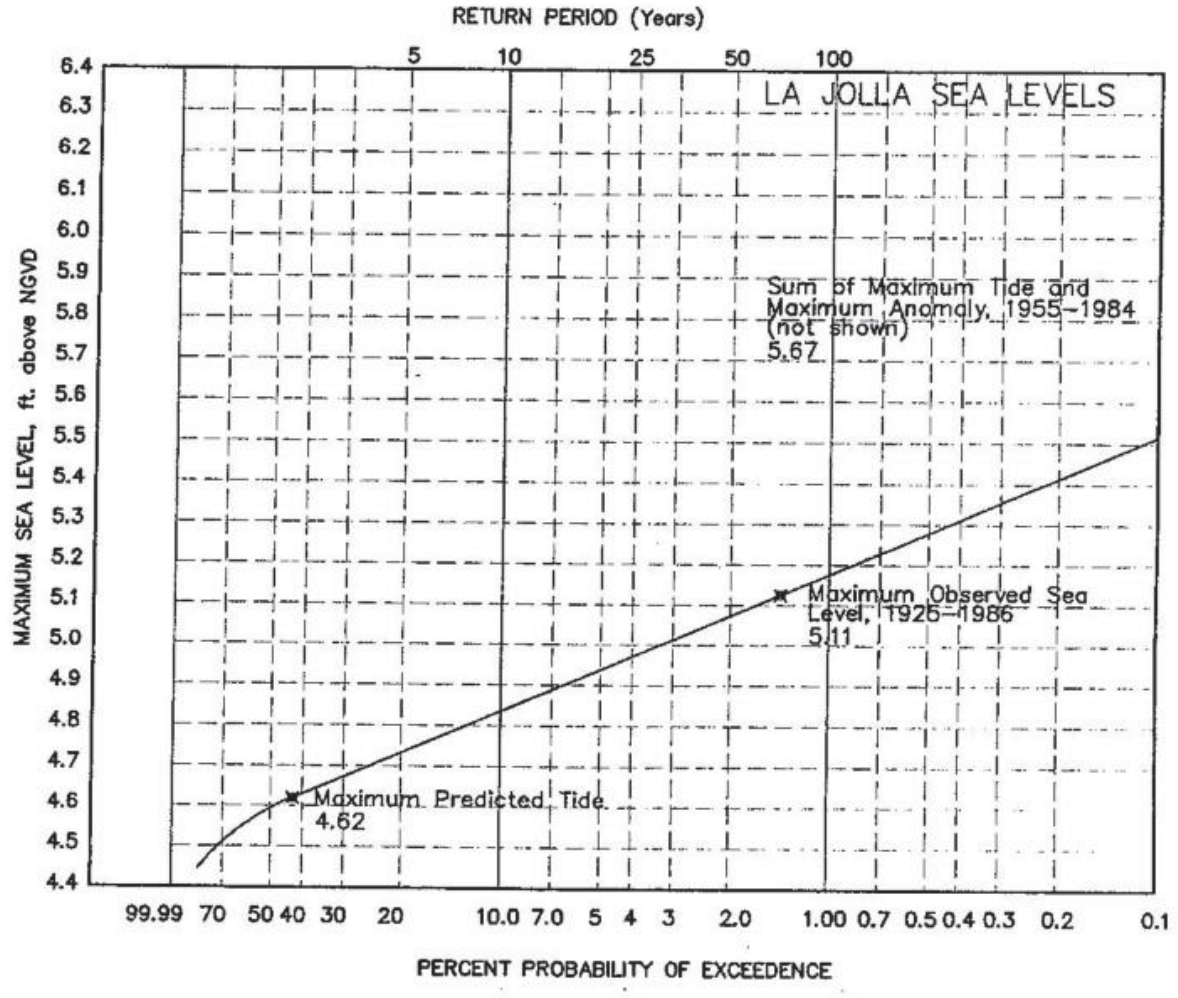


Figure 8-2. Design sea levels for various return periods.

Table 8-6. Design water level elevations for various return periods.

Return Period (Years)	Water Level Elevation, Scripps Pier	
	(ft, MLLW)	(ft, NGVD)
2	7.2	4.6
5	7.3	4.7
10	7.4	4.8
20	7.5	4.9
50	7.6	5.1
100	7.7	5.2

9.0 PROJECTION OF SEA LEVEL RISE

9.1 SEA LEVEL RISE PROJECTION METHODS

Sea level rise (SLR) can be attributed to two main factors: thermal expansion of the oceans and global ice melt. Greenhouse gas emissions (GHGs), especially carbon dioxide, are believed by many climatologists to increase ocean and air temperatures, which leads to thermal expansion of the oceans and global ice melt.

Global projections for SLR range from 0.59-6.6 ft (18-200 cm) by 2100, depending on the methodology and source used. Projecting SLR is determined using two different methods: (1) physical models, and (2) semi-empirical models.

Physical models quantitatively describe the main physical processes that contribute to SLR (thermal expansion and ice melt). They utilize climate models, which use well-established physical processes in the atmosphere, ocean, cryosphere, and land surface to reproduce observed features of climate and past climate changes. These models simulate how the global climate system will respond to various GHG emission scenarios based on future demographic development, socioeconomic development, and technological change. The GHG emission scenarios were developed by the Intergovernmental Panel on Climate Change (IPCC) and can be broadly categorized as high, medium-high, medium-low, and low emission scenarios. The six GHG emission scenarios (in order of high to low) are: (1) A1FI, (2) A2, (3) A1B, (4) B2, (5) A1T, and (6) B1. The IPCC is the world's leading climate change organization, consisting of 35 international scientists who are distinguished in their respective fields. Their study describes global SLR, and their results are discussed in detail in Section 9.2 of this report.

Semi-empirical models exploit the link between observed SLR and observed global temperature changes in the past to predict future SLR. This method measures how much the rate of SLR accelerates for a unit change in global temperature. The semi-empirical model was developed by Rahmstorf (2007) and results in larger SLR projections than the physical models. Rahmstorf (2007) projected global SLR of 1.64-4.59 ft (50-140 cm) by 2100, with the range dependent upon the GHG emission scenario used. This method has been utilized by researchers in California, including Cayan et al. (2009) and Tebaldi et al. (2012), as an alternate approach to the IPCC's (2007) methodology.

9.2 PROJECTED GLOBAL SEA LEVEL RISE (IPCC, 2007)

The GHG emission scenarios were developed by the IPCC. The six GHG emission scenarios are A1FI, A1T, A1B, A2, B1, and B2. Scenario A1FI results in the highest estimate for SLR, while Scenario B1 gives the lowest estimate for SLR. Short descriptions of these scenarios are given below:

1. The A1 family of scenarios is marked by rapid economic growth, global populations that peak mid-century and decline thereafter, and the rapid introduction of new, more efficient technologies. The A1 scenario contains three sub-scenarios (A1FI, A1T, and

A1B), each of which describes alternative directions of technological change in the energy system.

   a. A1FI is a fossil-fuel-intensive future,
   b. A1T is predominantly non-fossil-fuel-based, and
   c. A1B is balanced across energy sources.

2. The A2 scenario describes a heterogeneous world with a continuously increasing global population, regional economic growth, and fragmented economic development and technological change.
3. The B1 scenario describes a convergent world with the same global population that peaks in midcentury and declines thereafter as in the A1 scenario, but with rapid changes in economic structures toward a service-and-information economy, reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to issues of economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.
4. The B2 storyline and scenario describe a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 andA1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

The SLR ranges by 2090-2099 for these various scenarios are summarized in Table 9-1. Scenario B1 gives the lowest SLR ranges at 0.59-1.25 ft (18-38 cm), while the A1FI scenario gives the highest SLR ranges at 26-59 cm.

9.3 PROJECTED SEA LEVEL RISE IN CALIFORNIA

In California, three main reports are utilized by state and federal agencies when determining the impacts of projected SLR. These include:

1. “Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future” by the National Research Council (2012).
2. “Climate Change Scenarios and Sea Level Rise Estimates for the California Climate Change Scenarios Assessment” by Cayan et al. (2009).
3. “Climate Change and Sea Level Rise Scenarios for California Vulnerability and Adaptation Assessment” by Cayan et al. (2012).

Additionally, there are research papers that give SLR projections for California. These include: Tebaldi et al. (2012) and Cayan et al. (2008). Specific to the San Diego area is the Sea Level Rise Adaption Study for San Diego Bay (ICLEI, 2012). This study addressed adaptation strategies for seal level rise in San Diego Bay (Section 9.3.3). These studies are summarized below.

Table 9-1. IPCC (2007) global projections of SLR by 2090-2099 for various scenarios[1].

Scenario	Range (cm)	Range (ft)
B1 Scenario	18-38	0.59-1.25
A1T Scenario	20-45	0.66-1.48
B2 Scenario	20-43	0.66-1.41
A1B Scenario	21-48	0.69-1.57
A2 Scenario	23-51	0.75-1.67
A1FI Scenario	26-59	0.85-1.94

[1] SLR ranges relative to 1980-1999 levels.

9.3.1 National Research Council

The National Research Council (NRC) in 2012 created a report that documented past, present, and projected future SLR's for California, Oregon, and Washington. In this report, regional information extracted from global models, GPS data from along the coast, and the ice loss rates of large or nearby glaciers were used for SLR projections. The report uses both model and extrapolation approaches to make projections. The local thermal expansion and wind-driven contribution was estimated using climate models; the ice melt contribution, adjusted for gravitational and deformational effects, was extrapolated; and the contribution from vertical land movement was estimated using GPS data. Their SLR projections are based on thermal expansion, ice melt from glaciers and ice caps, and the Greenland and Antarctic ice sheets. The SLR projections for this study are summarized in Table 9-2.

9.3.2 California Energy Commission's California Climate Change Center

The California Energy Commission's California Climate Change Center has two reports that specifically focus on SLR. These are "Climate Change Scenarios and Sea Level Rise Estimates for the California 2008 Climate Change Scenarios Assessment" (Cayan et al., 2009) and "Climate Change and Sea Level Rise Scenarios for California Vulnerability and Adaptation Assessment" (Cayan et al., 2012). The 2009 report was prepared by Scripps Institution of Oceanography, the U.S. Geological Survey Water Resources Division, Texas Tech University's Department of Geosciences, and the California Department of Boating and Waterways, while the 2012 report was prepared by Scripps Institution of Oceanography only. The semi-empirical approaches developed by Rahmstorf (2007) (which estimates global sea level using surface air temperatures) and Chao et al. (2008) (which accounts for the global growth of dams and reservoirs) were utilized. Six climate models were used to predict changes in surface air temperature under the A2 (higher-emission) and B1 (lower-emission) scenarios. In this study, SLR in 2050 (relative to the 2000 level) ranges from 0.98-1.48 ft (30-45 cm). In the 2012 report, essentially the same data as that found in the 2009 report was used when estimating SLR for California, with the exception of a projection of 2.95-4.59 ft (90-140 cm) by 2100 (Cayan et al., 2012).

9.3.3 Sea Level Rise Adaption Study for San Diego Bay

This study utilized sea level projections of 0.85-1.41 ft (26-43 cm) by 2050 and 2.56-5.77 ft (78-176 cm) by 2100. These projections were based on data from the SLR Task Force of the Coastal and Ocean Working Group of the California Climate Action Team, as reported in the Interim Guidance Document (2010), which were derived from Vermeer and Rahmstorf (2009). The Adaptation Strategy project utilized SLR assumptions on the upper end of this range to ensure a risk-averse approach to planning.

Table 9-2. NRC committee's SLR projections for the U.S. Pacific Coast[1].

Contributor	2030 Range		2050 Range		2100 Range	
	cm	ft	cm	ft	cm	ft
Steric	1.7-11.0	0.06-0.36	4.0-18.9	0.13-0.62	9.6-46.2	0.31-1.51
Glaciers and Ice Caps	2.7-3.6	0.09-0.12	5.1-7.3	0.17-0.24	12.9-19.4	0.42-0.64
Greenland	1.8-4.0	0.06-0.13	4.3-10.2	0.14-0.03	14.8-33.8	0.48-1.11
Antarctica	1.5-5.1	0.05-0.17	3.0-13.3	0.10-0.44	7.7-46.2	0.25-1.51
Total Cryosphere	6.6-12.2	0.22-0.40	13.7-29.4	0.45-0.96	40.9-94.1	1.34-3.09
Sum	**8.3-23.2**	**0.27-0.76**	**17.6-48.2**	**0.58-1.58**	**50.4-167.2**	**1.65-5.5**

[1] SLR ranges relative to 2000 levels.

9.3.4 Published Papers

Tebaldi et al., 2012

This study used model output for global temperature changes, a semi-empirical model of global SLR, and long-term records from 55 nationally distributed tidal gauges to develop SLR projections at 11 gauge locations along the coasts of California, Oregon, and Washington. Based on this information and output from an ensemble of GCM simulations, they obtained SLR estimates of 0.098-0.39 ft (3-12 cm) by 2030 and 0.36-0.98 ft (11-30 cm) by 2050, relative to 2008, for the 11 locations.

Cayan et al., 2008

In this study, projected SLR in California during the next century is estimated using thermal expansion (from the IPCC Global Climate Models) and ice melt (from the MAGICC simple climate model). Three emission scenarios (A1FI, A2, and B1) were utilized to estimate a range of future SLR for the California coast. By mid-century (2035-2064), projections of global SLR range from ~0.20 ft (6.32 cm) above 1990 levels, with no discernible inter-scenario differences. By the end of the century (2070-2100), SLR projections range from 0.33-1.77 ft (10-54 cm) under B1, 0.46-2.0 ft (14-61 cm) under A2, and 0.56-2.36 ft (17-72 cm) under A1FI.

9.3.4 SLR Projections Utilized by State and Federal Agencies

The State of California has implemented a number of policies and created research institutions to address the impacts of climate change and to project regional SLRs. These include Executive Orders S-3-05 (2005) and S-13-08 (2008), which set GHG targets, called for the establishment of a Climate Adaptation Strategy, and asked the National Academy of Sciences to convene an independent panel to complete a Sea Level Rise Assessment Report; the establishment of the California Energy Commission's Public Interest Energy Research (PIER) program in 2001 to research potential impacts of climate change; and the establishment of the California Climate Change Center (CCCC) in 2003, which is devoted to climate change research. The creation of these organizations and regulatory policies resulted in a number of reports designed to provide projections of SLR and to address the implications of SLR and climate change from a policy standpoint.

Table 9-3 presents an overview of the recognized SLR projections by various federal and state agencies involved in policies regarding SLR in California.

9.3.5 Uncertainties of SLR Projections

Projections of SLR vary, depending upon the model (physical or semi-empirical) used for the estimations and the parameters used. Global projections of SLR range from 0.59-6.6 ft (18-200 cm) by 2100 (Church et al., 2013; NRC 2012; Parris et al., 2012; Vermeer and Rahmstorf, 2009; IPCC, 2007; Rahmstorf, 2007). The IPCC AR4 report published in 2007 projected a range of 0.59-1.93 ft (18-59 cm) by 2100. IPCC 2013 projections (Church et al., 2013) estimate slightly higher ranges than the 2007 report, mainly due to improved modeling of

Table 9-3. SLR projections utilized by California state and federal agencies.

Agency	2050		2100		Citation
	cm	ft	cm	ft	
USACOE			18-59	0.59-1.9	IPCC (2007)
CEC	30-45	0.98-1.5	90-140	2.9-4.6	Cayan et al. (2009)
SLC	30-45	0.98-1.5	90-140	2.9-4.6	Cayan et al. (2009)
CNRA	30-45	0.98-1.5	90-140	2.9-4.6	Cayan et al. (2009)
CalEPA	12-61	0.4-2.0	42-167	1.4-5.5	NRC (2012)
CCC	12-61	0.4-2.0	42-167	1.4-5.5	NRC (2012)

USACOE = United States Army Corps of Engineers
CEC = California Energy Commission
SLC = California State Lands Commission
CNRA = California Natural Resources Agency
CalEPA = California Environmental Protection Agency
CCC = California Coastal Commission

land-ice contributions. Global SLR projections from the IPCC 2013 report a range of 0.8-3.2 ft (26-98 cm). Rahmstorf (2007), using a semi-empirical approach (which utilizes statistical relationships between observed global sea level change) had higher SLR projections for 2100, ranging from 1.64-4.59 ft (50-140 cm). Updated data from Vermeer and Rahmstorf (2009), which also used a semi-empirical approach, projects 2.46-6.2 ft (75-190 cm) by 2100. Newer data from NOAA (Parris et al., 2012) and the NRC (2012) predict higher ranges than Rahmstorf (2007) and Vermeer and Rahmstorf (2009), with estimates of 0.7-6.6 ft (20-200 cm) from NOAA and 0.47-5.5ft (14.2-167 cm) from the NRC. The higher end estimate of 6.6 ft from NOAA is derived from a combination of estimated ocean warming (based on the IPCC AR4 global SLR projections) and a calculation of the maximum possible glacier ice sheet loss by the end of the century.

Despite better data about the current status of global ice sheets, there is still a substantial amount of uncertainty regarding the rate and magnitude of ice sheet loss, particularly in Antarctica, as well as future rates of glacier, ice cap, and ice sheet losses (Church et al., 2013). This unknown produces a high degree of uncertainty in extrapolation techniques used to estimate their contribution to SLR (NRC, 2012, Parris et al., 2012). The 2007 IPCC projections are largely based on the thermal expansion of water from ocean warming, with some contributions from glaciers and ice sheets. In their 2007 Fourth Assessment Report (AR4), they indicated that the scientific understanding for projecting the contributions of ice sheet loss from Greenland and Antarctica was too poorly understood to make projections based upon these factors (IPCC, 2007). In the 2013 report, the IPCC states that ice-sheet modeling for Greenland has made substantial progress, but that significant challenges exist in projecting loss of the Antarctic ice sheet. They also state that the representation of glaciers and ice sheets in Atmosphere-Ocean General Circulation Models (AOGCMs) is not yet at a stage where projections of their changing mass are routinely available (Church et al., 2013).

Other areas of uncertainty for SLR relate to regional variability. Factors such as vertical land movement caused by post-glacial rebound, subsidence, plate tectonics, and soil compaction, climactic factors such as the Atlantic Multidecadal Oscillation (AMO), the Pacific Decadal Oscillation (PDO), and the El Niño Southern Oscillation (ENSO), changes in ocean circulation patterns resulting from warming seawater, sediment supply to coasts, wave heights, periods, shoreline slopes, tidal ranges, and natural and human-made barriers to coastal flooding can all impact regional patterns of SLR (Parris et al., 2012). For example, Flick (2003) found higher rates of SLR on the Atlantic coast, which could be partially attributed to a slowdown of the Atlantic Ocean circulation. Bromirski (2011) attributed the largely stationary relative sea level on the U.S. West Coast since 1980 to changes in wind stress patterns from the PDO that occurred in the mid-1970s. However, a recent reversal of wind stress patterns in 2008 may result in a resumption of relative SLR that could approach or exceed global rates. The IPCC (2007) reported high rates of SLR over the western Pacific and eastern Indian Ocean and sea level decreases in the eastern Pacific and western Indian Ocean. This variation is largely attributed to ocean circulation patterns associated with ENSO events.

Due to the relative uncertainties regarding projections of SLR, no one scenario should be used in coastal management decisions. NOAA (Parris et al., 2012) states that their highest scenario for projected SLR should only be used in situations where there is little tolerance for

risk or for new infrastructure with a long anticipated life cycle. The U.S. Army Corps of Engineers (2011) recommends an adaptive management technique, in which alternative plans for multiple projected SLR scenarios are formulated and compared to each other. The selected alternative should be chosen based upon human health and safety, economic costs and benefits, environmental impacts, and other social effects. Regional and site-specific characteristics, such as vertical land movement, wave heights, periods, shoreline slopes, tidal ranges, climatic periods, and natural and human-made barriers should also be taken into account when determining coastal management strategies for a particular site.

9.4 SUMMARY

It is apparent from these studies that a large amount of variability exists with global and regional (California) SLR projections, ranging from 0.18-2 ft (5.5-61 cm) by 2050 and from 0.33-6.6 ft (10-200 cm) by 2100. This is especially apparent in California, where numerous regional studies have been implemented to address SLR. Table 9-4 summarizes all the SLR projections reviewed in this report.

In this report, the highest end SLR projections for 2100 from Cayan et al. (2012) of 4.59 ft (140 cm) are utilized. This source is utilized for a number of reasons, including: (1) many California state agencies, including the California Energy Commission, the California State Land Commission, and the California Natural Resources Agency utilize the projections from Cayan; (2) the work done by Cayan et al. (2012) are locally-derived SLR projections that are the most applicable to Southern California; and (3) this approach does not utilize ice sheet melt, which has a high degree of uncertainty.

Table 9-4. Summary of SLR projections.

Researcher	Year	Method	Region	Scenario	2050		2100	
					Cm	ft	cm	ft
IPCC	2007	Physical (TE[1], IM[2])	Global	A1FI (highest)	-	-	26-59	0.85-1.93
				A2 (medium-high)	-	-	23-51	0.75-1.67
				A1B (medium-high)	-	-	21-48	0.69-1.57
				B2(medium low)	-	-	20-43	0.66-1.41
				A1T (medium low)	-	-	20-45	0.66-1.48
				B1 (low)	-	-	18-38	0.59-1.25
IPCC	2013	Physical (TE[1], IM[2])	Global	RCP 2.6, 4.5, 6.0, 8.5	-	-	26-98	0.8-3.2
Rahmstorf	2007	Semi-Empirical	Global	B1 (low)	-	-	50	1.64
				A1FI (high)	-	-	140	4.59
Vermeer & Rahmstorf	2009	Semi-Empirical	Global	N/A	-	-	75-190	2.46-6.20
Cayan et al.	2008	Physical (TE, IM)	California	A1FI (high)	-	-	14-61	0.46-2.00
				A2 (medium-high)	6.32	0.21	17-72	0.56-2.36
				B1(low)	6.32	0.21	10-54	0.33-1.77
Cayan et al.	2009, 2012	Semi-Empirical, Dams & Reservoirs	California	B1(low)	30	0.98	90	2.95
				A2 (medium-high)	45	1.48[4]	140	4.59[4]
NRC	2012	Physical (TE, IM), Dams & Reservoirs	US Pacific Coast	TE (B1-A1FI)	9.9	0.32	24.2	0.79
				IM (Glaciers & caps)	5.5	0.18	14.3	0.47
				IM (Greenland Ice Sheet)	5.6	0.18	20.1	0.66
				IM (Antarctica)	7.0	0.23	24.0	0.79
				Total (TE&IM)	12-61	0.4-2	42-167	1.4-5.5
Tebaldi	2012	Semi-Empirical	La Jolla, CA	Not specified	11-30	0.36-0.98	-	-
Parris et al.	2012	Physical and Semi-Empirical	Global	Intermediate high	-	-	20-200	0.7-6.6[3]
Houston	2013	Physical	Global	Not specified	-	-	18-82	0.59-2.69
Minimum - Maximum Projection SLR					**6.32-61**	**0.18-1.48[4]/2.0**	**10-200**	**0.33-4.59[4]/5.5**

[1] TE= Thermal Expansion
[2] IM = Ice Melt
[3] The highest estimate of NOAA (Parris et al., 2012) for SLR (100-year) is substantially larger than the other estimates and will not be use in this study.
[4] SLR estimates for California

10.0 BEACH CHANGES DUE TO SEA LEVEL RISE

Concerns exist about the potential effects of SLR due to global warming on the shoreline in Southern California (Flick and Ewing, 2009). Changes in relative sea level can result in changes in shoreline shape, beach profile form, and beach width. These changes can be considered on a variety of timescales. It seems prudent to consider possible changes in California and worldwide during the next few decades for the purpose of planning and developing integrated coastal zone management. Table 10-1 provides projections of changes in beach width at Doheny State Beach from 2050 through 2100 due to SLR.

The estimation of changes in beach profile form (shape and width) in many studies has been dominated by the conceptual model of shoreline response to SLR level rise advanced by Per Bruun (1962). Other related papers, including those by Schwartz (1965 and 1967), have increased interest in Bruun's model, and the papers of both Bruun and Schwartz have been responsible for increasing initial interest in the model. It was Schwartz (1967) who proposed that the method of predicting shoreline change based on SLR developed by Bruun should be termed "Bruun's Rule."

Since the development of Bruun's Rule, several papers have been published testing the model and its predictive capability, with mixed results (Bruun, 1988 and 1983; Pilkey and Davis, 1987; Rosen, 1978; Schwartz, 1967 and 1987). Bruun's Rule assumes the following: (1) the beach profile maintains its form as it is translated onshore a distance, *x*; (2) the material that is eroded from the upper beach is deposited on the nearshore profile; and (3) the thickness of sediment deposition in the nearshore profile equals the increase in sea level, thus maintaining a constant water depth in the nearshore.

If the sea level rises gradually, then the position of the depth of closure should migrate landward and upward to a distance equal approximately to the SLR (a). This would result in the beach's nearshore profile elevation rising to a height equal to the SLR (a). Figure 10-1 shows the translation of the beach and bottom profiles, resulting in shore recession and deposition of sediments in the nearshore area. Figure 10-2 gives the predicted changes of beach profile R2 due to 1.48 ft SLR (top) and the predicted changes of beach profile R8 due to 1.48 ft SLR (bottom).

10.1 BRUUN'S RULE

Bruun (1962) estimated the response of the beach profile to SLR (a) using the following equation:

$$s = L\,(a/h) \qquad (10\text{-}1)$$

L, a, and *h* are shown in Figure 10-1. *L* is the length of the profile from the beginning of the beach profile to the closure depth (d) defined as the maximum water depth of exchange of sediment between the nearshore and the offshore, and *h* is equal to (d) plus the height of the berm (e).

Table 10-1. Changes in beach width due to SLR, west of San Juan Creek.

Parameter	2050		2100	
	Low	High	Low	High
Sea level rise, ft	0.18	1.48	0.33	4.59
Beach width change rate, ft/year	0.21	1.76	0.39	5.46
Beach width change, ft, from 2014-2050/2100 (36-86 years)	7.7	63.4	14.1	196.7

Table 10-2. Changes in beach width due to SLR, east of San Juan Creek.

Parameter	2050		2100	
	Low	High	Low	High
Sea level rise, ft	0.18	1.48	0.33	4.59
Beach width change rate, ft/year	0.19	1.54	0.34	4.78
Beach width change, ft, from 2013-2050/2100 (36-86 years)	6.8	55.5	12.4	172.1

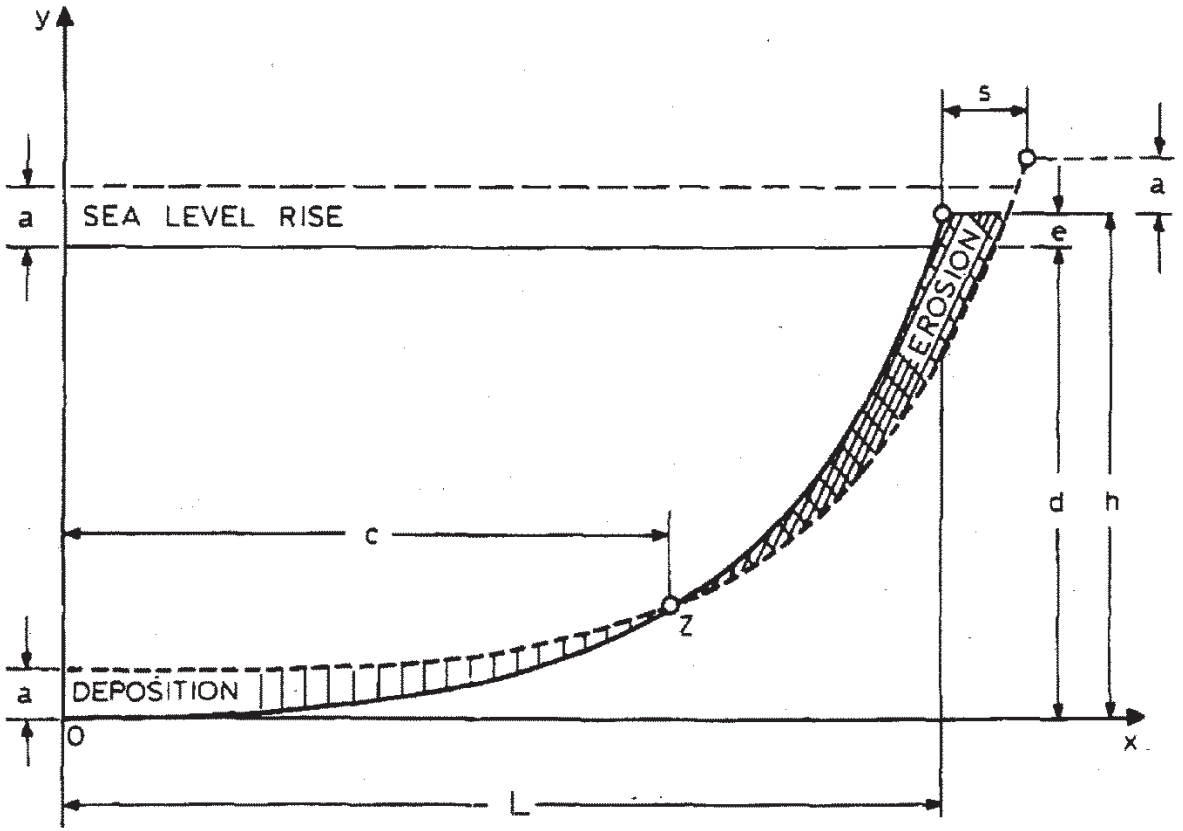


Figure 10-1. Translation of beach profile due to SLR by Per Bruun (1962).

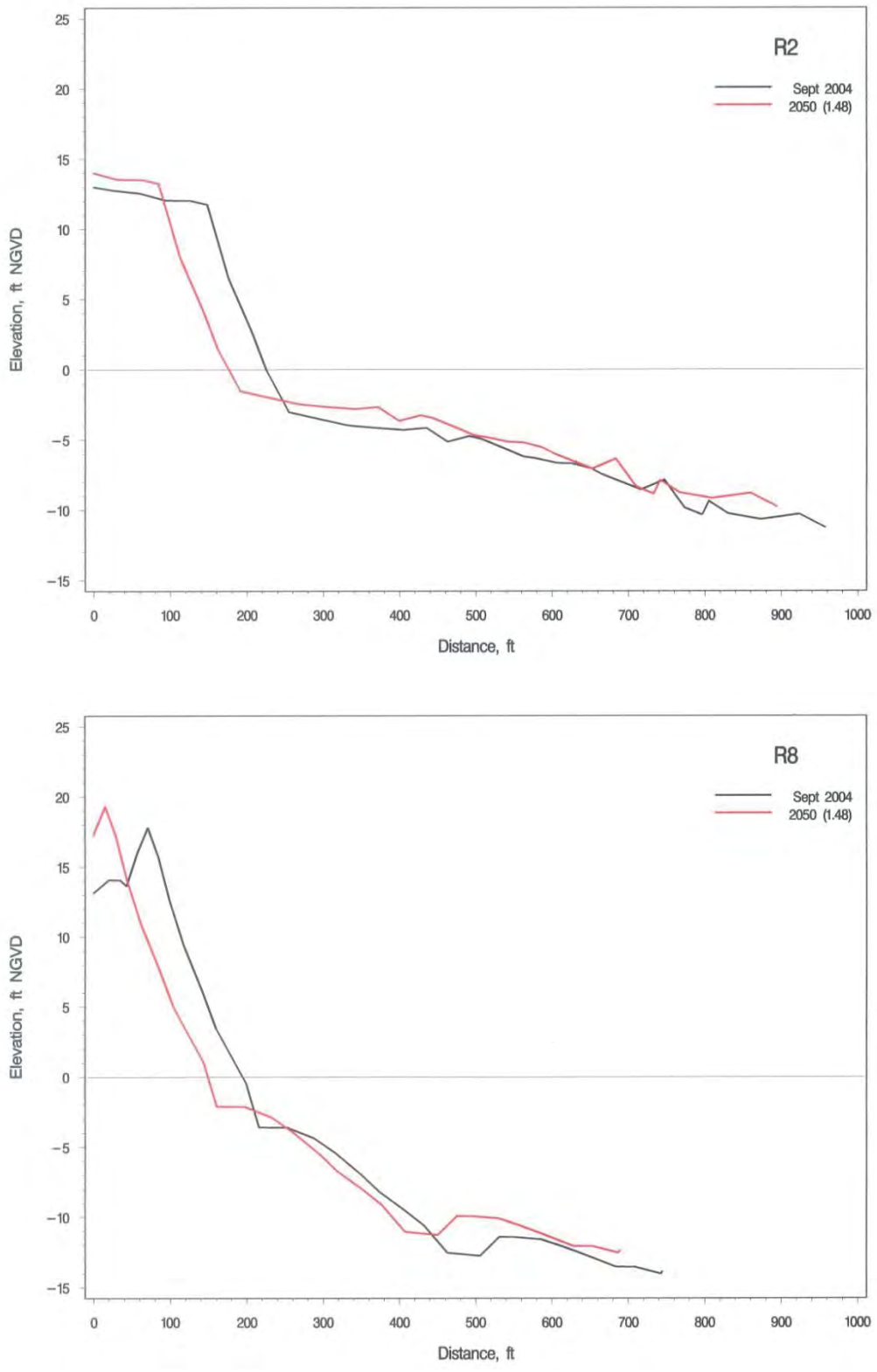


Figure 10-2. Predicted changes of beach profile R2 due to 1.48 ft SLR (top). Predicted changes of beach profile R8 due to 1.48 ft SLR (bottom).

Bruun (1983) has modified equation 10-1 to account for both sediment composition (1+ r/100) and possible losses in sand (1 + c/100), such that equation 10-1 reads as follows:

$$s = L\,(a/h)\,(1 + (r/100))\,(1+ c/100) \qquad (10\text{-}2)$$

where *r* is the percentage of fine-grained sand (smaller than 0.06 mm) in the sand along the profile and *c* is the percentage of sand losses from the profile. Bruun termed *c* as the "loss function" at the outer edge of the profile (Bruun, 1983).

10.2 CHANGES IN BEACH WIDTH AT DOHENY STATE BEACH

Sea level is likely to increase gradually over the next 30-40 years, giving time for the beach profile to adjust with waves and tides. Table 10-1 gives changes in beach width due to SLR for 2050 and 2100. These estimates are based on h = 35 ft for the west beach and 40 ft for the east beach, l = 1500 ft (for west and east beach), and the SLR by 2050 and 2100 and low and high estimates of SLR presented in Table 9-4. SLR estimates for 2050 varied between 0.18 and 1.48 ft, while sea level estimates for 2100 varied between 0.33 and 4.59 ft.

From Figure 4-5a,b the closure depth (d) at the Doheny State Beach is about 20 ft according and L= 1500 ft. The distance from the closure depth to the top of the berm (h) is estimated h=35 ft for the west beach and h= 40 ft for the east beach.

Based on the Bruun's Rule assumptions and limitations, the west beach would retreat by about 63.4 ft by 2050 and about 196 ft by 2100. The east beach will retreat about 55.5 ft by 2050 and about 172 ft by 2100.

Due to uncertainties in SLR projections, as explained in Section 9.3.5, these beach width values are approximations. The variations in beach widths between low and high projections of SLR rise reflect the uncertainties about SLR. It should be pointed out some of the estimates presented in Table 9-4 are higher than those used here for the calculations.

In addition, based on Bruun's Rule, the nearshore profile elevation of the beach would increase by a value equal to the SLR (a), which will vary by between 0.18 and 1.48 feet by 2050 and by between 0.33 ft and 4.59 ft by 2100.

11.0 RUNUP AND OVERTOPPING ANALYSIS

Wave runup is defined as the rush of water up a beach or coastal structure caused by or associated with wave-breaking. The runup elevation, designated *R* (Figure 11-1), is the maximum vertical height above 0 ft, NGVD that the runup will reach. If the runup elevation is higher than the beach berm (or back of the beach) elevation, the excess represents overtopping. Runup elevation depends on the incident wave characteristics, beach slope, and porosity, and if a structure is present, that structure's shape, slope, roughness, permeability, and water depth at the toe. Runup analysis is important to assess possible flooding and damage to the Doheny Beach.

Flooding may occur whenever the wave runup elevation exceeds 12-16 ft, NGVD, the approximate elevation of the beach berms west and east of San Juan Creek, respectively. The amount of damage depends on the runup elevation and amount of overtopping, as well as on storm wave duration and coincidence with tidal variations. If a storm or series of storms is of sufficient duration to erode the beach away and coincides with one or more episodes of high tide, much greater overtopping would occur. Under this scenario, some flood damages would be likely.

Several studies have been carried out since our previous study (CE, 2004) to calculate wave runup and overtopping based on field data for beaches with conditions and slopes similar to those of Doheny State Beach. We have adopted the results of these studies because they consider the random nature of waves and have been widely accepted by the scientific community.

11.1 RANDOM WAVE METHOD

Wave runup (R) is composed of wave setup and swash runup. The swash runup is defined as a super elevation of the mean water level and fluctuation about that mean (S). *R* is given by the equation:

$$R = \acute{\eta} + S/2 \tag{11-1}$$

Where $\acute{\eta}$ is the setup and *S* is swash runup.

A large number of both small and large-scale laboratory studies have been conducted to measure runup values for modeled beaches, sloped dikes, and seawalls (e.g., Hunt, 1959; Van der Meer and Jenssen, 1995; Hedges and Reis, 1998). Based on laboratory experiments, Hunt (1959) proposed various formulas for estimating wave runup, *R,* on a smooth slope as a function of offshore wave height, *H,* and the Iribarren number (surf similarity parameter) ζ, such as:

$$R=kH\zeta, \tag{11-2}$$

Where *k* is a constant and ζ is the Iribarren number defined as:

$$\zeta = \frac{\tan\beta}{\mathrm{Ho/Lo}} \tag{11-3}$$

Where *tan β* is beach slope, *Ho* is deepwater wave height, and *Lo* is deepwater wave length.

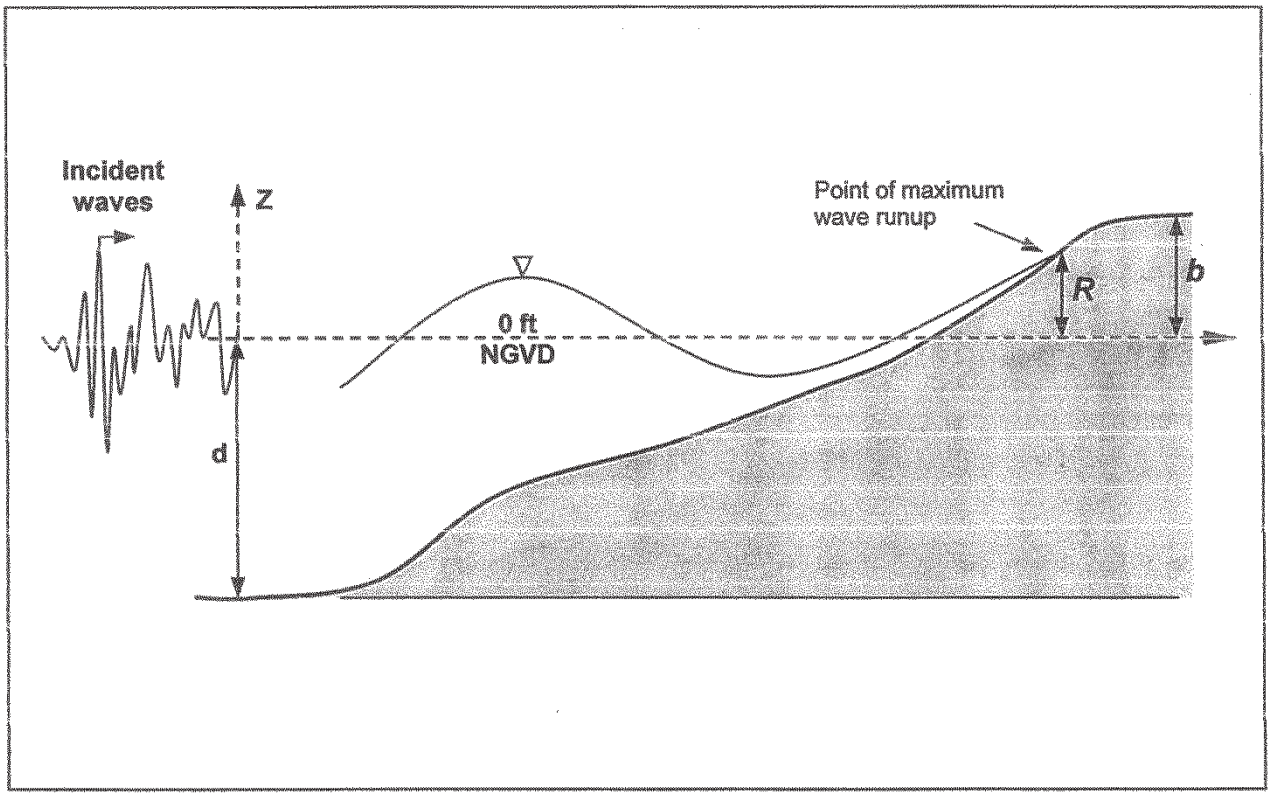


Figure 11-1. Wave runup on a slope. R is the runup elevation, b is the height of the beach berm. If R > b, then overtopping will occur.

Fewer studies have centered on runup on natural beaches (Holland and Holman, 1993; Raubenheimer et al., 1995; Ruggiero et al., 2004; Stockdon et al., 2006).

Stockdon et al. (2006) considered the contribution from both incident and infra gravity waves, using data from 10 field experiments with varying bathymetries and wave heights. They empirically estimated $R_{2\%}$ by:

$$R_2 = A \quad 0.35\,\beta_f \; H_0 L_0 \;^{1/2} + \frac{H_0 L_0 \quad 0.563\beta_f^2 + 0.004 \quad ^{1/2}}{2} \qquad (11\text{-}4)$$

where β_f is the foreshore beach slope and H_s is the deepwater significant wave height, A is coefficient equal to 1.1 as estimated by Stockdon, and $R_{2\%}$ is the 2% exceedance level of runup for each run. The units of the equation (11-4) are in meters.

Senechal et al. (2011) analyzed wave runup data collected during extreme storm conditions characterized by energetic long swells (peak period 16.4 s, offshore height up to 6.4 m) impinging on foreshore beach slopes (0.05-0.1). She found that a hyperbolic curve provides the best statistical fit for runup elevations.

The beach at Beach at Doheny State Beach has a slope, β, ranging from 0.12-0.16. Senechal et al. (2011) analyzed runup field data from beaches having a similar slope, β, under extreme storm wave conditions similar to those occurring at Doheny State Beach. The data from Senechal et al. for 88 runs are presented in Table A-1 (Senechal et al., 2011). We tested Stockdon's equation (11-4) on Senechal et al.'s data to determine the best estimate for the coefficient A in equation (11-4) for beaches similar to those at State Doheny Beach.

The comparison between Stockdon's equation with the coefficient A = 1.1 and Senechal's data is shown in Figure 11-2. Stockdon's equation predicted a runup of 0.4 m when the deep water wave height is 0, and the R-square value (R^2) of 0.78 implies that the equation explains 78% of the variance of the measured runup data. Figure 11-3 shows the comparison between Stockdon's model using A = 1.1 and Senechal's data when we forced the linear fit-line to go through zero (intercept=0). This improved the model fit (R^2) to 0.97. The slope of the best-fit line shown in Figure 11-3 is 0.82, implying that a change in coefficient A from 1.1-1.1 x 0.82 (A = 0.90) would considerably improve the runup calculations. Figure 11-4 shows a comparison between calculated runup using Stockdon's equation with coefficient A = 0.9 and Senechal's measured runup data. In this study, we used A = 0.9 as the best estimate for the coefficient A.

The beach profiles at ranges R2 and R3 are shown in Figure 11-5 (top). R2 and R3 ranges are located west of San Juan Creek. Figure 11-5 (bottom) shows the beach profiles at ranges R8 and R9 located east of San Juan Creek. Figure 11-5 gives the foreshore beach slope for these ranges.

Wave data at 10 m (Figure 5-6) were used to calculate the waver runup at Doheny State Beach from 2000 to present and the results are shown in Figure 11-6. The runup was calculated from equation (11-4) for foreshore beach slope was β=0.15. The Iribarren number (ζ) (surf similarity parameter) was calculated for each wave. The distribution of the surf similarity parameter (ζ) is presented in Figure (11-6).

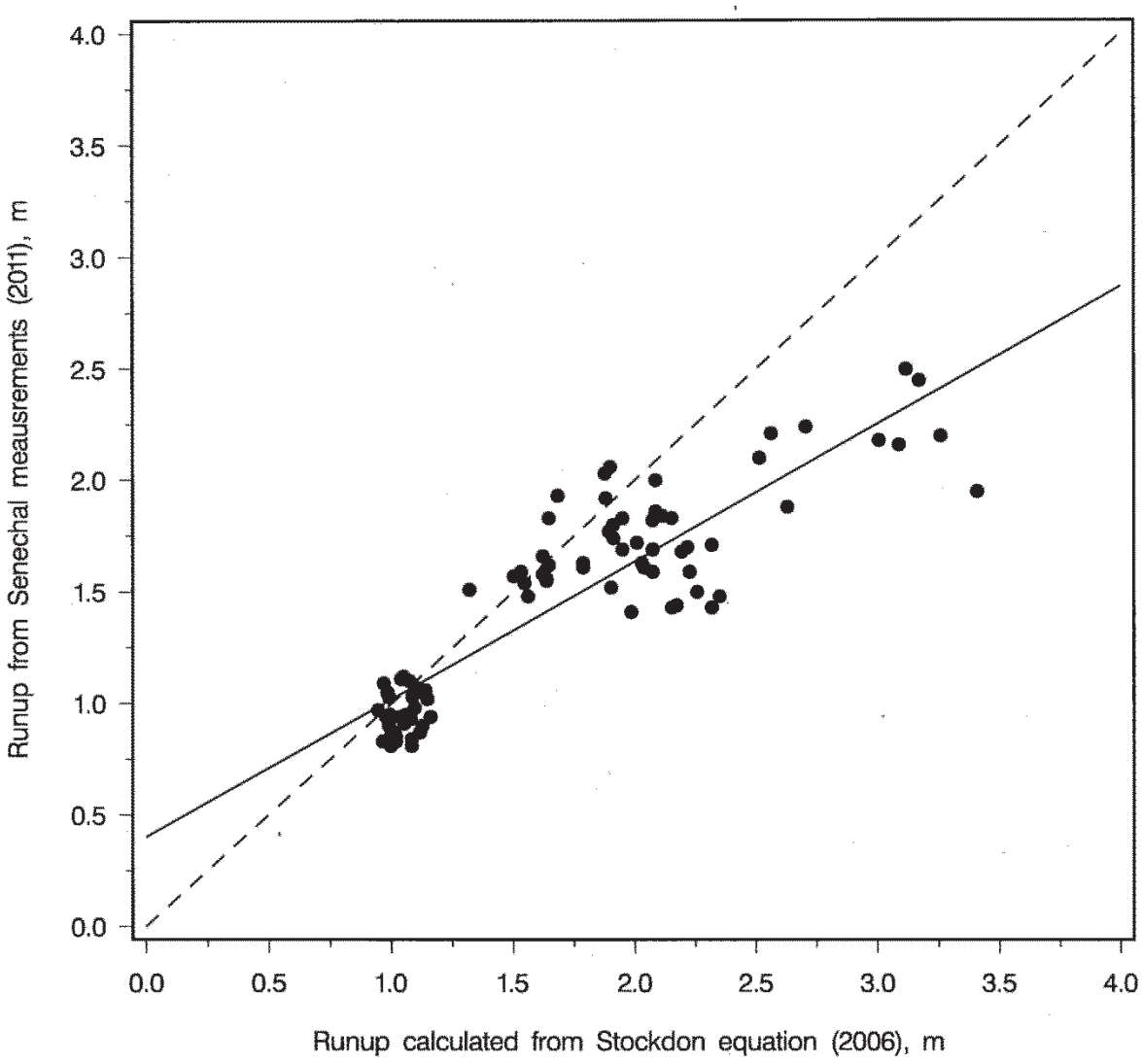


Figure 11-2. Comparison between wave runup estimates by Stockdon et al. (2006) with coefficient A equal 1.1 and Senechal runup measurements. The solid line represents estimates from the Stockdon equation (11-4), and the dashed line points to the deviation between the measured runup and the calculated runup.

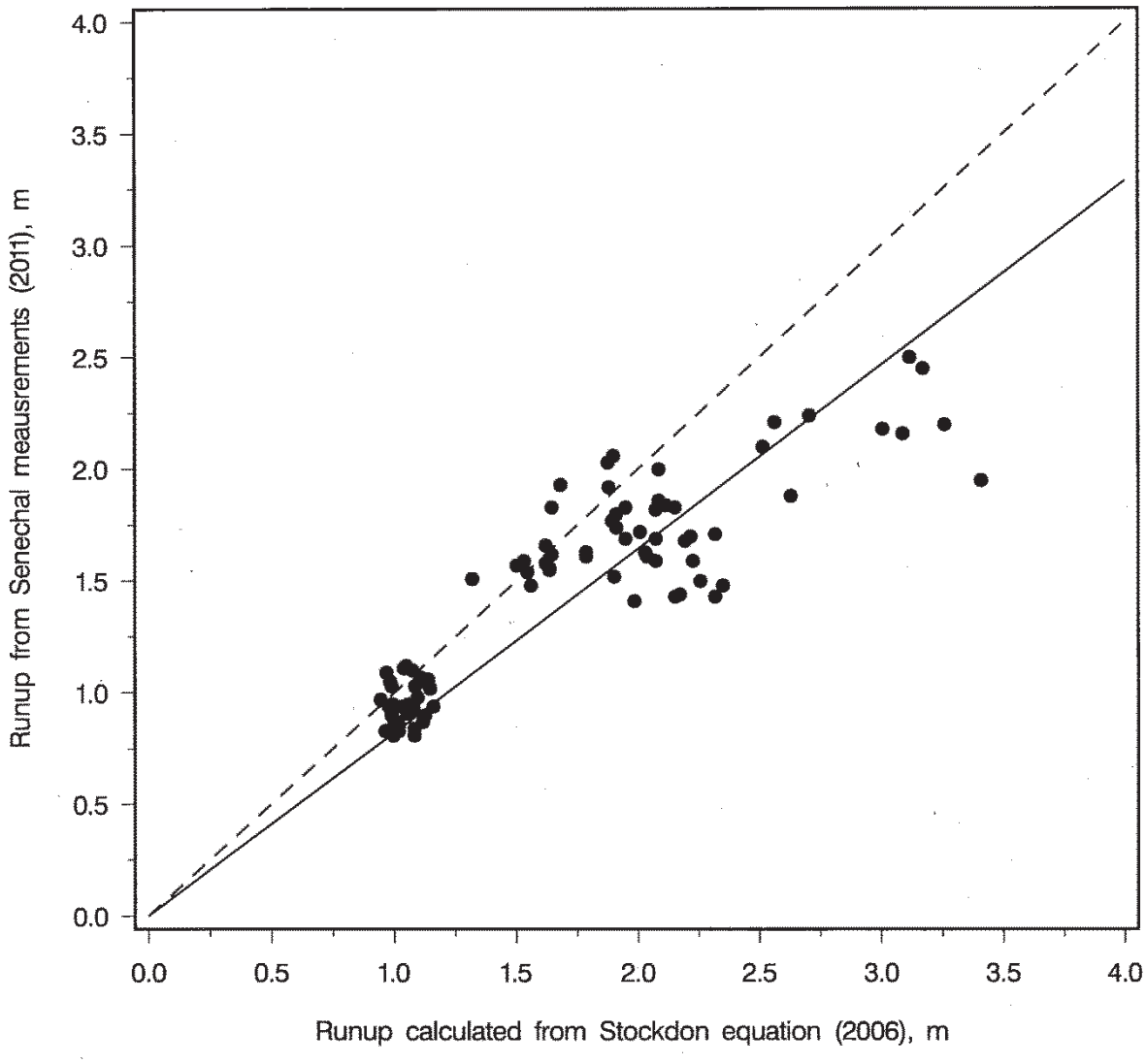


Figure 11-3. Comparison between wave runup estimates by Stockdon et al. (2006) with coefficient *A* equal 1.1 and with zero intercept and Senechal runup measurements. The solid line represent estimates from the Stockdon equation (11-5), and the dashed line points to the deviation between the estimated and calculated measurements of the runup.

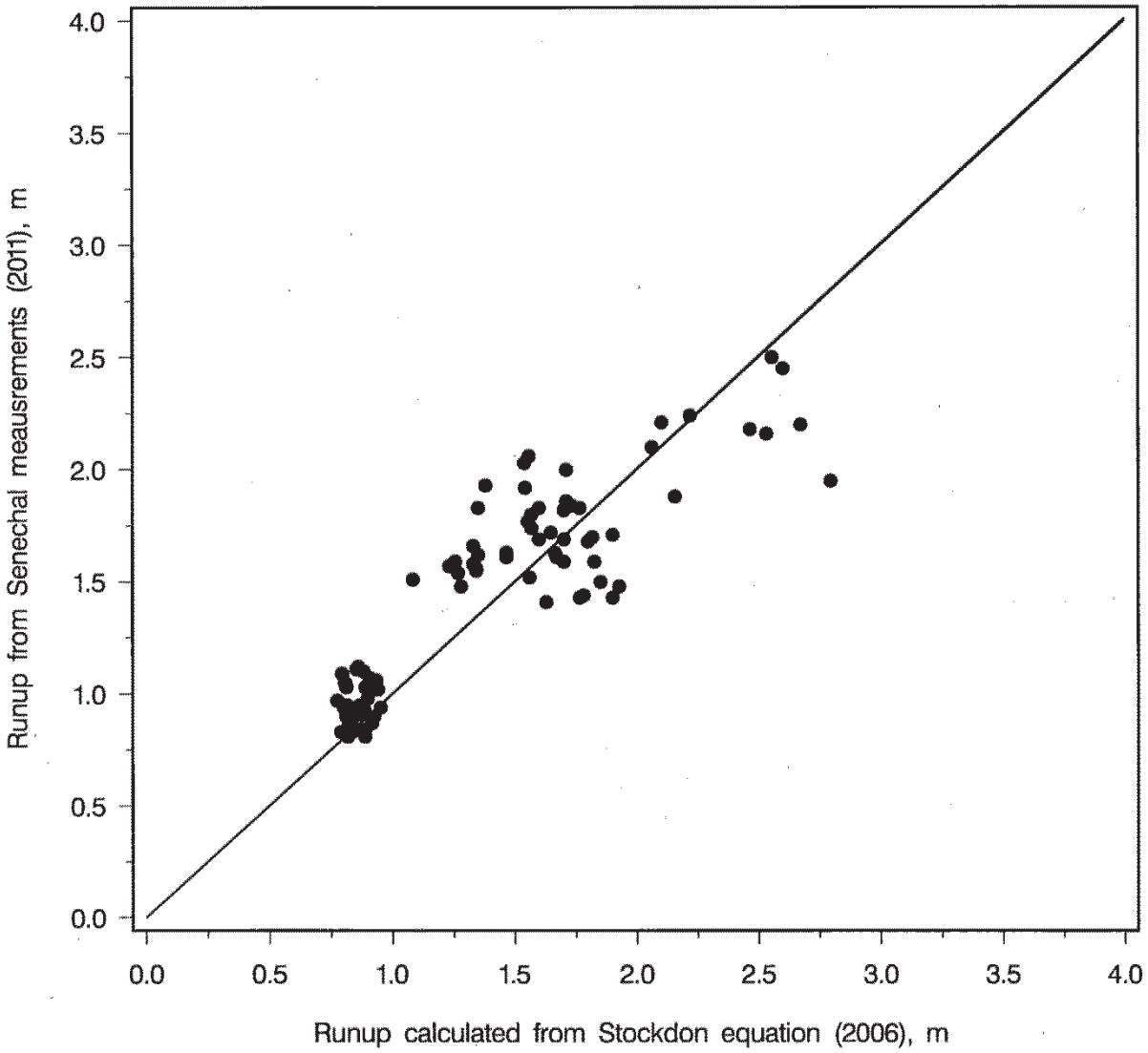


Figure 11-4. Comparison between wave runup estimates by Stockdon et al. (2006) with coefficient *A* equal 0.9 and Senechal runup measurements. The solid line represents estimates from the Stockdon equation (11-5), and the dashed line points to the deviation between the estimated runup and the calculated runup.

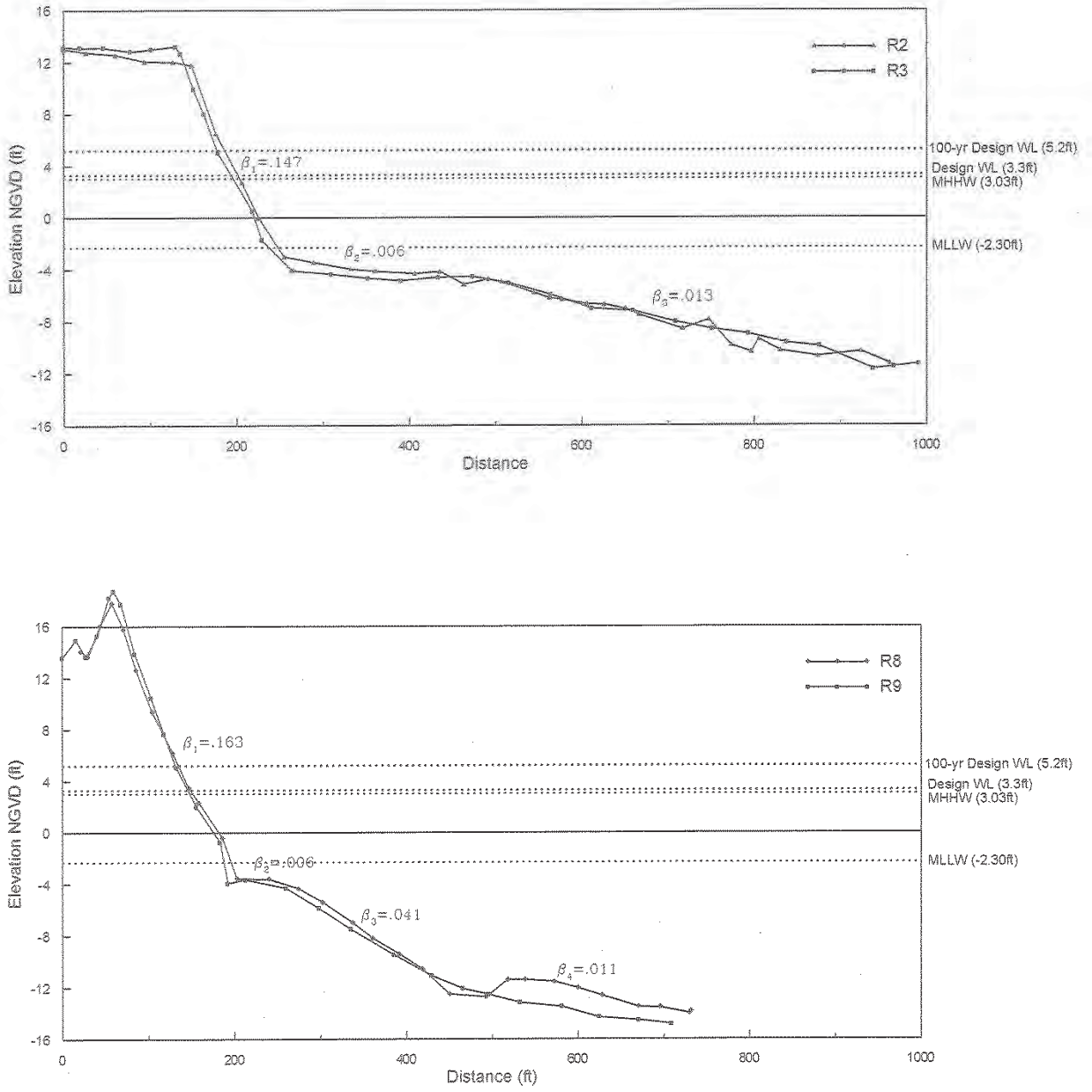


Figure 11-5. Beach slopes at profiles R2 and R3 (top) and R8 and R9 (bottom). The foreshore slope of R2 and R3 is 0.147 and for R8 and R9 is 0.163.

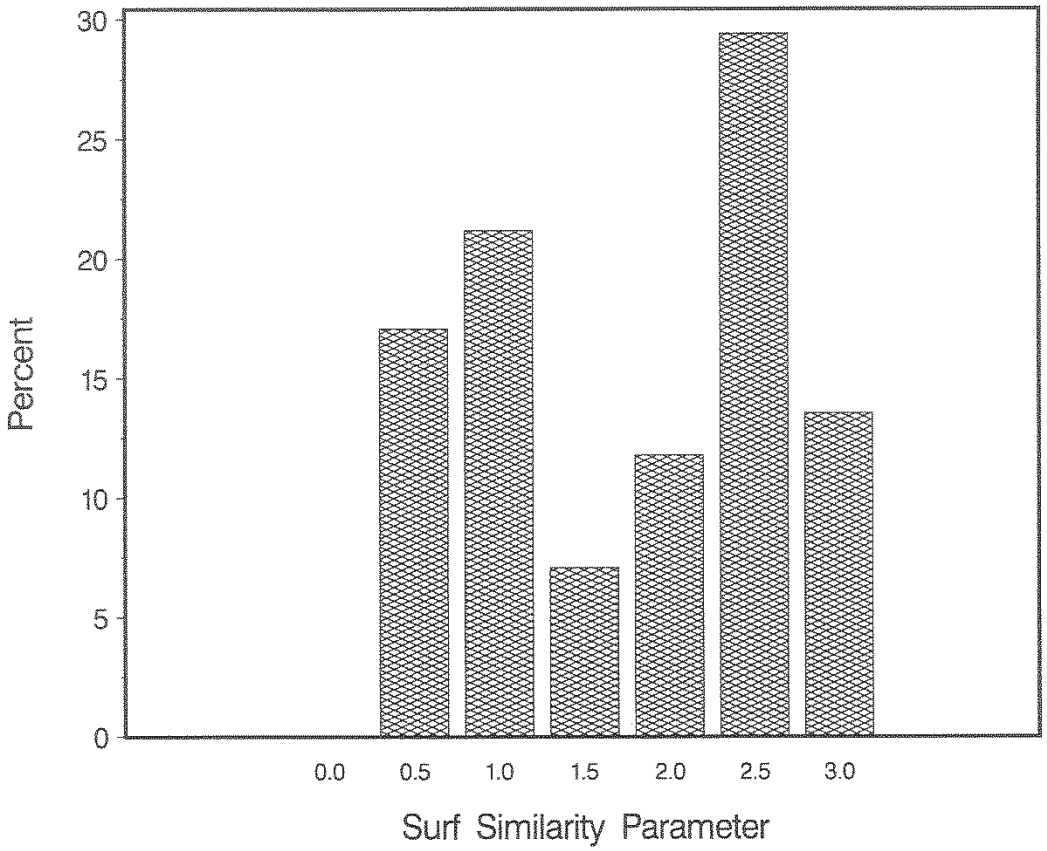


Figure 11-6. Distribution of the surf similarity parameter (ζ).

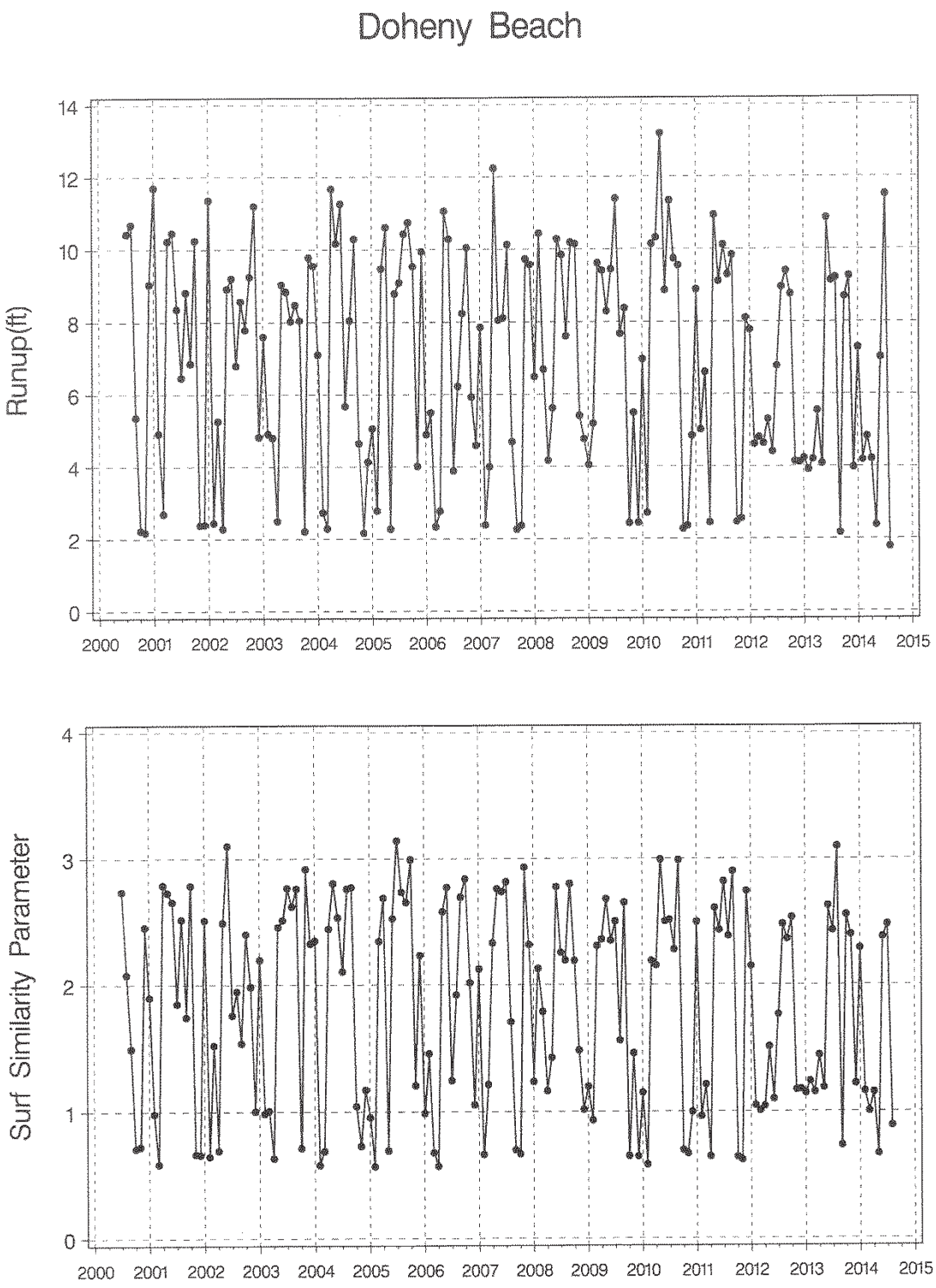


Figure 11-7. Runup of Doheny Beach from 2000 to present for maximum monthly observed waves (top). Surf similarity coefficient ζ is shown (bottom).

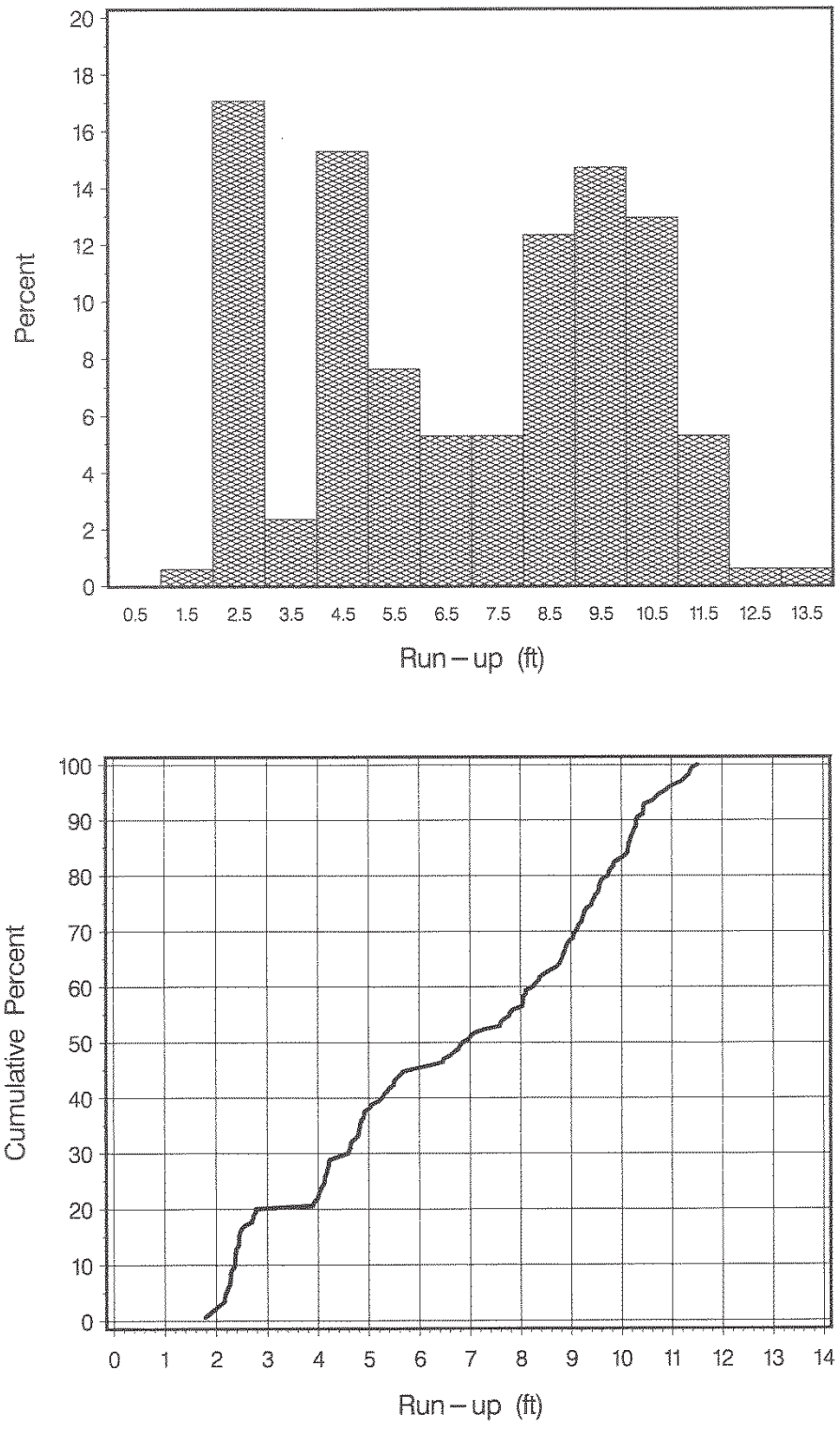


Figure 11-8. Percent and cumulative percent of wave runup on Doheny State Beach.

11.2 OVERTOPPING

The overtopping rate (Q) is defined as the volume of water that overtops a coastal structure or beach berm along the beach length. The units are volume per second per unit length (ft^3/sec-ft or m^3/sec-m). The overtopping empirical models are based on laboratory studies of the overtopping of structures. The models are used to test design specifications intended to limit the overtopping of levees and dikes, and they therefore give conservative values. A beach berm can act in the same manner as these structures in protecting the back of properties or the bay from wave attack and flooding.

Wave overtopping values depend on the ratio between freeboard height and wave runup height. Freeboard *Rc* is defined as the height of the berm crest above mean water level (MWL). In order for waves to overtop a berm, the runup heights must be greater than the freeboard height. Overtopping is dependent on the runup height and therefore dependent on incident wave height and period and beach slope.

Hedges and Reis (1998) introduced a semi-empirical model (H&R model) based on an overtopping theory for regular waves developed by Kikkawa et al. (1968), which assumed that a sea wall or beach berm acted as a weir whenever the incident water level exceeded the seawall level and the described instantaneous discharge by the weir formula. The H&R model extended the concept to random waves. Reis et al. (2008) compared the H&R model with three other methods used to estimate the overtopping rate for various structures subject to random wave action. The slopes of these structures varied from 1:1-1:20 and wave steepness varied from 0.01-0.3. The models were: 1) Owen model (Owen, 1980); 2) Van der Meer Janssen model (Van der Meer and Janssen, 1995); and 3) AMAZON Numerical Model (Hu, 2000). The results showed good agreement between the H&R model and the data. There was general agreement between H&R and AMAZON models, while Owen's model systematically over-predicted the discharges. Van der Meer and Janssen's model gave similar results to the H&R model, except that they over-predicted discharges for some conditions which are outside the ranges of applicability.

The H&R model extending the concept to random waves can be written as:

$$\frac{\mathrm{Q}}{\overline{gR3\max}} = A \quad 1 - \frac{Rc}{\gamma rRmax} \quad \mathrm{B} \qquad for 0 \leq \frac{Rc}{\gamma rRmax} < 1 \tag{11-5}$$

and

$$\frac{\mathrm{Q}}{\overline{gR3\max}} = 0 \qquad\qquad for \qquad \frac{Rc}{\gamma rRmax} \geq 1 \tag{11-6}$$

Where g is gravitational acceleration, R_{max} is the maximum runup on smooth slope, and γ is reduction factor to account for rough slope. In this study, R_{max} is estimated by equation number 9 presented by Reis et al (2008). Additionally, the coefficients of the HR model were given by Reis et al. (2008) as:

$$A = \begin{array}{ll} 0.0033 + 0.0025\ 1/\beta & for 0.08 \leq \beta \leq 1 \\ 0.0333 & for 0.05 \leq \beta < 0.083 \end{array} \tag{11-7}$$

$$B = \begin{array}{ll} 2.8 + 0.65\ 1/\beta & for 0.13 \leq \beta \leq 1 \\ 10.2 - 0.275\ 1/\beta & for 0.05 \leq \beta < 0.13 \end{array} \quad (11\text{-}8)$$

Where β is the beach slope.

11.3 RESULTS

Figure 11-5 shows beach profiles for R2, R3, R8 and R9, and the design water levels estimated at 3.3 ft and 5.2 ft (NGVD).

Tables 11-1 and 11-2 provides runup and overtopping results for the western and portion of the beach for all design wave and water level conditions calculated for a smooth, impermeable slope.

11.4 ESTIMATES OF RUNUP AND OVERTOPPING DUE TO SEA LEVEL RISE

Bruun's Rule suggests that the beach will maintain its form, but will retreat back as the sea level rises; as the beach retreats, its nearshore profile elevation will increase an amount equal to the SLR. Bruun's theory is based on the assumption that there is enough sand supply for the beach to maintain its form. If the Bruun's Rule assumptions are satisfied, then the elevation of the runup and overtopping discharge results (ft^3/sec-ft) given in Table 11-1 will be raised up by a value equal to SLR in 2050 or 2100.

However, to be conservative, in case the sand supply decreases (due to changes in global warming or in weather systems), the most likely change in the beach form pertaining to runup analysis is a change in beach slope in the nearshore area. In order to address this uncertainty of Bruun's rule, we assumed the beach slope β will change from 0.05-0.06 by 2050 and that it will change further from 0.06-0.07 by 2100, and we computed the runup and overtopping analysis based on these two assumptions. The results for 2050 and 2100 are presented in Tables 11-2 and 11-3, respectively.

Table 11-1. Runup and overtopping summary, west of San Juan Creek (2014, 2050, and 2100)

Return Period (yr)	Wave Height, Hs (ft)	Peak Period, Tp (sec)	Runup[a] (ft, NGVD)		Overtpping Rate (ft^3/sec-ft)	
			3.3 ft water level	5.2 ft water level	3.3 ft water level	5.2 ft water level
2	6.0	20	15.0	16.9	0.01	0.05
5	8.0	18	15.5	17.35	0.04	0.16
10	9.5	18	16.55	18.5	0.11	0.36
20	11.2	17	16.9	18.8	0.21	0.61
50	12.5	16.7	17.4	19.3	0.34	0.88
100	14.0	17	18.5	20.4	0.59	1.37

[a] 0.15 Slope

Table 11-2. Runup and overtopping summary, east of San Juan Creek (2014, 2050, 2100)

Return Period (yr)	Wave Height, Hs (ft)	Peak Period, Tp (sec)	Runup[a] (ft, NGVD)		Overtpping Rate (ft^3/sec-ft)	
			3.3 ft water level	5.2 ft water level	3.3 ft water level	5.2 ft water level
2	6.0	20	15.9	17.8	0.0	0.01
5	8.0	18	16.4	18.3	0.01	0.06
10	9.5	18	17.5	19.5	0.05	0.16
20	11.2	17	17.9	19.8	0.11	0.30
50	12.5	16.7	18.5	20.4	0.18	0.47
100	14.0	17	19.6	21.5	034	0.80

[a] 0.15 Slope

12.0 FLOW AND WATER LEVELS IN THE SAN JUAN CREEK WATERSHED

12.1 WATERSHED

The watershed area of San Juan Creek comprises 176 square miles (Figure 12-1). The creek itself is 27 miles long. Trabuco Creek is the major tributary of San Juan Creek, and is joined by Oso Creek before its confluence with San Juan Creek (Figure 12-2). The other tributaries of San Juan Creek are Horno Creek, Canada Chiquita, Canada Gobernadora, Bell Canyon, Verdugo Wash, Lucas Canyon, Cold Spring Canyon, and Hot Spring Canyon. San Juan Creek flows through an alluvial valley in San Juan Capistrano before flowing through the breached San Joaquin Hills into the Pacific Ocean at Doheny State Beach. The alluvial valley consists of Holocene alluvium, landslide deposits, and Pleistocene terrace deposits. The San Joaquin Hills consist of sedimentary rocks (sandstone, siltstone, shale) from the Capistrano and Santiago Formations.

Figure 12-3 is a photograph showing San Juan Creek north and south of Pacific Coast Highway. The reach from Camino Capistrano Road to the outlet at the Pacific Coast Highway Bridge consists of a concrete-lined trapezoidal channel. The lower 2.6 miles have concrete banks and an earthen bottom. The channel in this reach has a bottom width of 150 feet with an average height of 14 feet to the Pacific Coast Highway Bridge. The gradient is estimated to be 0.0045 at the channel mouth. Cobbles three to five inches in diameter are found in the bed material. Due to erosion and channel degradation, flood control issues, and degraded environmental resources, this reach is scheduled for additional flood control, channel stabilization, and ecosystem restoration evaluation (USACOE, 2002).

12.2 RIVER FLOWS AT SAN JUAN CREEK MOUTH

The 10 largest floods that have occurred at San Juan Creek are shown in Table 12-1. In a 2002 study, the USACOE computed the design flood discharges for San Juan Creek, Trabuco Creek and Oso Creek for various return periods. The results of that study are presented in Table 12-2. Frequency-overflow results (i.e., floodplain mapping) at the San Juan Creek mouth are presented in Figure 12-4 for inundation boundaries for 100- and 500-year flood events. Water surface profiles were computed using the HEC-2 program and the HEC-River Analysis System (HEC-RAS). The HEC-RAS results were utilized to define the floodplain boundaries. The results of the USACOE study indicate two circumstances by which flood damage may occur:

1. Overtopping of the existing levee system. Hydraulic analysis has shown that these levees can be overtopped by flood events with greater than 2% exceedance (about a 50-year flood).
2. Undermining and potential failure of the channel lining, with subsequent failure of the levee and inundation of surrounding floodplains. In 1996, with floods of 4% exceedance (roughly a 25-year frequency), failure of the lining did occur (USACOE, 2002).

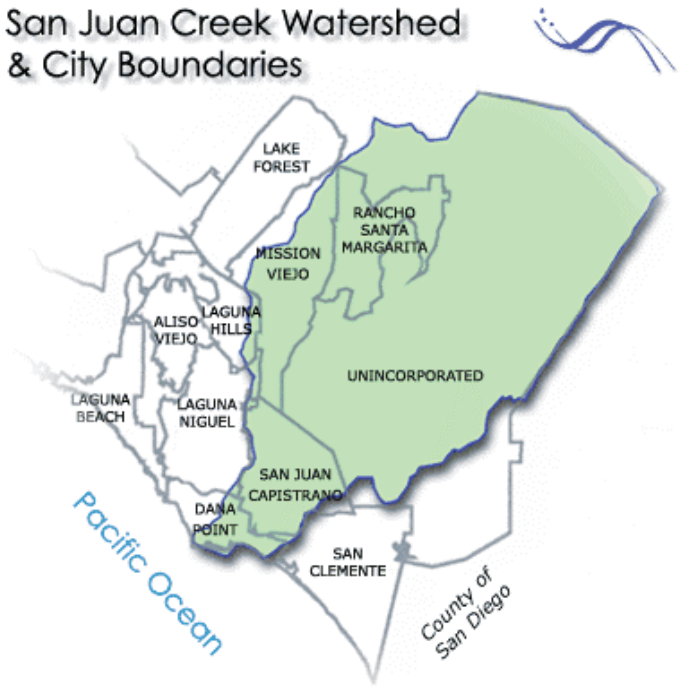


Figure 12-1. San Juan Creek watershed (from USACOE, 2002).

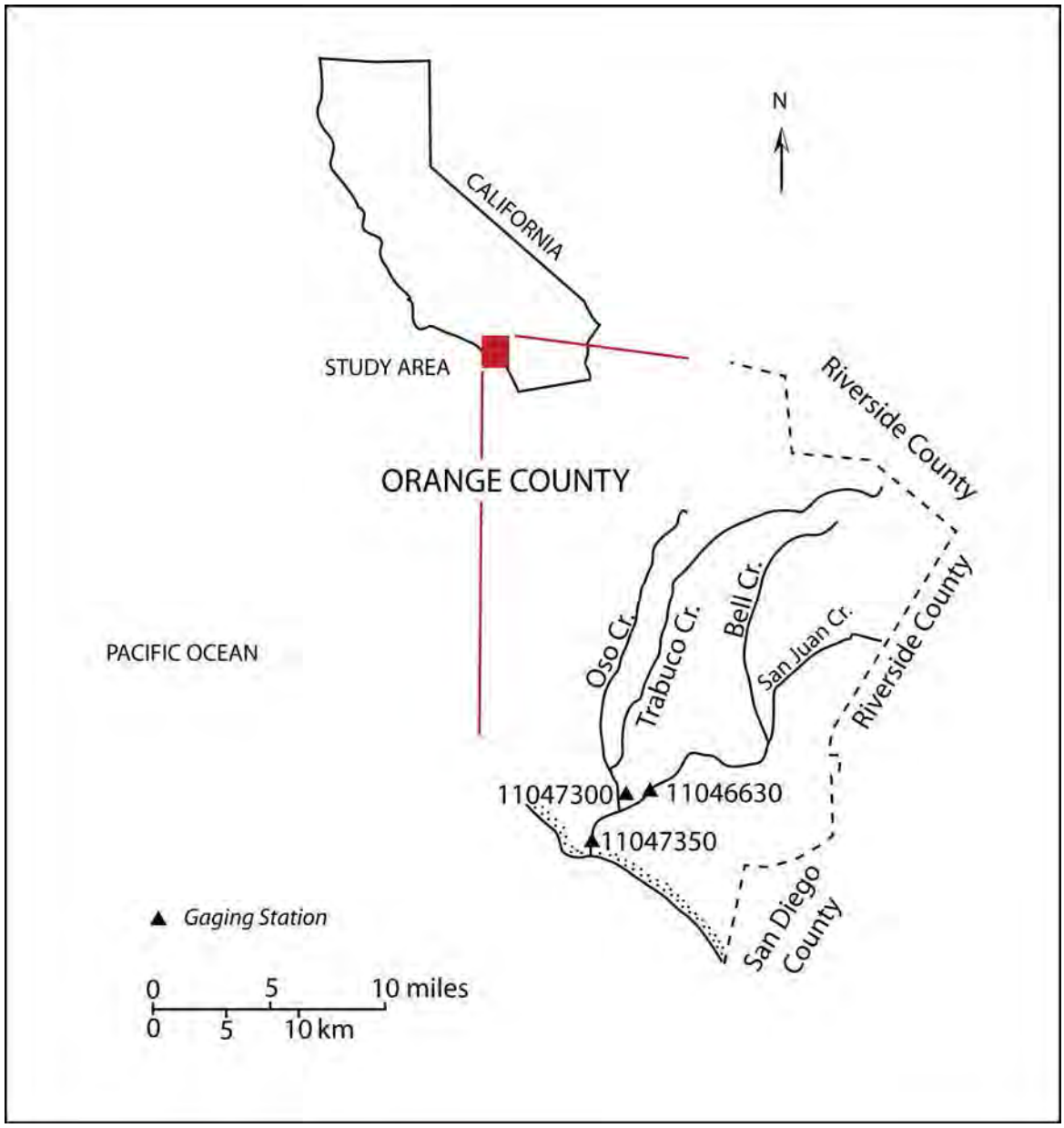


Figure 12-2. Locations of San Juan Creek, Oso Creek, Trabuco Creek, and USGS gaging stations along San Juan Creek.



Figure 12-3. Recent photo of San Juan Creek.

Table 12-1. Peak discharge flows at San Juan Creek.

Rank	River Flow (cfs)	Date
1	25,600	5 March 1995
2	22,400	25 February 1969
3	18,300	23 February 1998
4	14,700	4 March 1978
5	13,000	2 March 1938
6	11,400	20 February 1980
7	9,000	26 December 1966
8	8,320	16 January 1993
9	5,800	23 January 1943
10	5,770	2 March 1983

Table 12-2. Peak discharges at San Juan Creek, Trabuco Creek, and Oso Creek for various flood return periods.

Storm Frequency (yrs)	San Juan Creek at Ocean Outfall (cfs)	Trabuco Creek at Flow into San Juan Creek (cfs)	Oso Creek at Flow into Trabuco Creek (cfs)
2	2,600	330	2,600
5	4,400	800	4,300
10	10,000	1,600	4,400
25	22,600	3,300	4,600
50	35,500	5,200	4,900
100	53,300	6,900	5,400

From USACOE, 2002.
cfs = cubic feet per second.
Note that 5-yr and 10-yr discharges were determined graphically.

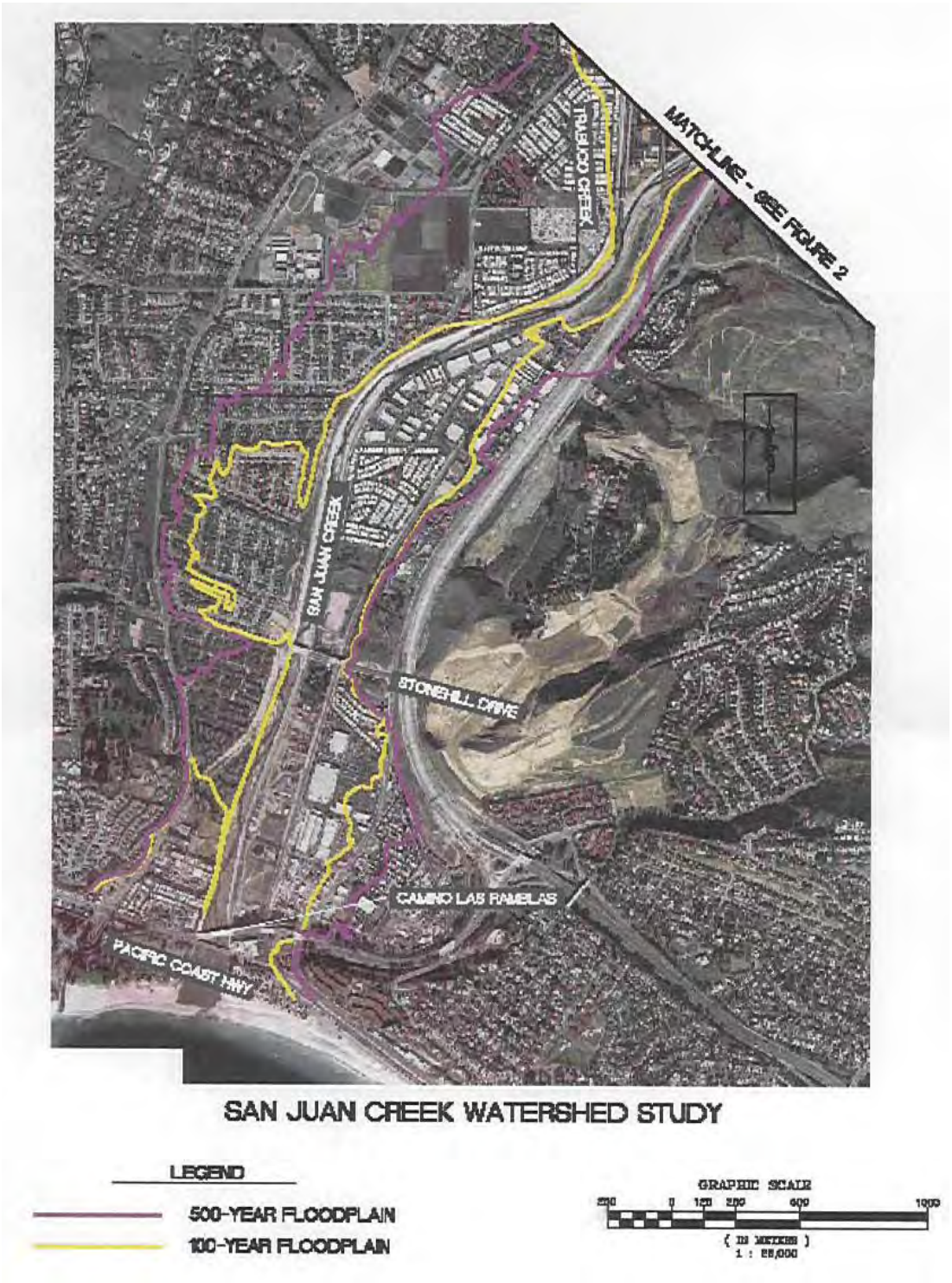


Figure 12-4. Floodplain mapping at San Juan Creek mouth for 100- and 500-year flood events (from USACOE, 2002).

The hydraulic analysis indicates that for the 100-year flood, flow overtops the Pacific Coast Highway Bridge (USACOE, 2002).

Flooding has occasionally occurred in San Juan Creek, with the largest flood in recorded history occurring in 1916. The creek's sediment-carrying capacity decreases as it approaches the ocean. This capacity also decreases after flooding due to sediment (primarily the coarser portion), which remains deposited within the channel. The 1916 flood was estimated at 55,000 cfs and is estimated to have a recurrence interval of 100 years. The channelization that was constructed in the 1960s was designed for 40,000 cfs. In 1969, flood flows of 22,400 cfs occurred during a winter storm. Flooding of the Pacific Coast Highway Bridge did not occur. However, the capacity of the channel at the bridge was nearly exceeded. Photographs presented in USACOE (1970) show one to two feet of clearance remaining between the bridge soffit and the water surface (USACOE, 1970).

In 1969, about one million cubic yards of sediment were carried to the ocean, creating a delta deposit. The USACOE cleared out the sediment from the creek and restored it to its design capacity. About 280,000 cubic yards that were removed from the creek were placed on Doheny State Beach. Similar deposition occurred during storms in 1978. Only a portion of the sediment (50,000 cubic yards) was placed on Doheny State Beach during this period. In 1980, storms again deposited sediment in the lower reaches of the creek. About 80,000 cubic yards were placed on the beach. Eight feet of sediment were deposited in the channel upstream of the Pacific Coast Highway Bridge, reducing channel capacity by 50%. Consequently, a study was conducted to increase flood protection and deliverability of sand to the beach (i.e., the San Juan Creek channel and side inlets from Pacific Coast Highway to the Trabuco Creek confluence) (Environmental Management Agency, 1982). Since that time, modifications have been conducted in the area from the Camino Capistrano Highway to the mouth at Doheny State Beach, including repairs and raising of the right and left levees (Simons, Li & Associates, 1984). Additional flooding has occurred during large storm years: for instance, 1983, 1988, 1993, 1995, and 1998. The ten largest floods that have occurred in San Juan Creek since 1928 are ranked in Table 12-1.

12.3 SAN JUAN CREEK CHANNEL GEOMETRY

The San Juan Creek channel slope near the creek mouth is shown in Figure 12-5 (USACOE, 2002). At the Pacific Coast Highway Bridge, creek width is about 540 ft, and there are eight piers in the creek bed. The water surface elevation at Pacific Coast Highway constrains the flow and dictates the amount that can pass under the highway during flood conditions.

On September 20, 2004, Coastal Environments conducted a topographical survey to determine: (1) the San Juan Creek channel cross-section midway between the shoreline and the Pacific Coast Highway Bridge, and (2) the elevation of the west bank of the creek and bike path. The results of this survey are shown in Figures 12-6 and 12-7. Creek width was about 500 ft, and bottom elevation about 3 ft, NGVD. Bank height was about 10 ft, NGVD, at this cross-section. The elevation of the bank and bikeway varied with location, but generally increased from the Pacific Coast Highway Bridge to the ocean (Figure 12-7).

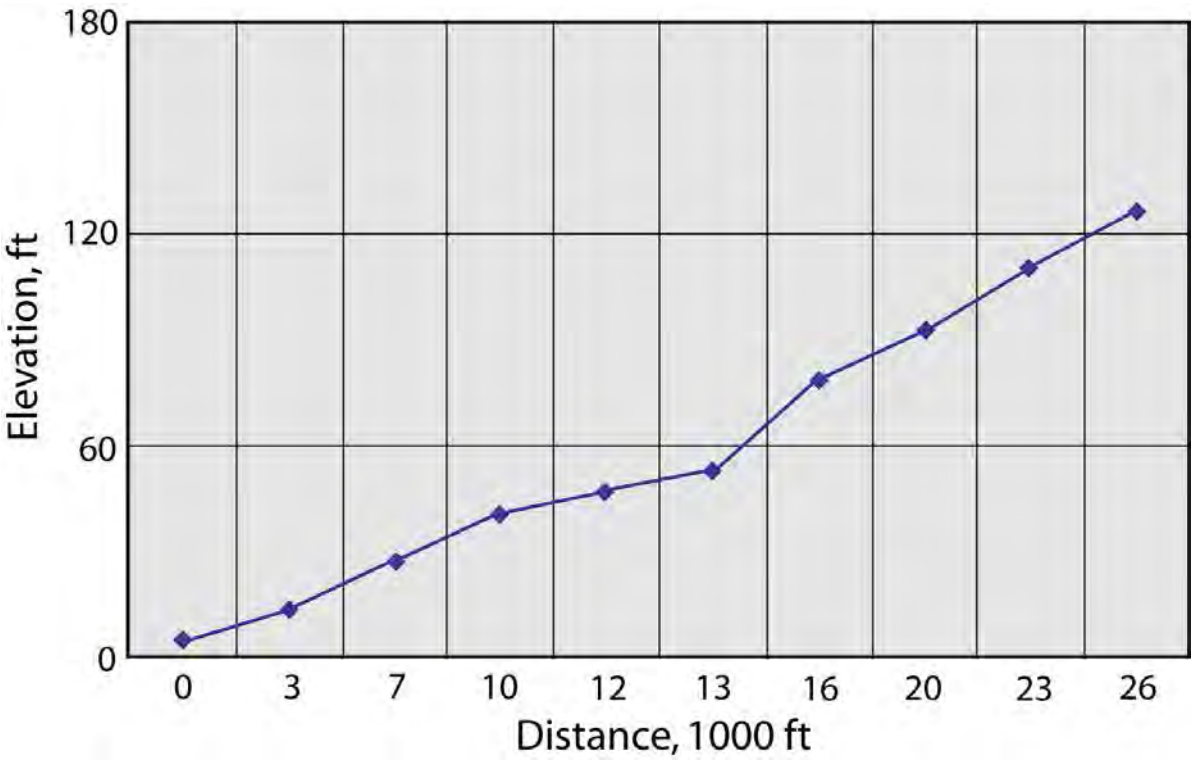


Figure 12-5. San Juan Creek channel slope near creek mouth (from USACOE, 2002).

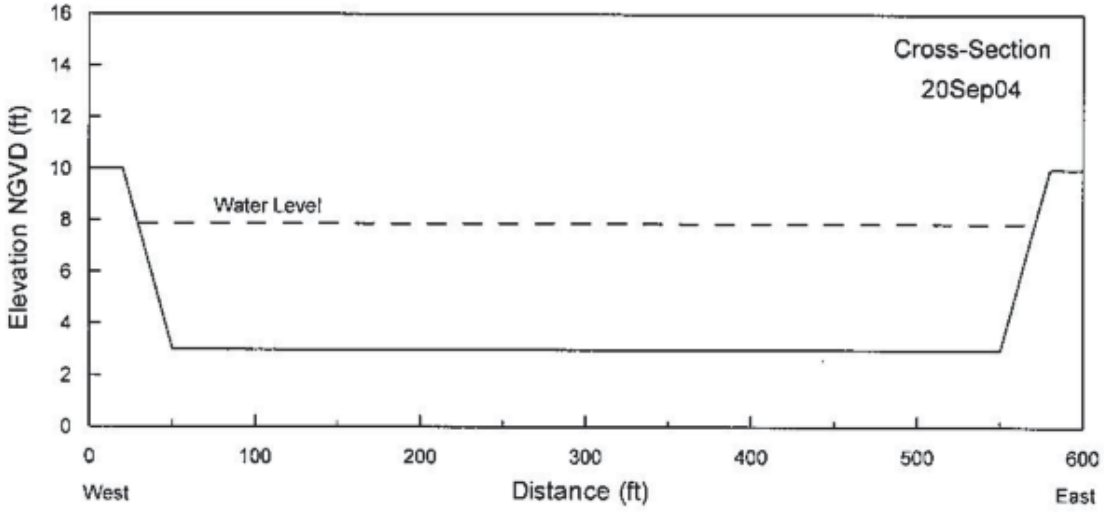


Figure 12-6. San Juan Creek channel cross-section as surveyed on 20 September 2004.

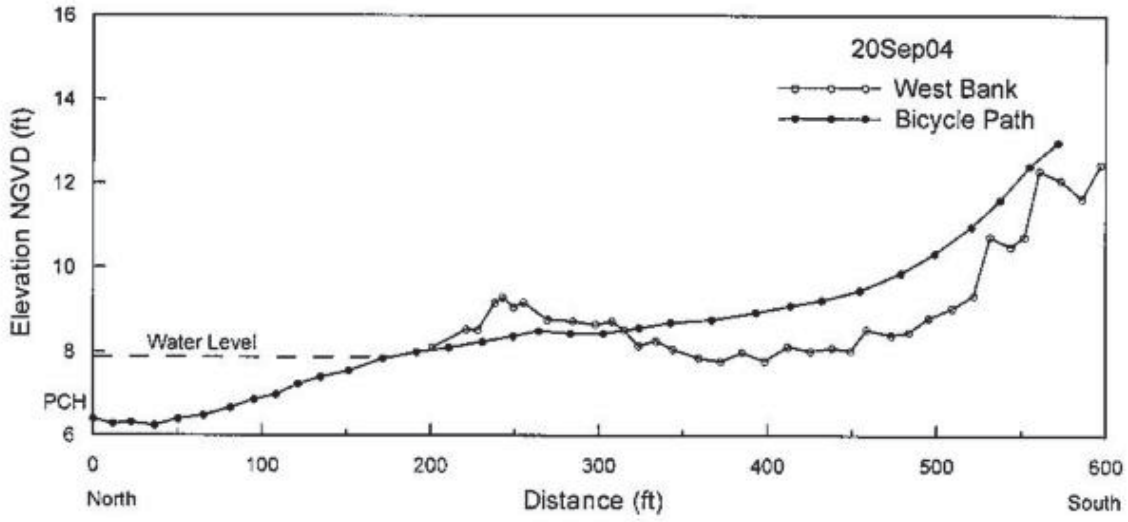


Figure 12-7. Elevations of San Juan Creek west bank and bike path, surveyed on 20 September 2004.

12.4 CARRYING CAPACITY OF SAN JUAN CREEK CHANNEL NEAR ENTRANCE

The procedure used to compute the carrying capacity of the San Juan Creek channel near the entrance is explained below.

The river discharge, Q, in the channel is given by

$$Q = VA \tag{12-1}$$

where Q is in ft^3/sec, V is the flow velocity in ft/sec, and A is the channel cross-section in ft^2. The flow velocity, V, can be calculated using Manning's formula, i.e.,

$$V = \frac{1.486}{n} R^{2/3} S^{1/2} \tag{10-2}$$

where R is the hydraulic radius in ft, S is the river channel downhill gradient, n is the coefficient of roughness (Manning's coefficient), and 1.486 is Manning's constant. The hydraulic radius, R, is defined by the channel cross-section area, A, divided by the wetted perimeter, P, of the channel.

Therefore, the river discharge may be rewritten as:

$$Q = \frac{1.486}{n} A^{5/3} P^{-2/3} S^{1/2} \tag{12-3}$$

Assuming that the channel geometry is rectangular, d is the depth of the channel, and b is the width of the channel bottom,

$$Q = \frac{1.486}{n} (d.b)^{5/3} (b + 2.d)^{-2/3} S^{1/2} \tag{12-4}$$

Substituting values for n, S and b, Eq. 12-4 can be solved for d. Manning's number (n = 0.03) was used, and for channel width, b = 150 ft was used. The value of Manning's number (n) and a channel slope value of about .0045 were both taken from the USACOE study for the main channel.

The channel bottom is sandy and erodable during high floods. Therefore, water depth, d, varies depending on the intensity of a flood. The bottom channel elevation is now about 3 ft, NGVD, and the elevation of the river bank near the project area is 10 ft. Therefore, the water depth, d, was calculated to be 7 ft. Substituting these values in Eq. 12-4 gives Q (channel's carrying capacity) as 33,270 ft^3/sec. This estimate is conservative since it does not take into consideration channel bottom scour. The existing channel's carrying capacity is slightly smaller than a 50-yr return period flood. Outflow velocity is 11.8 ft/sec based on Eq. 12-2. If the creek bottom channel scoured 1 ft during a flood, the carrying capacity of the channel would increase to 41,435 ft^3/sec, which is greater than the flow discharge of a 50-year return period flood.

13.0 TSUNAMI INUNDATION AT DOHENY BEACH

Figure 13-1 shows the inundation map at Doheny Beach (the inundation area is shaded gray). The extent of the propagation of tsunami waves along the beach or into San Juan Creek is defined by the end of the shaded gray area. This map was prepared based on tsunami modeling efforts performed by the University of Southern California (USC). Below is short summary for their efforts to model tsunami inundation extent and area. The full description of the numerical procedure is given in the following link (document):
http://www.conservation.ca.gov/cgs/geologic_hazards/Tsunami/Inundation_Maps/Orange/Documents/Tsunami_Inundation_DanaPointSanJuanCapistrano_Quad_Orange.pdf.

The numerical model allows for wave propagation over a variable bathymetry and topography used numerical procedures developed by Titov and Gonzalez (1997); and Titov and Synolakis (1998). The bathymetric/topographic data that were used in the tsunami models consist of a series of nested grids. The near-shore grids were about75-90 m resolution or higher. These grids were adjusted to "Mean High Water" sea-level conditions, representing a conservative sea level for the intended use of the tsunami modeling and mapping.

Several of tsunami source events was selected for modeling, representing realistic local and distant earthquakes and hypothetical extreme undersea, near-shore landslides (Table 13-1) such as offshore reverse-thrust faults, restraining bends on strike-slip fault zones and large submarine landslides capable of significant seafloor displacement and tsunami generation. Distant tsunami sources that were considered include great subduction zone events that are known to have occurred historically (1960 Chile and 1964 Alaska earthquakes) and others which can occur around the Pacific Ocean "Ring of Fire" (Figures 13-2 and 13-3).

The model nearby the shore area used high-resolution digital topographic data (3-10 m resolution) in order to enhance the result from the 75-90 m inundation grid data and consequently, better defines the location of the maximum inundation line and area. The high resolution bathymetry data were obtained from the following sources: (1) National Geophysical Data Center (Lander et al., 1993); (2) Intermap (2003); and (3) NOAA, 2004).

The accuracy of the inundation line shown on these maps is subject to limitations in the accuracy and completeness of available terrain and tsunami source information, and the current understanding of tsunami generation and propagation phenomena. Thus, although an attempt has been made to identify a credible upper bound to inundation at any location along the coastline, it remains possible that actual inundation could be greater in a major tsunami event.

This map does not represent inundation from a single scenario event. It was created by combining inundation results for an ensemble of source events affecting a given region (Table 13-1). For this reason, all of the inundation region in a particular area will not likely be inundated during a single tsunami event.

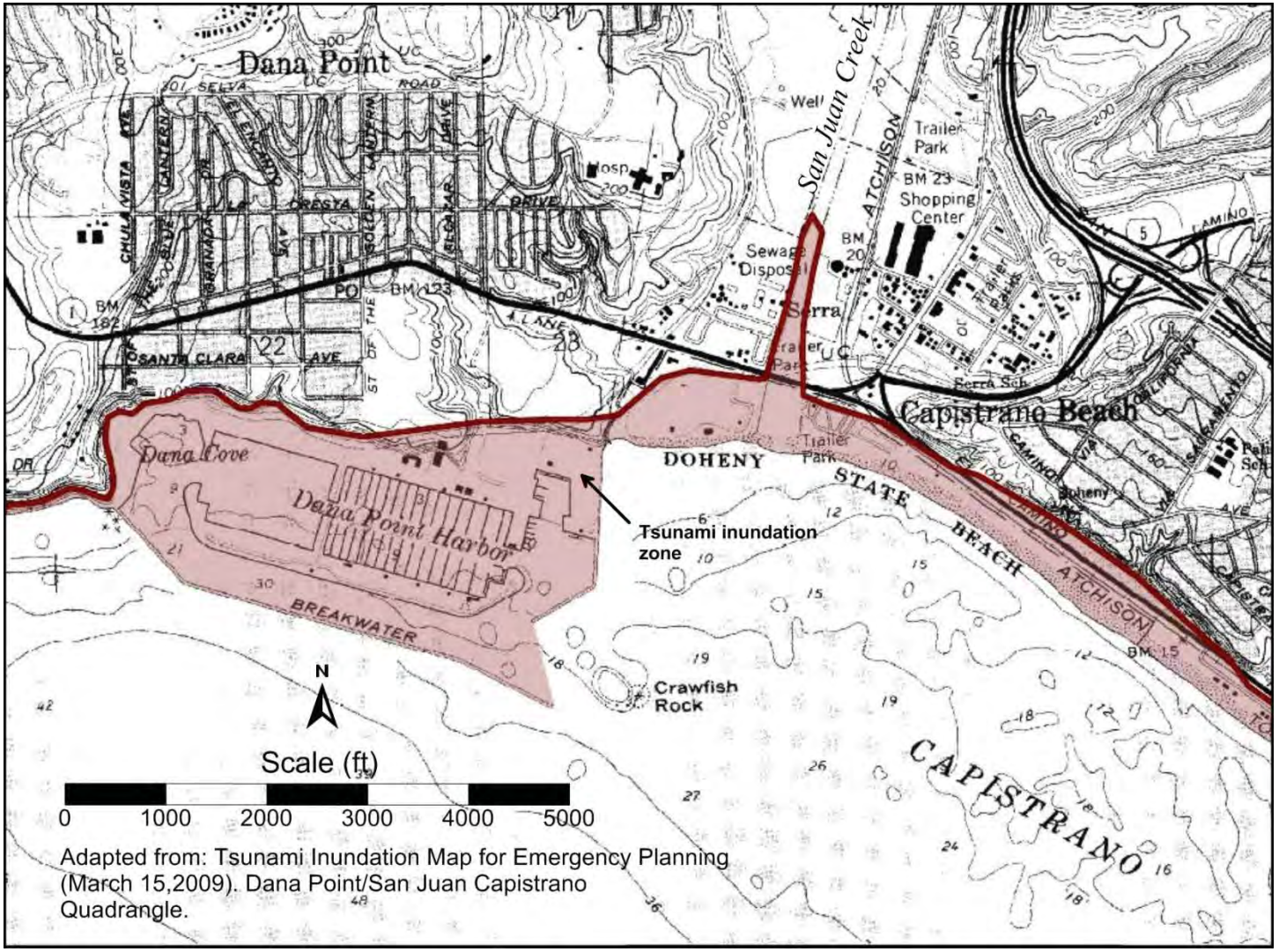


Figure 13-1. Tsunami inundation map at Doheny Beach (prepared by the University of Southern California).

Table 13-1. Tsunami sources modeled for the Orange County coastline.

Sources (M = moment magnitude used in modeled event)		Areas of Inundation Map Coverage and Sources Used
		Dana Point
Local Sources	Catalina Fault	X
	Channel Island Thrust Fault	X
	Newport-Inglewood Fault	X
	San Mateo Thrust Fault	X
	Palos Verdes Submarine Landslide #1	
	Palos Verdes Submarine Landslide #2	
Distant Sources	Cascadia Subduction Zone #3 (M9.2)	X
	Central Aleutians Subduction Zone #1 (M8.9)	X
	Central Aleutians Subduction Zone #2 (M8.9)	X
	Central Aleutians Subduction Zone #3 (M9.2)	X
	Chile North Subduction Zone (M9.4)	X
	1960 Chile Earthquake (M9.3)	X
	1952 Kamchatka Earthquake (M9.0)	X
	1964 Alaska Earthquake (M9.2)	X
	Japan Subduction Zone #2 (M8.8)	X
	Kuri Islands Subduction Zone #2 (M8.8)	X
	Kuri Islands Subduction Zone #3 (M8.8)	X
	Kuri Islands Subduction Zone #4 (M8.8)	X

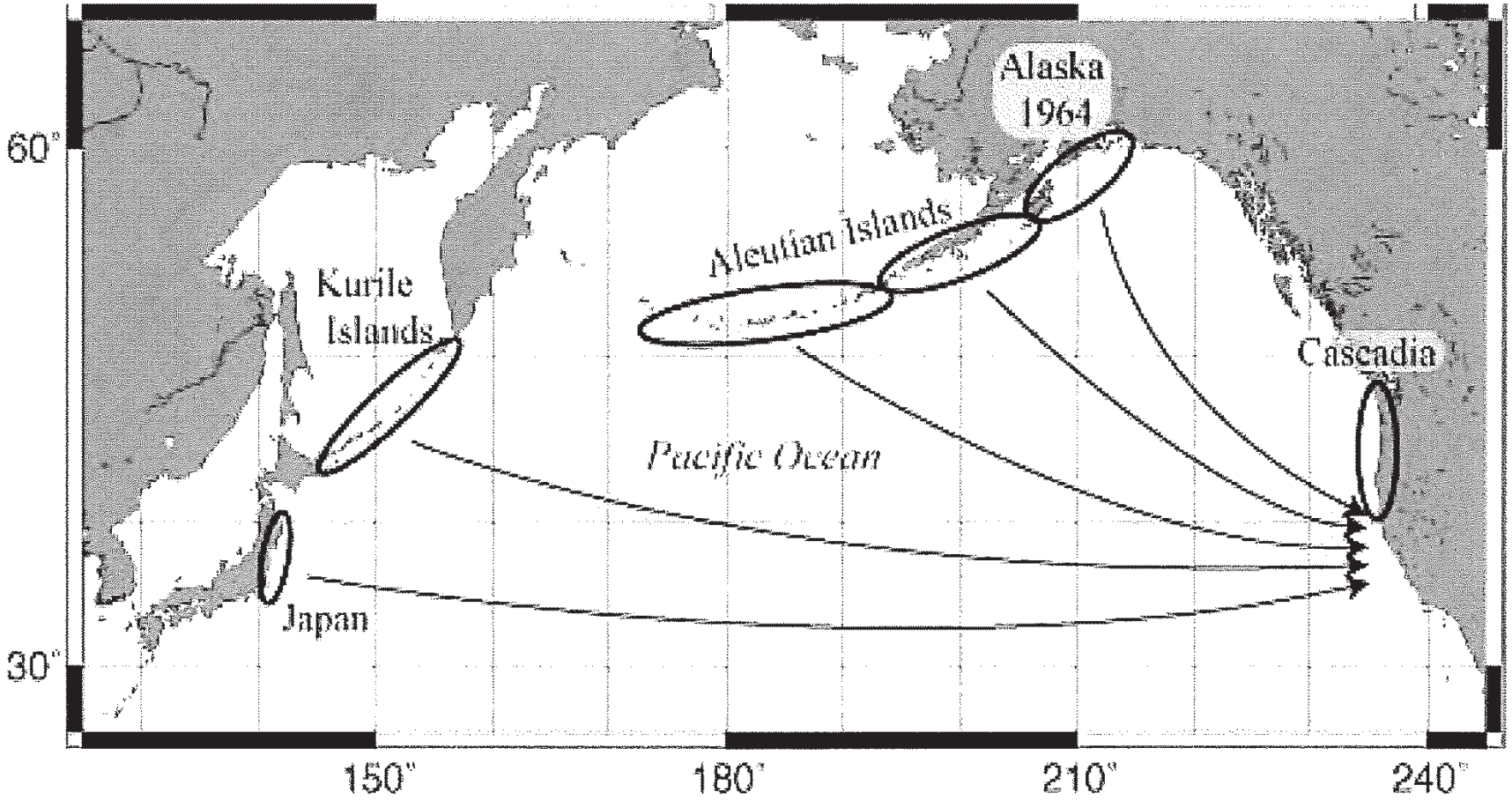


Figure 13-2. Source regions in the north Pacific for far-field tsunamis propagating into Northern California (from Borrero et al., 2006).

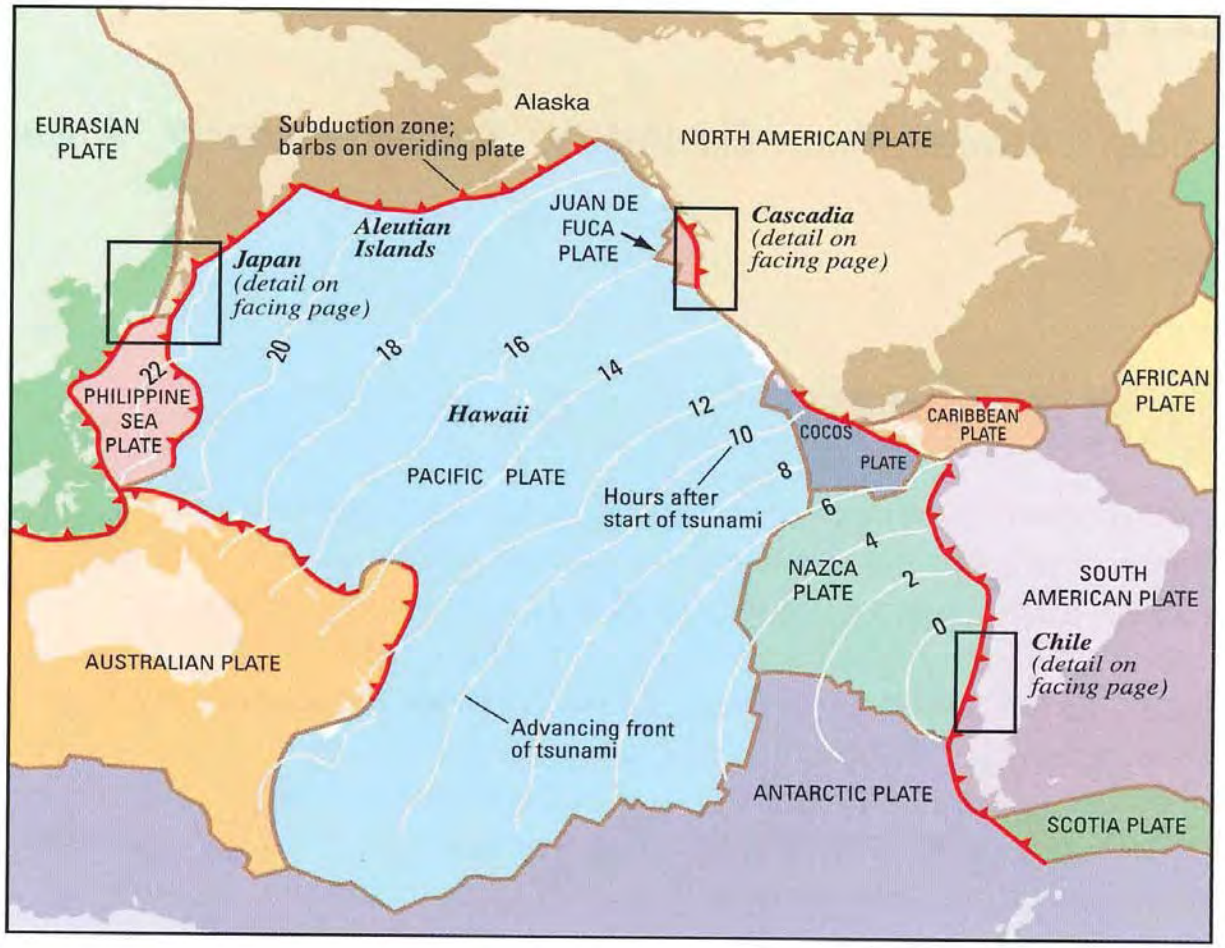


Figure 13-3. Map showing the Pacific Plate and subduction zones (red line) in the Pacific Ocean region (from USGS, 1999).

The map also does not give the height of the tsunamis at Doheny State Beach. In this study we used data from observed tsunami runup for the region from Huntington Beach (North) to the Mexican border (South) from 1812 and 2007 to quantify the height of tsunami run-up at Doheny Beach. The data were obtained from the National Geophysical Data Center (NGDC) at www.ngdc.noaa.gov. From these data set we excluded runup values less than 1.6 ft.

Table 13-2 provides the observed runup at Dana Point Harbor, Carlsbad, Encinitas and La Jolla. The maximum observed runup was 3.3 ft. This value is from Dana Point Harbor. Harbors and bays magnify the height of tsunami waves; therefore this is conservative estimate of runup for tsunamis that occur from a far distance. Local sources, which are rare, can produce higher tsunamis than presented in this report.

Table 13-2. A history of the location of tsunami occurrences, runup, date, distance from source, source location, and earthquake magnitude for tsunamis in Southern California.

Location	Runup (ft)	Date	Distance From Source (KM)	Source Location	Earthquake Magnitude
Dana Point Harbor	2.3	27Feb2010	9031	Off southern coast of Chile	8.8
Dana Point Harbor	2.0	11Mar2011	8539	Honshu Island, Japan	9.0
Carlsbad	2.0	11Mar2011	8587	Honshu Island, Japan	9.0
Encinitas	3.3	11Mar2011	8598	Honshu Island, Japan	9.0
La Jolla	1.7	22May1960	9175	Central Chile	9.5
La Jolla	2.0	27Feb2010	8953	Off southern coast of Chile	8.8
La Jolla	3	11Mar2011	8612	Honshu Island, Japan	9.0

14.0 SUMMARY AND CONCLUSIONS

This report describes the oceanographic conditions, coastal processes, and creek hydraulics/hydrology associated with the Doheny State Beach area. The study addresses the risks associated with constructing a new desalination plant at the back of the beach either west or east of the San Juan Creek.

West Doheny State Beach is bordered by Dana Point Harbor on the west and by the Thor's Hammer jetty (designed to prevent flooding from San Juan Creek) on the east. Both the harbor and the jetty have played major roles in the stability of the west beach, as discussed in Chapter 4. The average beach width prior to breakwater construction, which began in 1966 and was finished by 1968, was 186 ft (based on three aerial photographs). The average beach width after harbor construction was 418 ft (based on 33 aerial photos).

The beach undergoes cycles of erosion and accretion due to the "natural" supply of sand from San Juan Creek. The beach is now near its minimum width, since the last flood was in the winter of 1997-1998. San Juan Creek delivers, on average, 50,000 yd^3 of sand per year. The sediment budget for the reach of the coast between San Mateo and Dana Point shows that during dry periods, there is a deficit of -56,000 yd^3 (erosion), and during wet periods, a credit of 3,000 yd^3 (accretion). Since Doheny State Beach is located at the end of the littoral cell and is protected from north-northwest waves, the shoreline is likely to lose a small amount of sand during dry periods and to accrete sand during wet periods. Although the west beach width on Doheny State Beach fluctuates, it maintains a minimum width greater than 300 ft. The east beach appears to be more responsive to floods, becoming wide after a flood and consequently eroding until the next flood.

Doheny State Beach is a south-facing beach; therefore it is exposed to waves from south swells and tropical storms during the summer season. These waves have a mean direction of 215^o at a 33-ft water depth. Their heights range from 4-8 ft, with an average height of 6 ft. Doheny State Beach is relatively sheltered from waves approaching from the northwest, and thus from large winter wave swells, although local seas can still generate high waves.

Design wave characteristics for typical 5-year, 10-year, 25-year, 50-year, and 100-year storm waves were determined at a 36-ft water depth (Chapter 8). PWA hindcasts at deepwater for the Coast of California Storm and Tidal Waves Study, San Diego Region (USACOE, 1984), were used as the source of deepwater wave information. In addition, a hindcast of the 17-18 January 1988 "Storm of the Century" (O'Reilly, 1989), which occurred after the publication of the PWA hindcasts, was added to the PWA list of storms. Numerical wave modeling (using the spectral-refraction model) was used to transfer the measured wave data to 36 ft at Doheny State Beach. The data were ranked and fitted to a Weibull (Type III) distribution to estimate the extreme wave heights and return periods.

Data from the tide gauge at Scripps Pier in La Jolla, California, were used to estimate water level design parameters in the study area. The design water level values used in this study were 3.3 ft and 5.2 ft, NGVD. The 5.2-ft water level corresponds to a 100-year return period,

whereas the 3.3-ft level corresponds to a water level that is exceeded only five percent of the time. If large waves were to occur during times of elevated water levels, such as spring tides, they could cause damage to properties in the vicinity of the beach. However, there is low probability that large waves will occur during high tides (Figure 6-3).

Doheny State Beach is a south facing beach with steep beach foreshore slope (β=0.15). In the summer season, the beach is subject to southern swells which are characterized by long wave periods (16-24 seconds). These southern swells can cause frequent wave runup and overtopping.

As seen in Chapter 9, projected SLR varied from study to study. This is mainly due to uncertainties in the estimation values for some of the model parameters used in the emission models, specifically ice cap melting. Additionally, the overall short time period since SLR models have been developed does not allow for a long data set to be utilized in model calibrations, indicating that not enough time has passed to test these models' predictions. That being said, the projected SLR utilized for this study for the next 50 years was 1.5 ft (45 cm), and for the next 100 years, 4.6 ft (140 cm). The projections utilized were the higher end estimates from Cayan et al. (2012), which represent locally derived projections utilized by many California state agencies. However, in a recently published paper by Houston and Dean (2013), they estimate SLR to be 2.73 ft (82 cm) in 2100.

Bruun's Rule (1962) was used in this study to estimate the changes in beach width and form. Sea level is likely to increase gradually over the next 30-40 years, giving time for the beach profile to adjust with waves and tides. Based on the Bruun's Rule assumptions and limitations, the beach width at Doheny State Beach would retreat by about 55.5-63.4 feet by 2050 and 172.1-196.7 feet by 2100. These values represent the worst-case scenarios, based on the higher-end sea level rise predictions utilized in this study. Due to uncertainties about sea levels in 2050 and 2100, estimates of these beach width values are approximations.

In addition, based on Bruun's Rule, the nearshore profile elevation of the beach would increase by a value equal to the SLR, which will vary by between 0.18 and 1.48 feet by 2050 and 0.59 and 4.59 feet by 2100.

To assess the potential for storm waves to cause coastal flooding, we have conducted a wave runup and overtopping analysis. Flooding and inundation resulting from wave runup and overtopping are dependent upon beach characteristics, including beach width, sand porosity, wave conditions, and ocean water levels. In this study, we have adopted the results of the most recent studies by Stockdon et al. (2006) and Senechal et al. (2011) because they are based on field data and consider the random nature of waves. The results of the runup and overtopping analysis are presented in Table 11-1 and 11-2 for the present (2014), 2050, and 2100. It should be noted that the results for the wave runup and overtopping do not change with SLR since, according to the Brunn's Rule (Figure 10-1), the beach form will increase at the same rate as SLR.

The results of the wave runup and overtopping analysis are presented in Tables 11-1 and 11-2. They show that there would be no significant wave runup or overtopping with 2- or 5-year return period design waves. Ten-year or greater return period conditions could cause some level

of concern. However, no significant damages can be expected to occur near the project area if the beach retains its minimum width of > 300 ft.

The carrying capacity of the channel at the mouth of San Juan Creek was computed (Chapter 12), as well as the channel at its present depth (3 ft, NGVD). It was determined that the creek could carry a flood as large as 33,270 ft^3/sec. If the creek bed was scoured by only one foot, the carrying capacity of the channel would increase to 41,435 ft^3/sec; a value greater than the flow discharge for a 50-year return period flood.

Though tsunami hazards appear to be minimal for far distance earthquakes (according to the USC inundation map and the data from observations of tsunami wave runup on beaches), local offshore earthquakes or landslides may cause more inundation and higher runup than indicated in this study.

15.0 REFERENCES

Borrero, J. C., Dengler, L., Uslu, B., and Synolakis, C. E. (2006a). Numerical modeling of tsunami effects at marine oil terminals in San Francisco Bay. Technical report, The California State Land Commission.

Bromirski, P., Miller, A., Flick, R., Auad, G., 2011. Dynamical suppression of sea level rise along the Pacific coast of North America: indications for imminent acceleration. Journal of Geophysical Research, 116.

Bruun, P., 1962. Sea level rise as a cause of shore erosion. *Journal of Waterways and Harbors Division,* ASCE, 88, 117-130.

Bruun, P., 1983. Review of conditions for uses of the Bruun's Rule of erosion. *Coastal Engineering*, 7, 77-89.

Bruun, P., 1988. The Bruun's Rule of erosion by sea-level rise: a discussion on large-scale two- and three-dimensional usages. *Journal of Coastal Research*, 4(4), 627-648.

California Coastal Commission, 2013. Draft Sea-Level Rise Policy Guide -Public Review Draft. 45 Fremont, Suite 2000, San Francisco, CA 94105-2219. 12 pp.

California Department of Parks and Recreation, 2003. Preliminary General Plan and Draft Environmental Impact Report, SCH No. 2003021146. 291 pp. and 5 appendices

Cayan, D.R., Bromirski, P.D., Hayhoe, K., Tyree, M., Dettinger, M., and Flick, R., 2008. Climate change projections of sea level extremes along the California coast. *Climate Change*, 87, S57-S73.

Cayan, D.R., Tyree, M., Dettinger, M., Hidalgo, H., Das, T., Maurer, E., Bromirski, P., Graham, N., Flick, R., 2009. Climate change scenarios and sea level rise estimates for the California 2008 Climate change scenarios assessment, Prepared for the California Climate Change Center, Prepared by Scripps Institution of Oceanography, the U.S. Geological Survey Water Resources Division, Texas Tech University's Department of Geosciences, and the California Department of Boating and Waterways.

Cayan, D.R., Tyree, M., Pierce, D., Das, T., 2012. Climate change and sea level rise scenarios for California vulnerability and adaptation assessment, A White Paper from the California Energy Commission's California Climate Change Center, Prepared for: California Energy Commission, Prepared by: Scripps Institution of Oceanography. http://www.energy.ca.gov/2012publications/CEC-500-2012-008/CEC-500-2012-008.pdf

CDIP, 1992. Coastal Data Information Program, Multi-Year Report, Vol. I, 1975-1991. Scripps Institution of Oceanography, SIO Ref. No. 91-32. 295 pp. and 2 appendices.

Chao, B.F., Wu, Y.H., Li, Y.S., 2008. Impact of artificial reservoir impoundment on global sea level. *Science*, 320 (5873). 212-214.

Church, J.A., P.U. Clark, A. Cazenave, J.M. Gregory, S. Jevrejeva, A. Levermann, M.A. Merrifield, G.A. Milne, R.S. Nerem, P.D. Nunn, A.J. Payne, W.T. Pfeffer, D. Stammer and A.S. Unnikrishnan, 2013: Sea Level Change. *In*: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Coastal Environments. 1999. Coastal and Oceanographic Conditions in the Vicinity of the Proposed Manchester Resort Development: Oceanside, California. Submitted to Manchester Resorts, 1 Market Place, 33rd Floor, San Diego, California and City of Oceanside, 300 N. Coast Highway Oceanside, California, 22 March 1999. 74 pp., 5 appendices.

Coastal Environments, 2002. Coastal Processes and Hydraulic/Hydrology Study for Crystal Cove State Park Historic District, Volume I: Technical Report. Prepared for State of California, Department of Parks and Recreation, on 8 October 2002, CE Ref. No. 02-08. 8 chapters and 5 appendices.

Coastal Environments, 2004. Coastal processes and hydraulic/hydrology studies for Doheny State Beach, Technical Report. Prepared for the State of California Department of Parks and Recreation on 13 December 2014. CE Ref No. 04-14. 12 chapters and 2 appendices.

Coastal Frontiers, Inc. 2014. Personal communication. Doheny State Beach: Beach profiles east of San Juan Creek.

Department of Navigation and Ocean Development (DNOD), 1977. Study of Beach Nourishment Along the Southern California Coast. State of California Resources Agency. 151 pp.

Elwany, M.H.S., 1998. Harbor Precise Plan Amendment and Environmental Impact Report: History, Width, and Stability of Harbor Beach, Oceanside, CA. Submitted to BRG Consulting, Inc., San Diego, CA, by Coastal Environments on 4 May 1998 (revised 9 June 1998), CE Ref. No. 98-07. 24 pp. and 2 appendices.

Elwany, M. H. S., A-L. Lindquist, R. Flick, W. O'Reilly, J. Reitzel, and W. Boyd, 1999. Study of sediment transport conditions in the vicinity of Agua Hedionda Lagoon. Scripps Institution of Oceanography, Center for Coastal Studies, La Jolla, California, 8 January 1999, SIO Ref. No. 00-07. 108 pp. and 3 appendices.

Elwany, M.H.S., R.E. Flick, and M.M. Hamilton, 2003. Effect of Small Southern California Lagoon Entrance on Adjacent Beach. *Estuaries* 26 (3): 700–708.

Environmental Management Agency, 1982. South Coast Planning Unit, Capistrano Beach, Volume 5, Environmental Impact Report, Capistrano Beach Specific Plan/Local Coastal Program, SCH #81070206.

Everts Coastal, 1997. Sedimentation budget analysis: Dana Point to Newport Bay, California. Technical report prepared for U.S. Army Corps of Engineers, Los Angeles District. 67 pp.

Flick, R.E.; Murray, J.F.; and Ewing, L.C., 2003. Trends in United States tidal datum statistics and tide range. *Journal of Waterway, Port, Coastal, and Ocean Engineering* 129.4, 155-164.

Flick, R. and L. Ewing. 2009. Sand volume of southern California beaches as a function of future sea-level rise rates. *Shore and Beach*, 77(4), 36-45.

Goda, Y., 1985. *Random Seas and Design of Maritime Structures*. University of Tokyo Press. 323 pp.

Goda, Y., 1988. On the methodology of selecting design wave height. In *Proceedings of 21st Coastal Engineering Conf., ASCE*, pp. 899-913.

Griswold, G. M., 1964. Surf Forecasting. Navy Weather Research Facility, Norfolk, Virginia, Report No. 36-1264-099.

Hall, J. V., and G. Watts, 1953. Laboratory investigation of the vertical rise of solitary waves on impermeable slopes, TM-33. U.S. Army Corps of Engineers, Beach Erosion Board, Washington, D.C.

Hasselmann, K., et al., 1973. Measurements of wind-wave growth and swell decay during the Joint Sea Wave Project (JONSWAP). *Dsch. Hydrogr. Z.*, 8 (12), Supplement A. 95 pp.

Hedges, T.S. and M.T. Reis, 1998. Random wave overtopping of simple seawalls: a new regression model. Proceedings from the Institution of Civil Engineers: Water, Maritime, and Energy, 130(1), 1-10.

Holland, K.T. and R.A. Holman, 1993. The statistical distribution of swash maxima on natural beaches. *Journal of Geophysical Research*, 98(10), 271-10,278.

Houston, J.R., 2013. Global sea level projections to 2100 using methodology of the Intergovernmental Panel on Climate Change. *Journal of Waterway, Port, Coastal, and Ocean Engineering* (March-April), 129(2), 82-87.

Hu, K., 2000. High-Resolution Finite Volume Methods for Hydraulic Flow Modelling. Manchester, U.K.: Centre for Mathematical Modelling and Flow Analysis, Manchester Metropolitan University, Doctoral thesis. 194 p.

Hunt, I.A., 1959. Design of a seawall and breakwaters. *Journal of the Waterways and Harbours Division*, ASCE, 85, ww3, pp. 123-153.

ICLEI, 2012. Sea level rise adaption study for San Diego Bay. 69 pp, 3 appendices.

Inman, D.L., 1985. Damming of rivers in California leads to beach erosion. In *Oceans 85, Ocean Engineering and the Environment*, Marine Technological Society and IEEE, v. 1, pp. 22-26.

Inman, D.L., P.D. Komar, and A.J. Bowen, 1968. Longshore transport of sand. In *Proceedings of 11th Intl. Conf. on Coastal Engineering*, ASCE, pp.298-306.

Inman, D. L., and J. D. Frautschy, 1965. Littoral processes and the development of shorelines. In *Proceedings of 10th Intl. Conf. Coastal Eng.*, *ASCE,* Santa Barbara, CA, pp. 511-536.

Inman, D.L., and S.A. Jenkins, 1983. Oceanographic Report for Oceanside Beach Facilities. Unpublished report prepared for the City of Oceanside, CA. 206 pp.

Inman, D.L., M.H.S. Elwany, and S.A. Jenkins, 1993. Shore rise and bar-berm profiles on ocean beaches. *Jour. Geophys. Res*., 98 (C10): 18,181-18,199.

Intermap Technologies, Inc., 2003, Intermap product handbook and quick start guide: Intermap NEXTmap document on 5-meter resolution data, 112 p.

IPCC (Intergovernmental Panel on Climate Change), 2007. Fourth Assessment Report (AR4).

Kikkawa, H. H. Shi-igai, and T. Kono, 1968. Fundamental study of wave overtopping on levees, *Coastal Engineering in Japan*, 11, 107-115.

Komar, P.D., and D.L. Inman, 1970. Longshore sediment transport on beaches. Journal of Geophysical Research, 75: 5914-5927.

Lander, J.F., Lockridge, P.A., and Kozuch, M.J., 1993, Tsunamis Affecting the West Coast of the United States 1806-1992: National Geophysical Data Center Key to Geophysical Record Documentation No. 29, NOAA, NESDIS, NGDC, 242 p.

LeMahaute, B., and J.D. Wang, 1982. Wave spectrum changes on a sloped beach. Journal of Waterway, Port, Coastal and Ocean Eng., 108(WWI): 33-47.

Longuet-Higgins, M.S., 1957. On the transformation of a continuous spectrum by refraction. In Proceedings of Cambridge Phil. Soc., 53(1): 226-229.

Longuet-Higgins, M.S., 1970. Longshore currents generated by obliquely incident sea waves. Jour. Geophys. Res., 75 (33): 6778-7689.

Mitsuyasu, H., et al., 1975. Observation of the directional spectrum of ocean waves using a cloverleaf buoy. J. Phys. Oceanography, 5 (4).

National Atmospheric and Oceanic Administration (NOAA), 2004, Interferometric Synthetic Aperture Radar (IfSAR) Digital Elevation Models from GeoSAR platform (EarthData): 3-meter resolution data.

NRC (National Research Council), 2012. Sea level rise for the coasts of California, Oregon, and Washington: past, present, and future, National Academic Press, ISBN: 978-0-309-25594-3, 201 pp.

O'Reilly, W. C., 1989. Modeling the storm waves of January 17-18, 1988. Shore and Beach, 57 (4).

O'Reilly, W.C., and R. T. Guza, 1991. Comparison of spectral refraction and refraction-diffraction wave models. Jour. Waterway, Port, Coastal and Ocean Eng., 117 (3): 199-215.

Owen, M.W. 1980. Design of seawalls allowing for wave overtopping. Technical Report EX-924. HR-Wallingford, UK.

Parris, A., P. Bromirski, V. Burkett, D. Cayan, M. Culver, J. Hall, R. Horton, K. Knuuti, R. Moss, J. Obeysekera, A. Sallenger, and J. Weiss. 2012. Global Sea Level Rise Scenarios for the US National Climate Assessment. NOAA Tech Memo OAR CPO-1. 37 pp.

Pawka, S. S., 1982. Wave directional characteristics on a partially sheltered coast. Ph.D. dissertation, University of California, San Diego. 246 pp.

Pawka, S. S., 1983. Island shadows in wave directional spectra. Jour. Geophys. Res., 88(C4): 2579-2591.

Pilkey, O.H. and T. W. Davis (1987). An analysis of coastal recession models—North Carolina coast, in D. Nummedal, D., Pilkey, O.H., and Howard, J.D., eds., Sea-level fluctuation and coastal evolution: Tulsa, Okla., Society of Economic Paleontologists and Mineralogists, pp. 59–68.

Raubenheimer, B., R. T. Guza, S. Elgar, and N. Kobayashi, 1995. Swash on a gently sloping beach. Journal of Geophysical Research, 100(C5): 8751-8760.

Reis, MT. K. Hu, T.S. Hedges, H. Mase, 2008. Comparison of empirical, semi-empirical, and numerical wave overtopping models. *Journal of Coastal Research*, 24, 250-262.

Reitzel, J., et al., 1987. Summaries of Data, Physical and Chemical Oceanography Program at San Onofre Nuclear Generating Station (SONGS). Marine Review Committee, Department of Biological Sciences, University of California, Santa Barbara.

Revelle, R., 1983. Probable future changes in sea level resulting from increased atmospheric carbon dioxide. In Changing Climate: Report of the Carbon Dioxide Assessment Committee, pp. 433-488. Washington, DC: National Research Council.

Rahmstorf, S, 2007. A semi-empirical approach to projecting future sea level rise. *Science*, 315(5810), 368-370.

Rosen, P.S., 1978. A regional test of the Bruun Rule on shoreline erosion. *Marine Geology,* 26, M7-M16.

Ruggiero, P. R. Holman, R. Beach, 2004. Wave run-up on a high-energy dissipative beach. *Journal of Geophysical Research*, 109(C06025).

Schwartz, M.L., 1965. Laboratory study of sea-level as a cause of shore erosion. *Journal of Geology*, 73, 528-534.

Schwartz, M.L., 1967. The Bruun theory of sea-level rise as a cause of shore erosion. *Journal of Geology*, 75, 76-92.

Schwartz, M.L., 1987. The Bruun Rule – twenty years later. *Journal of Coastal Research*, 3, ii-iv.

Senechal, N., G. Coco, K. R. Bryan, and R. A. Holman, 2011. Wave runup during extreme storm conditions. Journal. of Geophysical. Research,, v. 116. 1-13.

Seymour, R.J., and A.L. Higgins, 1978. Continuous estimation of longshore sand transport. In Coastal Zone '78, San Francisco, California, March 14-16, 1978, pp. 2308-2318.

Shaw, M. J., 1980. Sediment Management for Southern California Mountains, Coastal Plains, and Shoreline, Part F: Artificial Sediment Transport and Structures in Coastal Southern California. Scripps Institution of Oceanography, SIO Ref. No. 80-41, December 1980. 109 pp.

Simons, Li & Associates, Inc., 1984. San Juan Creek and Trabuco Creek, Facility Nos. L01 and L02, Aggradation/Degradation Study. Prepared for Orange County Environmental Management Agency, Santa Ana, August, 1984.

Stockdon, H. F., R. A. Holman, P.A. Howard, and A. H. Sallenger Jr., 2006. Empirical parameterization of setup, swash and runup. Coast. Eng. 573-588.

Tebaldi, C., B.H. Strauss, and C.E. Zervas, 2012. Modelling sea level rise impacts on storm surges along US coasts, *Environmental Research Letters*, 7, doi:10.1088/1748-9326/7/01432.

Titov, V.V., and Gonzalez, F.I., 1997, Implementation and Testing of the Method of Tsunami Splitting (MOST): NOAA Technical Memorandum ERL PMEL –112, 11 p.

Titov, V.V., and Synolakis, C.E., 1998, Numerical modeling of tidal wave runup: *Journal of Waterways, Port, Coastal and Ocean Engineering*, ASCE, 124 (4), pp 157-171.

U.S. Geological Survey, 1993, Digital Elevation Models: National Mapping Program, Technical Instructions, Data Users Guide 5, 48

U.S. Army Corps of Engineers, 1970. Flood Plain Information, San Juan Creek, November.

U.S. Army Corps of Engineers, 1984. Shore Protection Manual. Waterways Experiment Station, Coastal Engineering Research Center. 2 vols.

U.S. Army Corps of Engineers, 1986. Southern California coastal processes data summary. CCSTWS 86-1, Corps of Engineers, Los Angeles District, Los Angeles, CA. 572 pp.

U.S. Army Corps of Engineers, 1987. Oceanside Littoral Cell Preliminary Sediment Budget Report: Coast of California Storm and Tidal Waves Study, CCSTWS 87-4. Prepared by Tekmarine, Inc., for the Corps of Engineers, Los Angeles District.

U.S. Army Corps of Engineers, 1988. Historic wave and sea level data report: San Diego region. Ref. No. CCSTWS 88-6.

U.S. Army Corps of Engineers, 1991. State of the coast report, San Diego region: Main report. Coast of California Storm and Tidal Waves Study (CCSTWS), Vol. 1. U.S. Army Corps of Engineers, Los Angeles District, Los Angeles, CA.

U.S. Army Corps of Engineers, 1996. Draft San Juan Creek and Aliso Creek Watershed Management Study, Orange County, California. 234 pp. and appendices. [Available at http://www.ceres.ca.gov/wetlands].

U.S. Army Corps of Engineers, 1997. Gatwood, Elden. Personal communication to California Resources Agency. [Available at http://www.ceres.gov/wetlands

U.S. Army Corps of Engineers, 2002. San Juan Creek Watershed Management Study, Orange County, California, Feasibility Phase, F-5 Report. U.S. Army Corps of Engineers, Los Angeles District, August 2002. 291 pp. + 5 appendices. [Available at http://www.ocwatersheds.com]

US Army Corps of Engineers, 2011. Sea level change considerations for civil works programs. Circular No. 1165-212.

Van der Meer, J.W. and W. Janssen, 1995. Wave run-up and wave overtopping at dikes. In: Kabayashi, Demirbilek (Eds.), Wave Forces on Inclined and Vertical Wall Structures. American Society of Civil Engineers, New York: ASCE, 1-27.

Vermeer, M and S Rahmstorf, 2009. Global sea level linked to global temperature. *PNAS*, 106 (51): 21527–21532.

Wiegel, R. L., 1994. Ocean beach nourishment on the USA Pacific coast. Shore and Beach, 62(1): 11-36.

Wyland, R. M., and E. B. Thornton, 1991. Extremal Wave Statistics Using Three Hindcasts. Jour. Waterway, Port, Coastal, and Ocean Eng., 117 (1): 60-74.

Zampol, J., R. Flick, and H. Elwany, 1997. Sand Supply to Beaches in San Diego County. Report submitted to Frederic R. Harris, Inc., in May 1997. 10 pp.

APPENDIX A

PHOTOGRAPHS OF DOHENY STATE BEACH



Photo A-1. Photo taken in September 2004 looking west from San Juan Creek toward Doheny Beach.



Photo A-2. Photo taken in September 2004 showing current condition of Thor's Hammer jetty.



Photo A-3. Photo taken in September 2004 showing the west bank of San Juan Creek. Notice the bike path.



Photo A-4. Photo taken in September 2004 showing the bike path. Notice the wall and sand bags to protect the area from flooding.



Photo A-5. Aerial photo of Doheny State Beach showing waves approaching the beach.



Photo A-6. Aerial photo of Doheny State Beach area, including Dana Point Harbor, showing offshore rocky formation.



Photo A-7. Photo taken in September 2004 showing the San Juan Creek entrance open. Notice the birds on the beach.



Photo A-8. Photo taken in September 2004 showing the San Juan Creek entrance open. Notice the birds on the beach.



Photo A-9. Historical photo of Doheny State Beach in 1946. Note abundance of rocks on beach. [Source: dohenystatebeach.org]





Photo A-10. Photos of Thor's Hammer jetty. Left photo shows its condition in 1966 (courtesy of www.park.ca.gov), and right photo shows its present condition (September 2004).

APPENDIX B

AERIAL PHOTOGRAPHS OF DOHENY STATE BEACH PRE-HARBOR CONSTRUCTION WITH BLACK OVERLAY REPRESENTING 3 APRIL 1990 SHORELINE

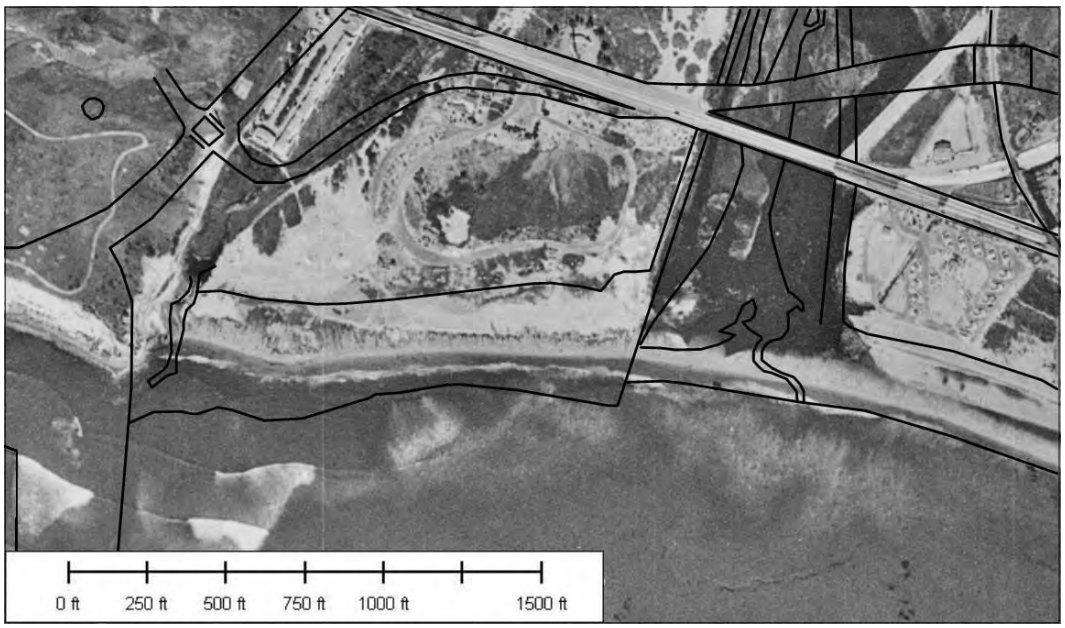


Photo B-1. Photo taken on 1 October 1939.

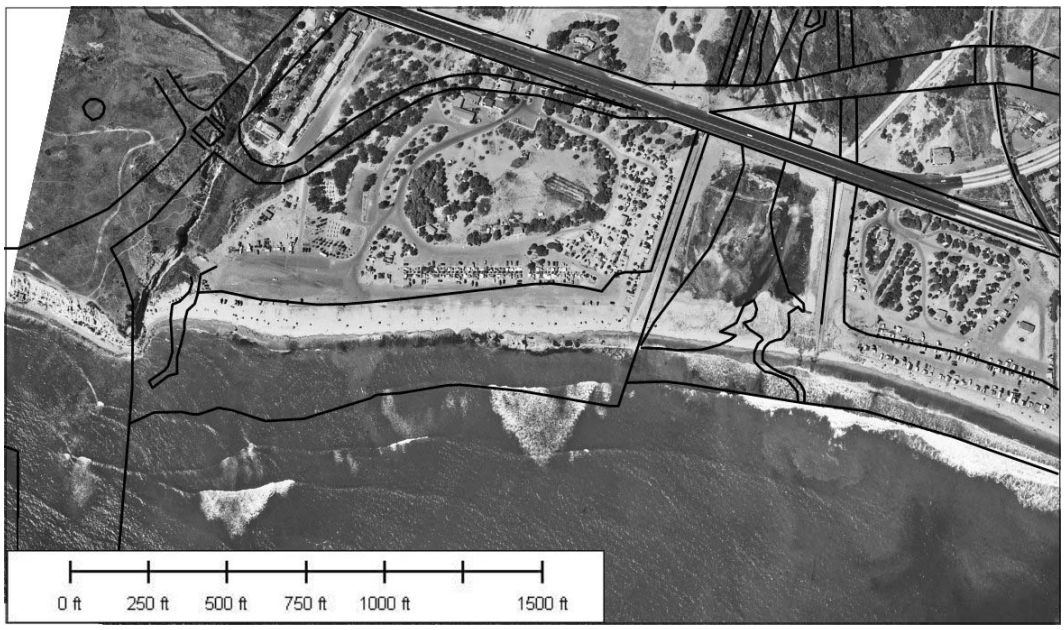


Photo B-2. Photo taken on 1 August 1947.

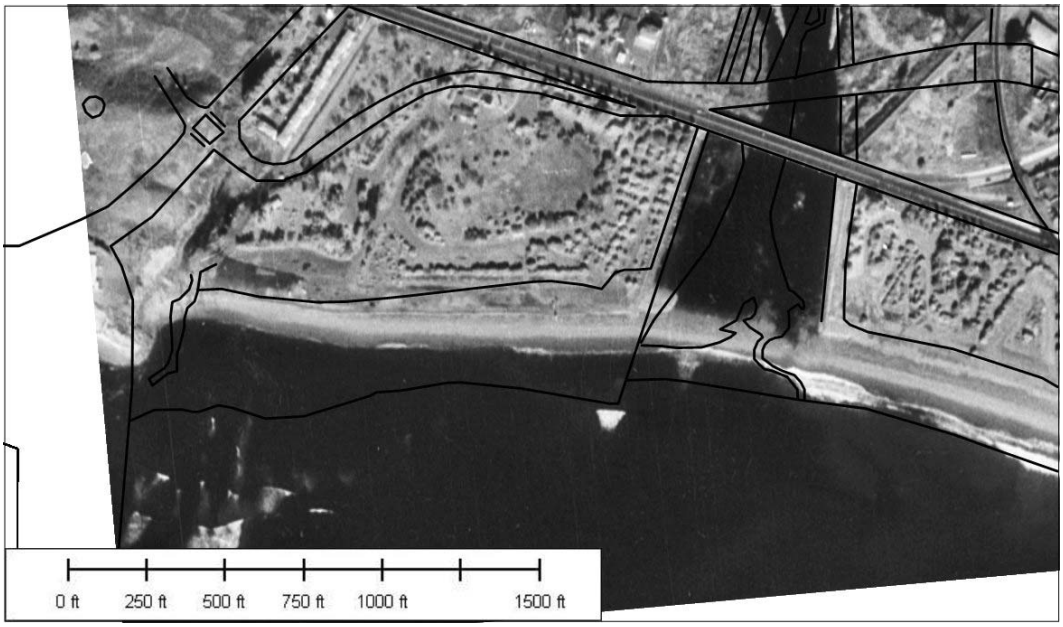


Photo B-3. Photo taken on 8 January 1958.



Photo B-4. Photo taken on 29 November 1962.

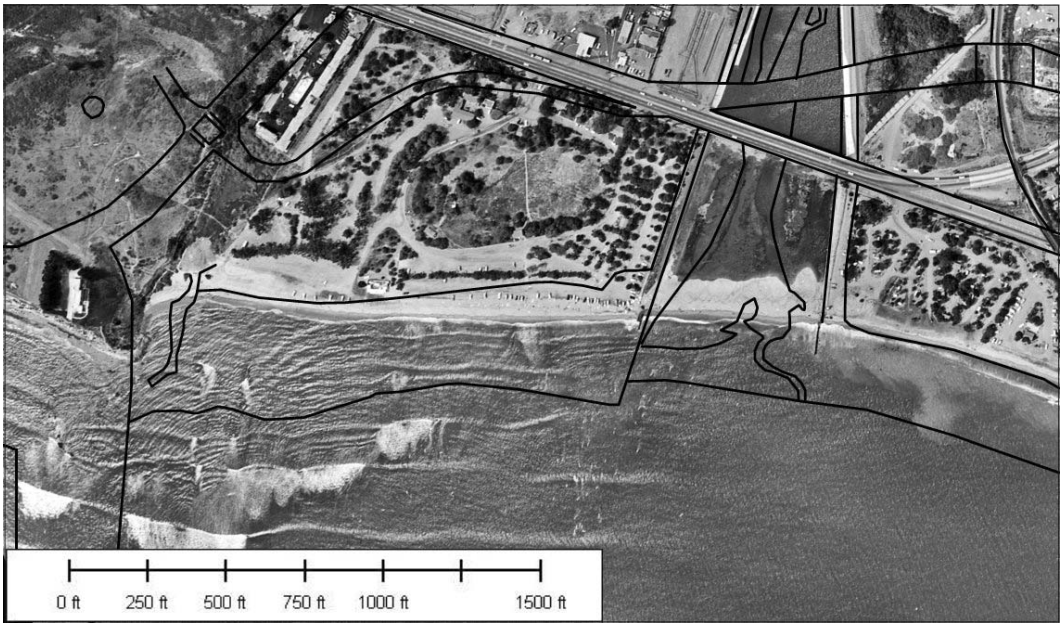


Photo B-5. Photo taken on 12 June 1963.

APPENDIX C

AERIAL PHOTOGRAPHS OF DOHENY STATE BEACH POST-HARBOR CONSTRUCTION WITH BLACK OVERLAY REPRESENTING 3 APRIL 1990 SHORELINE

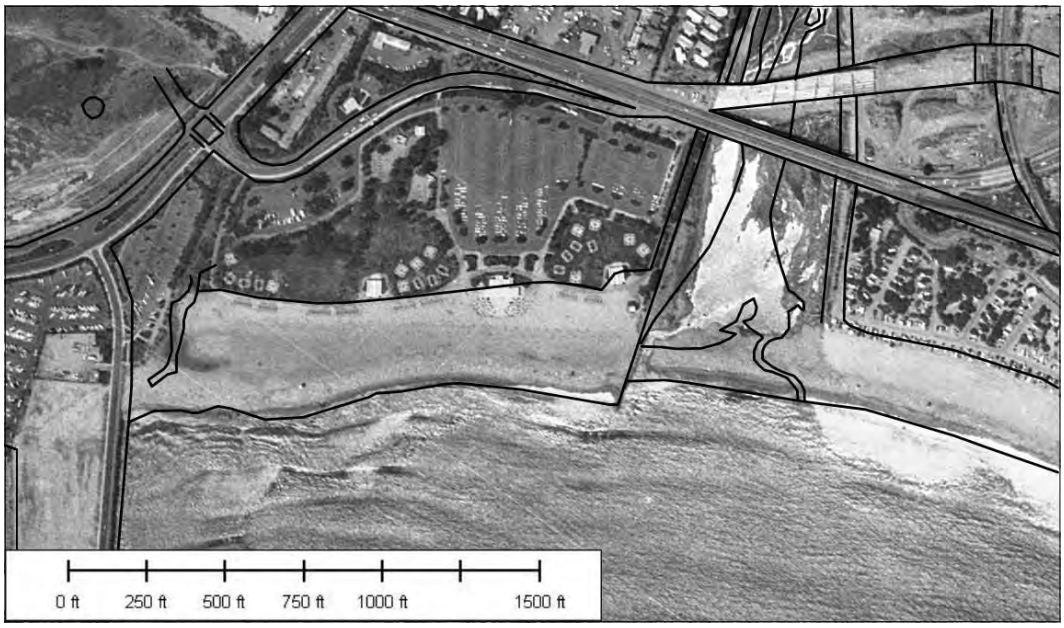


Photo C-1. Photo taken on 1 July 1975.

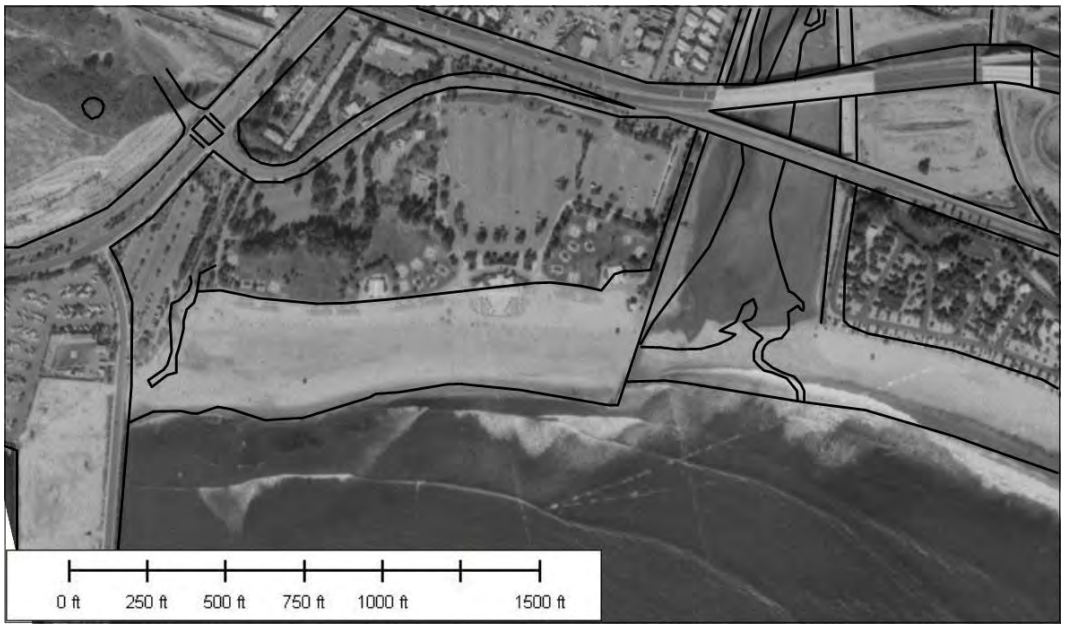


Photo C-2. Photo taken on 1 February 1977.

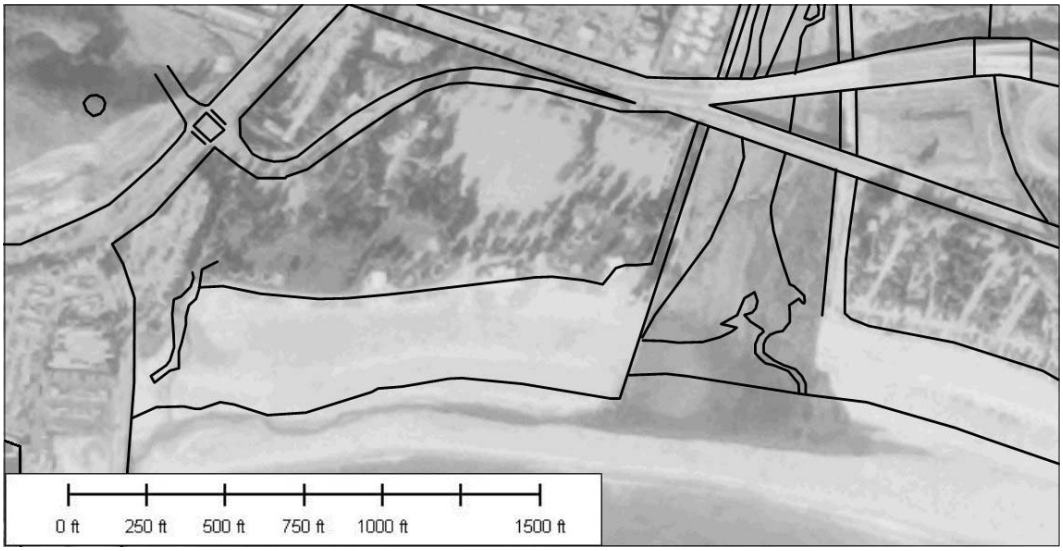


Photo C-3. Photo taken on 30 December 1980.

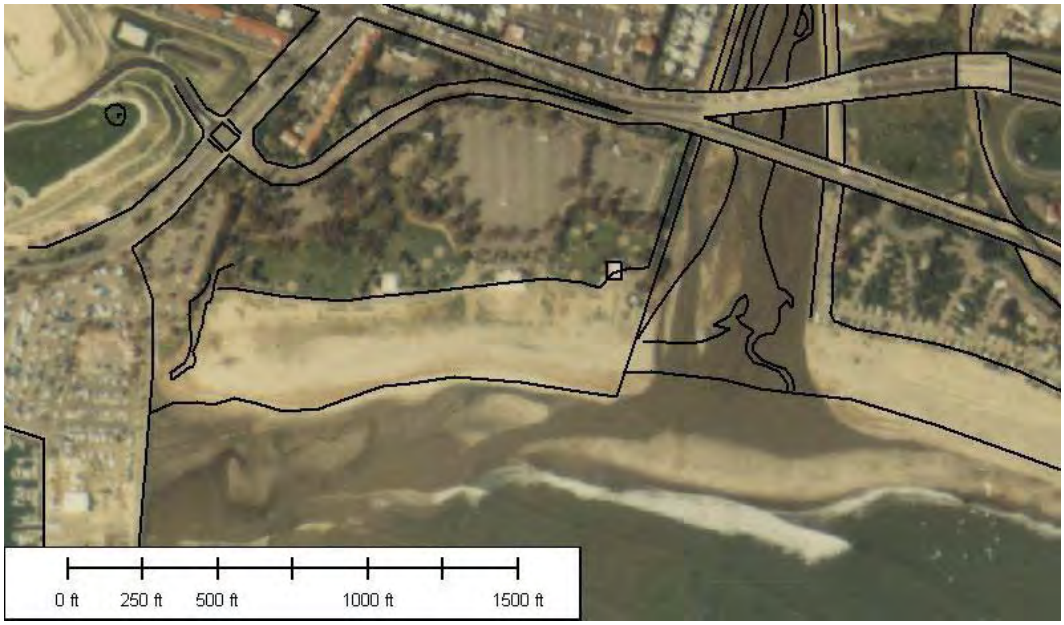


Photo C-4. Photo taken on 9 March 1983.

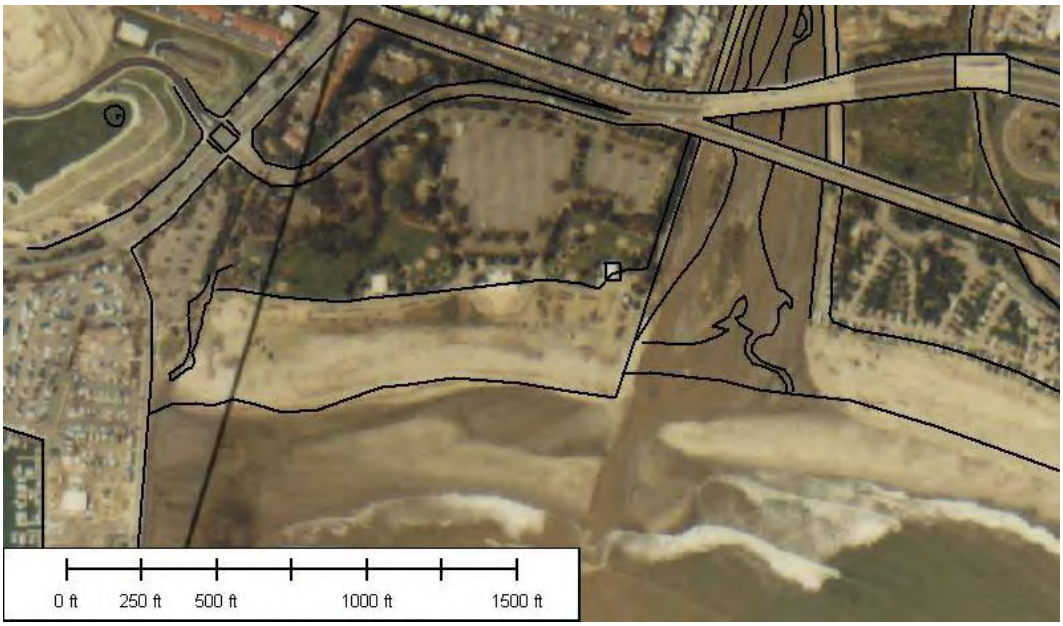


Photo C-5. Photo taken on 25 March 1983.

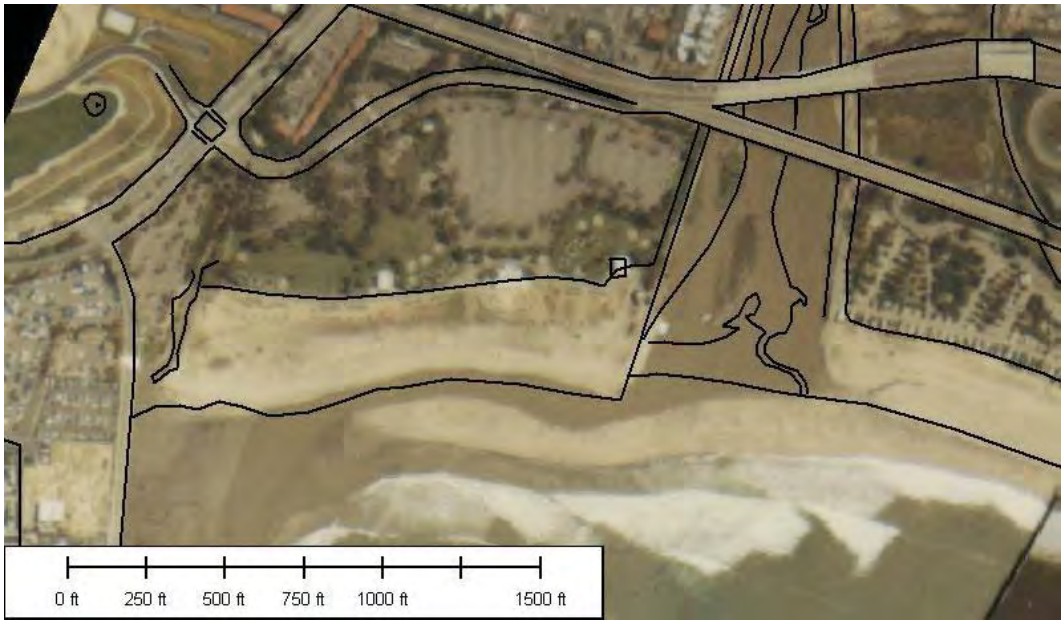


Photo C-6. Photo taken on 3 May 1983.

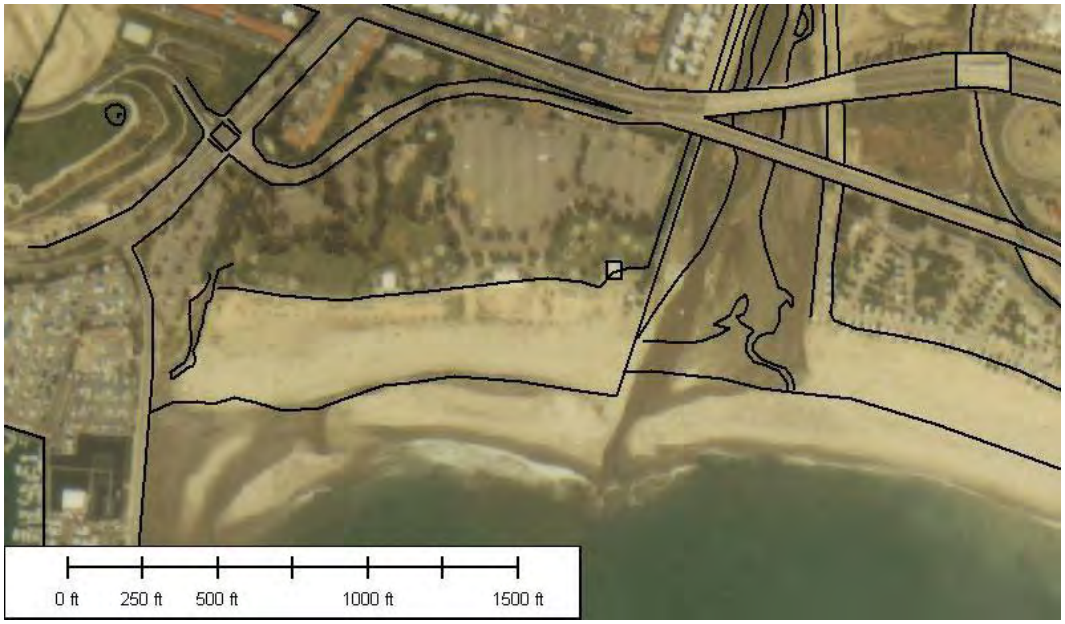


Photo C-7. Photo taken on 17 May 1983.

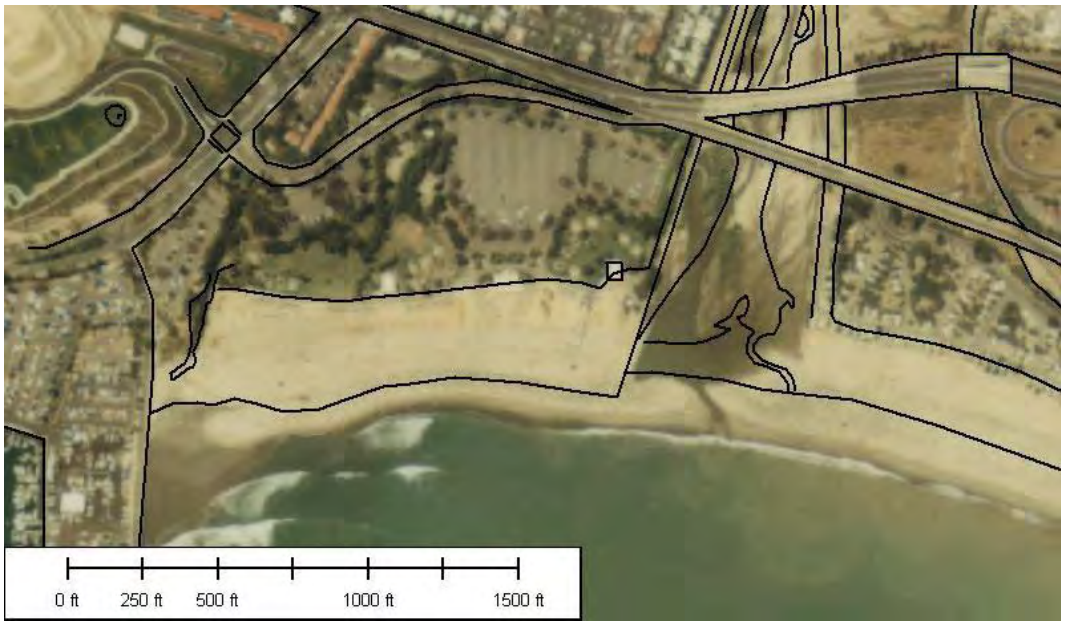


Photo C-8. Photo taken on 28 July 1983.

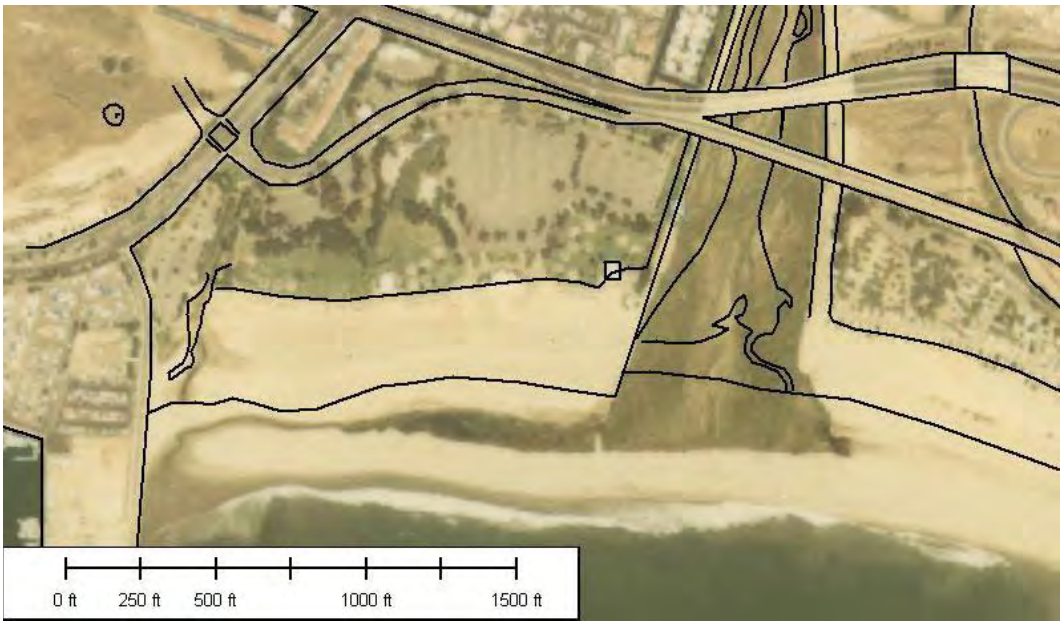


Photo C-9. Photo taken on 18 September 1983.



Photo C-10. Photo taken on 6 October 1983.



Photo C-11. Photo taken on 2 November 1983.



Photo C-12. Photo taken on 11 November 1983.



Photo C-13. Photo taken on 6 December 1983.



Photo C-14. Photo taken on 13 January 1986.



Photo C-15. Photo taken on 3 April 1990.



Photo C-16. Photo taken on 2 December 1991.

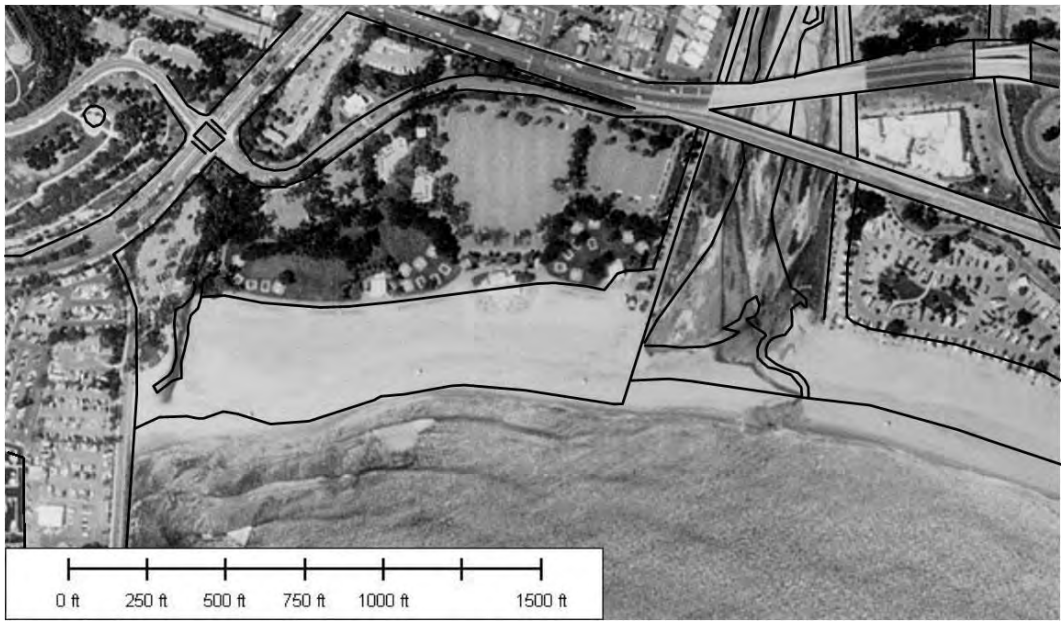


Photo C-17. Photo taken on 1 June 1994.



Photo C-18. Photo taken on 1 November 1997.



Photo C-19. Photo taken on 15 April 2001.

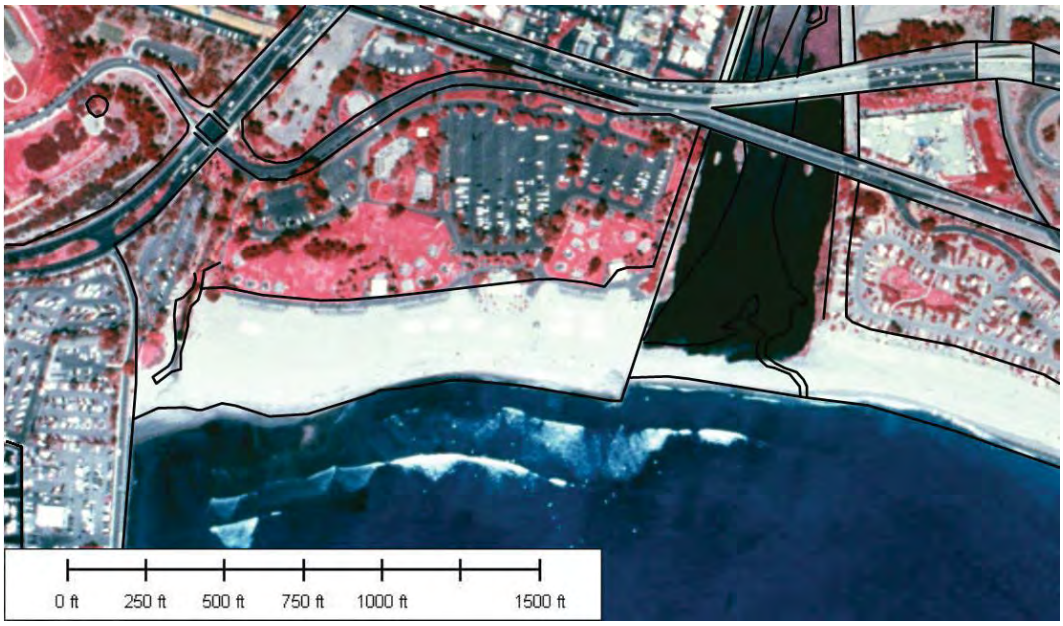


Photo C-20. Photo taken on 15 June 2002.



Photo C-21. Photo taken on 21 January 2004.



Photo C-22. Photo taken on 7 September 2004.



Photo C-23. Photo taken on 7 June 2005.



Photo C-24. Photo taken on 1 March 2007.



Photo C-25. Photo taken on 22 June 2009.



Photo C-26. Photo taken on 28 March 2010.



Photo C-27. Photo taken on 1 May 2010.



Photo C-28. Photo taken on 18 January 2011.



Photo C-29. Photo taken on 19 May 2012.