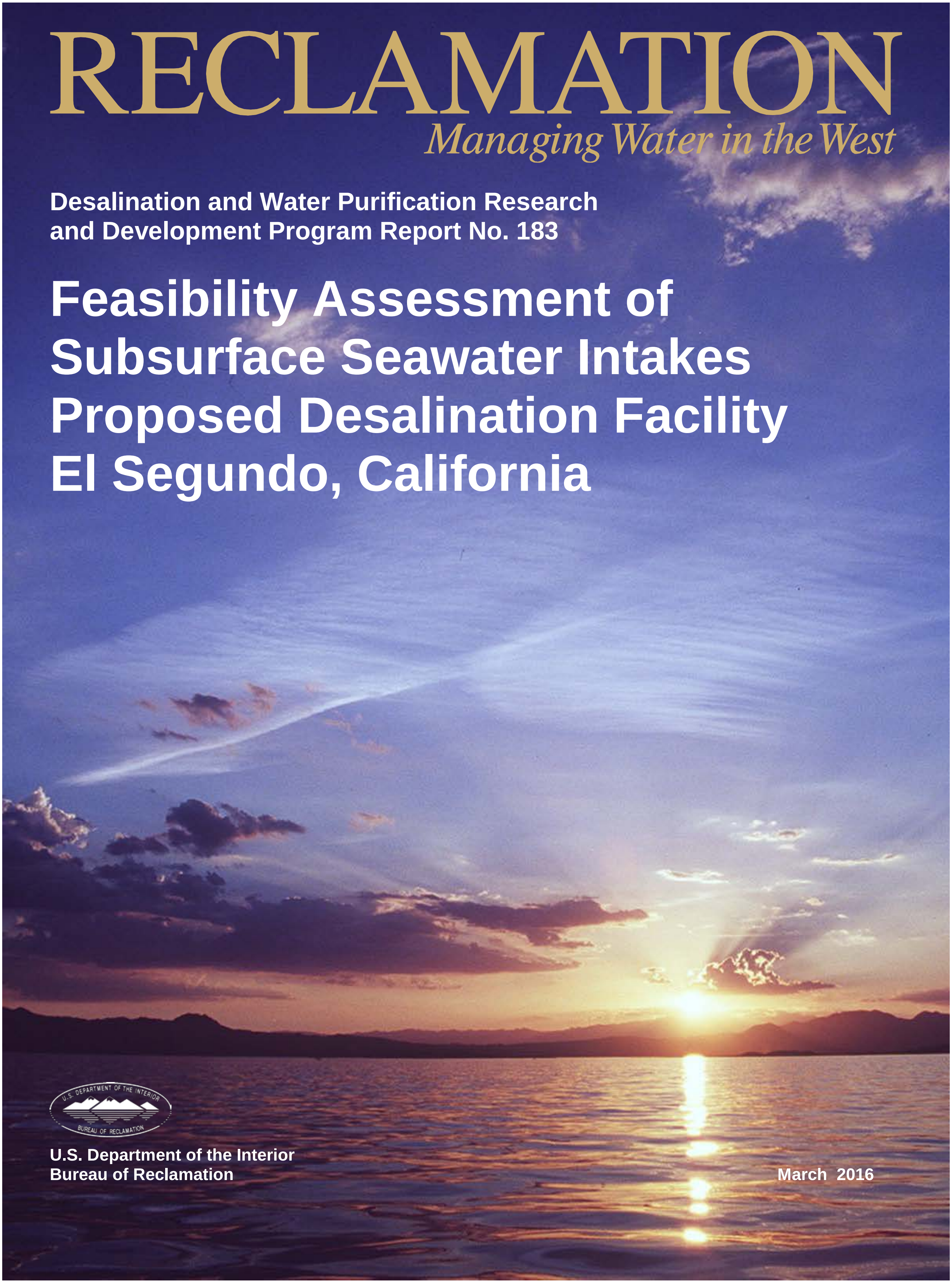

RECLAMATION

Managing Water in the West

Desalination and Water Purification Research and Development Program Report No. 183

Feasibility Assessment of Subsurface Seawater Intakes Proposed Desalination Facility El Segundo, California

U.S. Department of the Interior
Bureau of Reclamation

March 2016

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14. ABSTRACT

Feasibility of subsurface seawater intakes (SSIs) was assessed for a proposed desalination facility at El Segundo, California. The minimum design production capacity is 20 million gallons per day (MGD) of potable water, which requires a seawater intake rate of 40 MGD. The assessment included literature review, the development and application of a computer-based general guidance tool for evaluating technical feasibility of SSIs, review of the site-specific hydrogeology of the coastal margin setting at El Segundo based on existing data and additional field investigations, and groundwater flow modeling of SSIs. Seven SSI technologies were evaluated based on hydrogeologic, oceanographic, geochemical and water quality constraints, land use and sensitive habitat, maintenance and other technical and economic risk factors. The analysis determined that none of the SSI technologies are feasible for the required intake rate of 40 MGD at the proposed project location as a result of technical, social, environmental, and economic factors.

15. SUBJECT TERMS

Ocean desalination, subsurface seawater intakes, hydrogeology, feasibility assessment

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Bureau of Reclamation
Technical Service Center
Civil Engineering Services
Water Treatment Group
Denver, Colorado **March 2016**

Desalination and Water Purification Research and Development Program Report No. 183

Feasibility Assessment of Subsurface Seawater Intakes
Proposed Desalination Facility
El Segundo California

Prepared for Reclamation under Agreement No. 5-FC-81-1158

by

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consultants

engineers | scientists | innovators
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Project Number: LA0324

for

West Basin Municipal Water District

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Civil Engineering Services
Water Treatment Group
Denver, Colorado

March 2016

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Disclaimer

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This feasibility assessment was made possible by the cost sharing provided by the United States Department of the Interior, Bureau of Reclamation, Desalination and Water Purification Research and Development Program with funding provided through West Basin Municipal Water District.

Geosyntec Consultants, Inc. was responsible for developing the subsurface seawater intake feasibility screening tool.

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Finally, special appreciation goes to Project Manager Ms. Diane Gatza, Mr. Eric Owens and Mr. Justin Pickard from the West Basin Municipal Water District, and to the Board of Directors of the West Basin Municipal Water District for their stewardship and leadership in supporting this project.

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Glossary

BIG	beach infiltration galleries
CEQA	California Environmental Quality Act
CO-CAT	Coastal and Ocean Working Group of the California Climate Action Team
CPT	Cone Penetration Test
DDW	California Water Resource Control Board Division of Drinking Water
Desal PMP	Ocean Water Desalination Program Master Plan
DIG	deep infiltration galleries
DPW	California Department of Public Works
DWR	California Department of Water Resources
EIR	Environmental Impact Report
HDD	Horizontal Directionally Drilled
IAP	Independent Advisory Panel
ISTAP	Independent Scientific Technical Advisory Panel
LARWQCB	Los Angeles Regional Water Quality Control Board
LACFCD	Los Angeles County Flood Control District
MGD	million gallon per day
MF	micro-filtration
NA	Not Applicable
NOAA	National Oceanic and Atmospheric Administration
NRG Facility	NRG Generating Station site in El Segundo
NTU	Nephelometric Turbidity Unit
NWRI	National Water Research Institute
RO	reverse osmosis
SBT	sub-bottom profile
SDI	Silt Density Index
SIG	Seabed infiltration galleries
SSI	Subsurface Seawater Intake
USFWS	United States Fish and Wildlife Service
USGS	U.S. Geological Survey
UWMP	Urban Water Management Plan
West Basin	West Basin Municipal Water District

Executive Summary

Background

West Basin Municipal Water District (West Basin) provides imported drinking water and recycled water to nearly one million people in the coastal Los Angeles area. To reduce dependency on imported water, and reduce vulnerability of the water supply to drought, West Basin is evaluating the feasibility of developing ocean water desalination (desal) as a component of its water supply portfolio. In accordance with the California State Water Board's updated Ocean Plan (2015), analysis of the demand and need for desalinated water by West Basin is based on their Desal Program Master Plan (Malcolm Pirnie – Arcadis, 2013) and their 2010 Urban Water Management Plan, which reviews water demands for the West Basin service areas through 2035.

Following more than 10 years of pilot testing of small scale desalination, West Basin completed a master plan in 2013 that identified an Environmental Impact Report (EIR) as a next step for a proposed desal facility. After investigation of several potential locations, the NRG Facility in El Segundo is the site West Basin is considering for a desal facility. The proposed desal facility would produce 20 to 60 million gallons per day (MGD) of potable water. For a production capacity of 20 MGD, which is considered the minimum capacity for the project, the desal facility would require an ocean water intake (feed water) rate of approximately 40 MGD. The feed water intake structure is a critical component of ocean water desal operations. Screened ocean intakes, which are used by power plants and sewer facilities, collect seawater directly from the ocean typically via offshore inlet structures. However, because screened ocean intakes can impact marine life, the updated Ocean Plan (2015) requires the use of subsurface seawater intakes (SSIs), which collect water from beneath the seafloor and coastal margin, instead of screened ocean intakes unless a site-specific evaluation determines SSIs are not feasible. If SSIs are not feasible, the affected Regional Water Board (e.g., for West Basin the Los Angeles Regional Water Quality Control Board [LARWQCB]) may approve screened ocean intakes using best available technology to minimize entrainment and impingement. The feasibility definition in the context of the Ocean Plan (2015) is "*capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors*", which is also the feasibility definition in California Coastal Act of 1976 (California Coastal Commission, 2004). The same definition is used in the context of this study.

West Basin initiated a study of SSIs that includes a literature study and overview of SSIs (Appendix B to this report), development of a computer-based general guidance tool for evaluating technical feasibility of SSIs, application of the guidance tool for initial screening of technical feasibility of SSIs for the proposed desal facility at the NRG facility, and follow-up field investigations and analysis to enhance the site-specific SSI feasibility evaluation.

Seven SSI technologies were evaluated:

- Vertical wells
- Slant wells
- Radial Collector Wells
- Horizontal directional-drilled (HDD) wells (sometimes called drains)
- Seabed infiltration galleries (SIGs)
- Beach (surf zone) infiltration galleries (BIGs)
- Deep infiltration galleries (Water Tunnel)

Guidance Tool for Evaluation of Technical Feasibility of SSIs

The guidance tool, which was peer reviewed and approved by an Independent Advisory Panel (IAP) coordinated by the National Water Research Institute (NWRI), includes evaluation of potential fatal flaws and potential challenges. For SSIs not eliminated by a technical fatal flaw, the tool provides a scoring system to quantify relative challenges for different SSI technologies. For the five following general categories, 18 criteria were identified as potential challenges affecting the overall feasibility of an SSI:

- Construction of the SSI;
- Operation of the SSI;
- Operation of the treatment system;
- Potential inland interference; and
- Technical risk/uncertainty for project implementation.

The initial screening results using the guidance tool indicate that all the SSI technologies are theoretically technically feasible to provide the design intake rate of 40 MGD for the proposed desal facility at the NRG Facility. The initial screening with the guidance tool was conducted with no constraints on the siting of the SSI infrastructures; e.g., 8.2 miles of linear beach front, from Redondo (South) to Marina Del Ray (North), was assumed to be available for siting of the infrastructure in the guidance tool. However, based on the guidance tool screening results, the linear beach front distance required for vertical wells, slant wells and radial collector wells would exceed the length of the NRG Facility. Construction outside of the NRG footprint would present problems due to construction-related disturbances and long term operational impacts either in front of residential property to the south or snowy-plover habitat to the north. The potential for interfering with sensitive habitats or existing land use (e.g. residential property) will be evaluated under the California Environmental Quality Act (CEQA) and could significantly impact the CEQA and permitting process.

Additional field investigations and groundwater modeling were conducted to enhance the understanding of the local hydrogeology in the vicinity of the NRG Facility and enhance the site-specific evaluation of the technical feasibility of the SSI technologies.

Hydrogeological Setting

The El Segundo site is at the coastal margin of the West Coast Basin, which is a major coastal groundwater basin in the greater Los Angeles area. The nearshore area of El Segundo is underlain by a thick, interbedded sequence of Quaternary clays, silts, sands, and gravels (e.g., California State Lands Commission, 2010). Existing data compiled and reviewed include numerous borings and monitoring wells at the NRG and adjacent Chevron Refinery Facilities (e.g., CA RWQCB Geotracker website), several shallow seafloor borings 800 to 2,500 feet offshore (Appendix G in El Segundo Power, 2000) and shallow seafloor samples 1,000 to 6,000 feet offshore (Fugro West 2004, 2007 in California State Lands Commission, 2010).

Figure ES.1 shows locations of existing borings and samples in the vicinity of the NRG Facility.

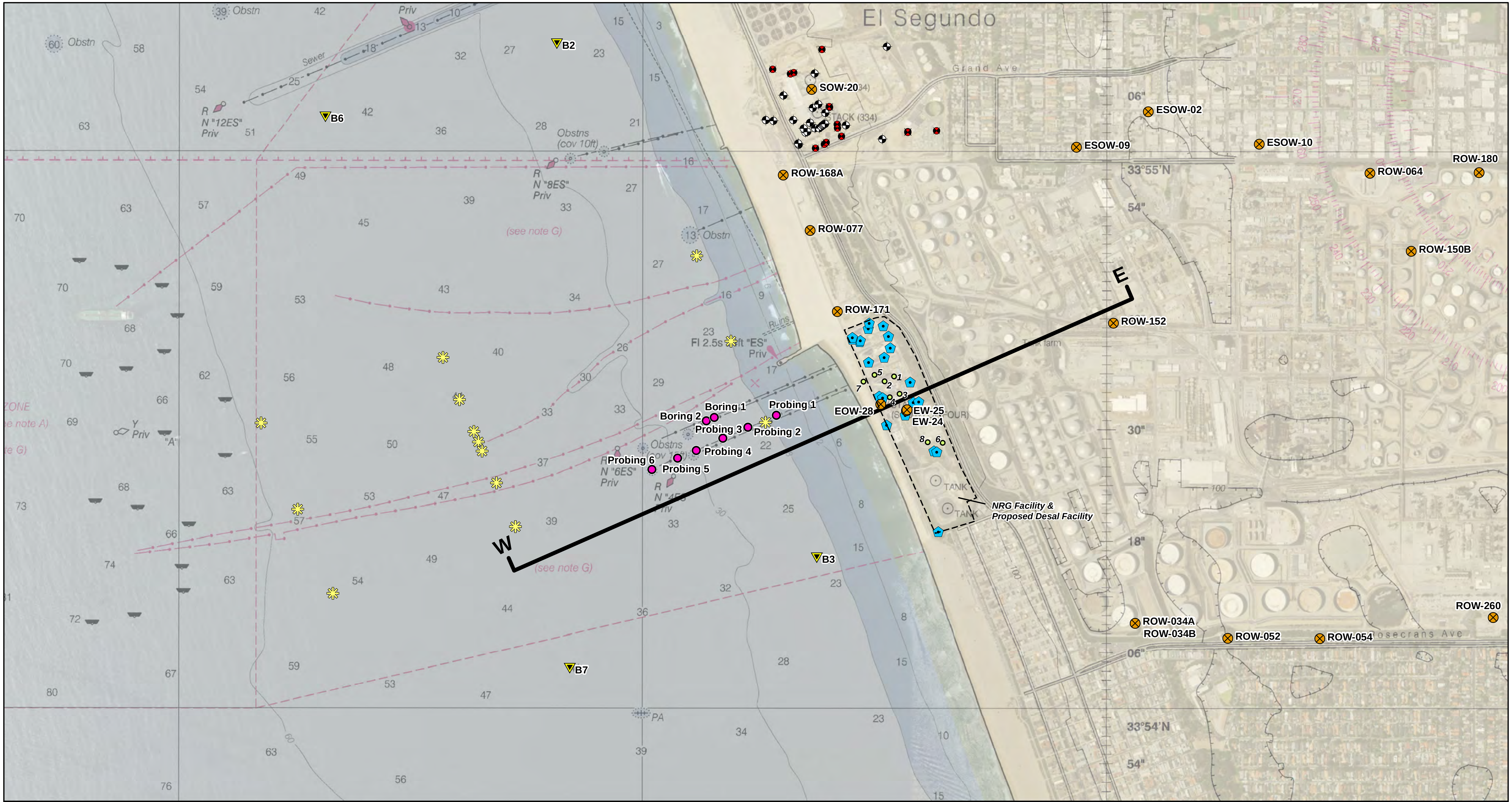
Based on review of these data, the subsurface near the coastal margin in the vicinity of the NRG Facility has a generally consistent stratigraphy to depths of approximately 100 feet below sea level (California State Lands Commission, 2010), which is illustrated in Figure ES.2 and summarized below:

- Old Dune Sand Aquifer: Recent and Upper Pleistocene dune sands, consisting of well-sorted, fine- to medium-grained sand, along with discontinuous lenses of silt, coarse-grained sand, gravel and cobbles. The thickness of this aquifer is approximately 55 feet in the vicinity of the NRG Facility.
- Manhattan Beach Aquitard: multi-layered assemblage of clay, silt, and very fine-grained sand of variable thickness and presence (California State Lands Commission, 2010). Although previous investigations have reported that the presence of the Manhattan Beach Aquitard is uncertain beneath the northern portion of the NRG Facility, offshore borings and jet

probes from 1954 and 1962, and the offshore geophysical survey conducted as part of this study show a thin fine-grained layer that appears to correlate with the Manhattan Beach Aquitard extending at least 1,500 feet north of the NRG Facility and approximately 2,000 feet offshore.

- Gage Aquifer: coarse poorly-graded sand with localized layers of silt and clay with a relatively constant thickness of approximately 20 feet. The Old Sand Dune and Gage Aquifers are reported to merge where the Manhattan Beach Aquitard is not present.
- El Segundo Aquitard: laterally extensive, dense silty clay; thickness varies between 10 and 25 feet in the vicinity of the NRG Facility.
- Silverado Aquifer: fine- to coarse-grained sand and gravel with interbeds of pebbles, also localized lenses of silt and clays up to 10 feet thick. The thickness of the Silverado Aquifer is not documented by borings in the vicinity of the NRG Facility, but based on the offshore geophysical survey, the Silverado Aquifer or similar material is estimated to extend to depths of approximately 600 feet.

The upper clayey interval that begins at an elevation of approximately 40 to 50 feet below sea level (approximately 20 feet below the seafloor) is an important factor in evaluating feasibility and conceptual design of shallow SSIs beneath the seafloor, particularly HDD wells. This low permeability clayey interval was encountered in five borings 800 to 1,600 feet offshore of the NRG Facility at depths of approximately 20 to 25 feet below the seafloor (Figure ES.3); based on onshore borings it may be 5 to 10 feet thick. The vertical hydraulic conductivity of the clayey interval is likely to be at least 100 to 1,000 times lower than the horizontal hydraulic conductivity of the overlying very fine sand (e.g., Anderson et al., 2015), which was estimated in the order of 1 to 50 feet per day (ft/d). Because this shallow clayey interval may be a key limitation in the hydraulic connection between the ocean and SSIs completed beneath it, additional investigations were performed to delineate its extent and estimate its hydraulic conductivity.



Legend

✳ Offshore Seafloor Sediment Sample Location
(State Lands EIR, Chevron El Segundo Refinery, 2010; Fugro West 2004, 2007.)

▼ **B7** Benthic Station Location*

○ *8* Dames & Moore Boring (1962)*

⊗ **ROW-052** Monitoring Well Location**

● **Probing 6** Boring (1954)/Probing (1962) Location*

Scattergood Monitoring Well ***

● Decommissioned Scattergood Monitoring Well ***

⬟ El Segundo Energy Center Monitoring Well****

W — E Cross-Section

N

0 1,000 Feet

Source:
* El Segundo Power, II LLC, 2000. Application for Certification Submitted to the California Energy Commission, El Segundo Power Redevelopment Project. Appendix G.
** Geotracker, Chevron El Segundo Refinery, Site # SL372482441
*** Chevron Decommissioning Wells Report
**** Shaw Environmental, Groundwater Well Map

Former Investigation Locations

Subsurface Seawater Intake Study
West Basin Municipal Water District

Geosyntec consultants

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Figure

ES.1

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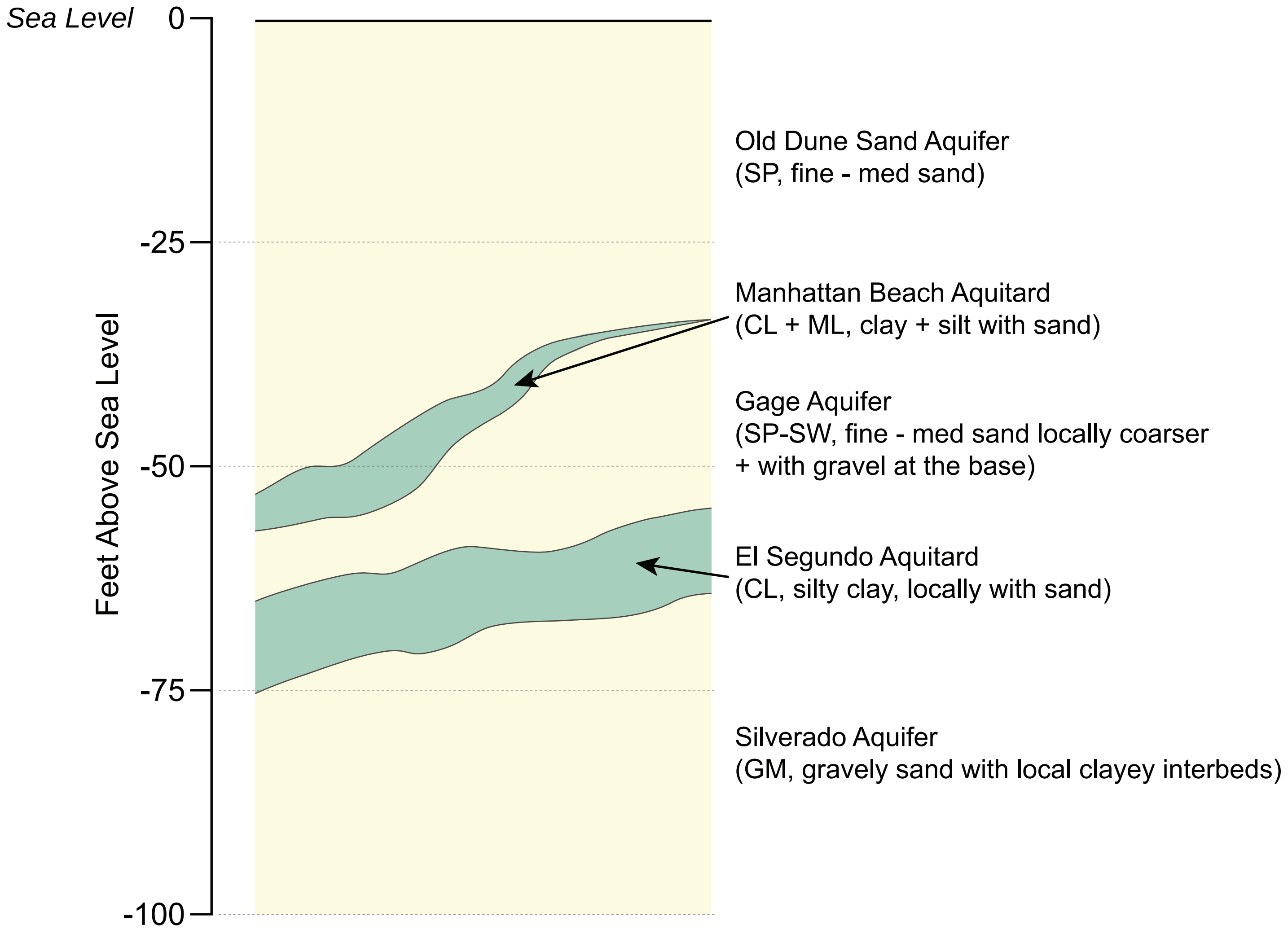

Legend

🟨 Coarse Grained Material

🟩 Fine Grained Material

Schematic Stratigraphic Column
El Segundo Coastal Margin

Subsurface Seawater Intake Study
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Figure

ES.2

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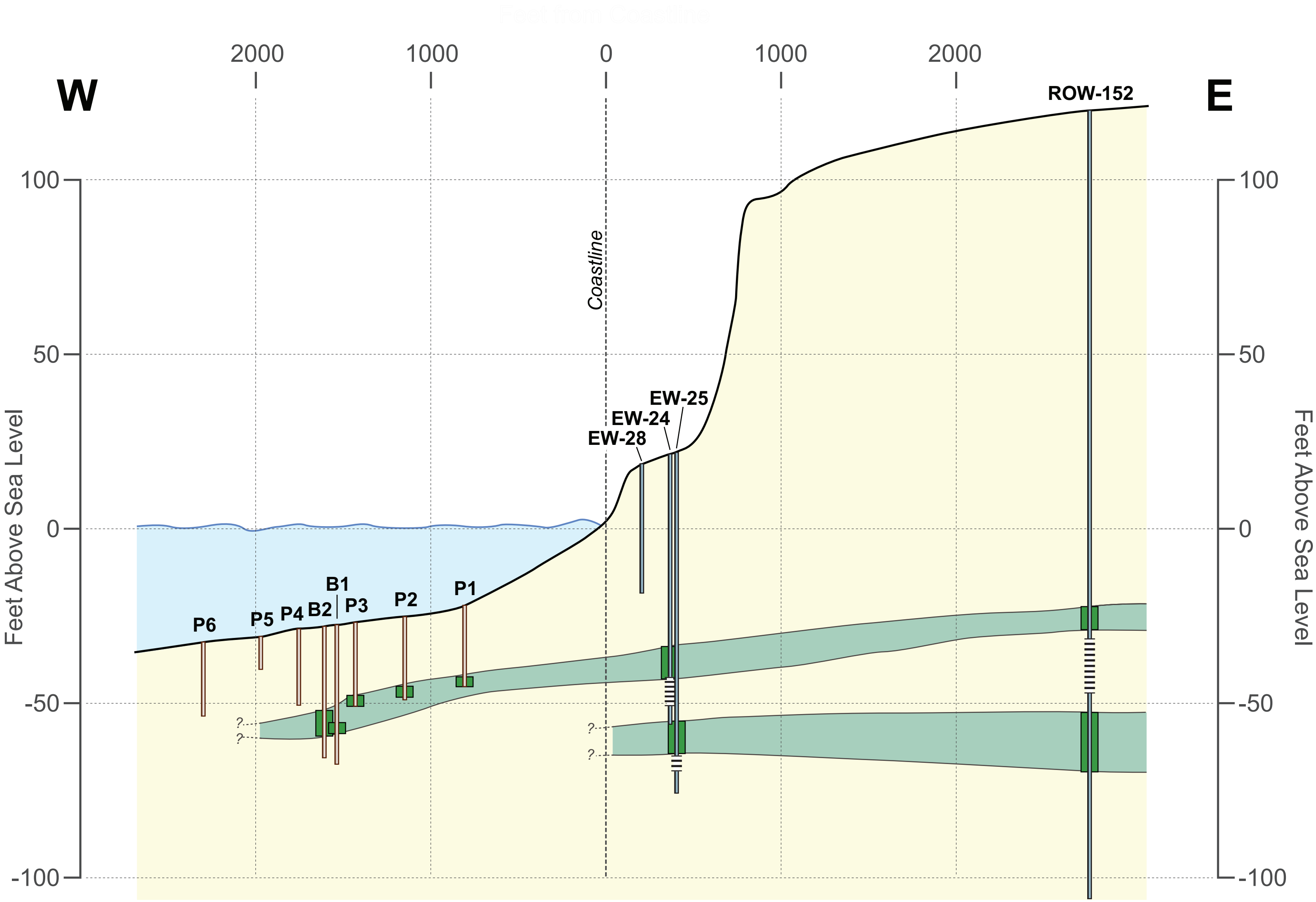

Legend

🟨 Coarse Grained Material

🟩 Fine Grained Material

B2

Soil Boring

Soil Log Indicating Fine Grained Material

EW-24

Extraction Well

Well Screen

Note:
Cross-section location shown on Figure 3.1.

Cross-Section
El Segundo Vicinity

Subsurface Seawater Intake Study
West Basin Municipal Water District

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Figure

ES.3

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Additional Field Investigations

Locations of field investigations conducted as part of this study are shown on Figure ES.4 and included the following:

- Grain size analysis of samples collected on the beach and at the surf zone to estimate hydraulic conductivity of the shallow sediments;
- Cone penetrometer testing (CPT) borings along the coastal margin in the NRG Facility to characterize the subsurface stratigraphy, and pore-pressure dissipation testing to measure permeability of the subsurface sediments; and
- Offshore sub-bottom profiling and multi-channEl Seismic reflection geophysical surveys to characterize the shallow offshore stratigraphy, specifically the extent and continuity of the clay interval.

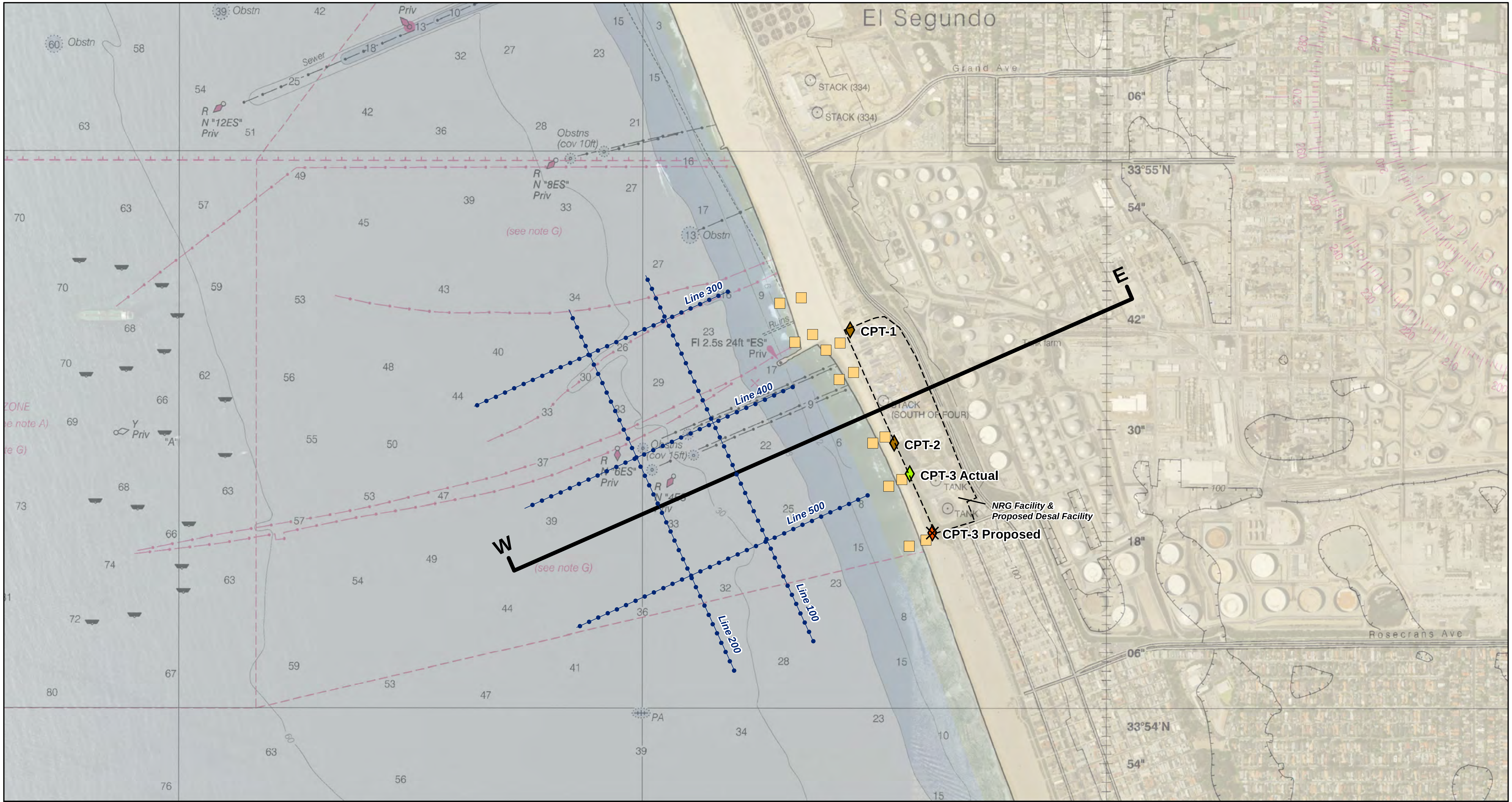
CPT borings were advanced at three locations within the NRG Facility. Refusal was encountered at 27 feet at two locations, likely due to the presence of cobbles, but CPT-3 was advanced to a depth of 81 feet. Localized hydraulic conductivity values were estimated based on the CPT data. Like the boring logs discussed above, the CPT data show two low permeability intervals: the upper between approximately -30 and -38 feet mean sea level (feet msl), and the lower between -50 and -60 feet (msl), with estimated vertical hydraulic conductivity values of 0.005 to 0.01 ft/day and 0.001 to 0.01 ft/day, respectively. The hydraulic conductivity values are representative of low permeability media, which will limit the hydraulic connection between the ocean and SSIs completed beneath the low permeability interval. For comparative reference, hydraulic conductivity of aquifer materials is typically in the range of at least 1 ft/d to greater than 500 ft/d (e.g. Driscoll, 1986; Heath, 1989; swcd[2], 2010).

Seismic reflection geophysical surveys were conducted offshore of the NRG Facility on 3 September 2015 along three lines perpendicular to the shoreline and two lines parallel to the shoreline. The survey lines are within an area extending approximately 3,800 feet offshore and 4,500 feet parallel to the shore. The locations of the survey lines are shown in Figure ES.4. The main findings are summarized below:

- Gravel and/or cobbles are present locally beneath the sandy seafloor to depths of 10 to 15 feet. Areas of gravel exposure on the seafloor are also present.
- A transition from the shallow interbedded sand, gravel and cobbles to relatively uniform sand occurs 10 to 15 feet below the seafloor.

- The upper clay layer is present approximately 20 to 25 feet below the seafloor. The thickness of the clay layer is less than the resolution of the seismic reflection imaging and in places it may be as thin as 1 or 2 feet. This shallow clay layer appears to be continuous and nearly horizontal to approximately 2,200 feet offshore beyond which it appears to be truncated by an erosional unconformity.
- The top of the lower clay layer is imaged at a depth of approximately 50 to 60 feet below the seafloor (-80 to -110 feet msl). This clay layer correlates well with the El Segundo Clay and is contiguous to at least 3,800 feet offshore. It is estimated to be 10 to 15 feet thick and roughly parallels the seafloor.
- Based on the interpreted geophysical survey, the Silverado sand deposits below the El Segundo Clay are more than 500 feet thick.
- Fine-grained marine deposits appear to underlie the Silverado Sands below approximately -600 feet msl.

The previous existing data and additional investigation provide a good understanding of the hydrogeologic conditions that are pertinent to the evaluation of feasibility of SSIs for the proposed desal facility at the NRG Facility. The most important site-specific criteria for the refined evaluation of SSIs are summarized below.



Legend

- ◆ Refusal at 27 ft bgs
- ◆ Refusal at 81 ft bgs
- ☒ Unable to access with CPT rig
- 🟧 Beach and Surf-Zone Sand Sample (July 2015)
- •–• Seismic Reflection Lines
- W—E Cross-Section

Note:
ft bgs - feet below ground surface

Field Testing Locations

Subsurface Seawater Intake Study
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Figure
ES.4

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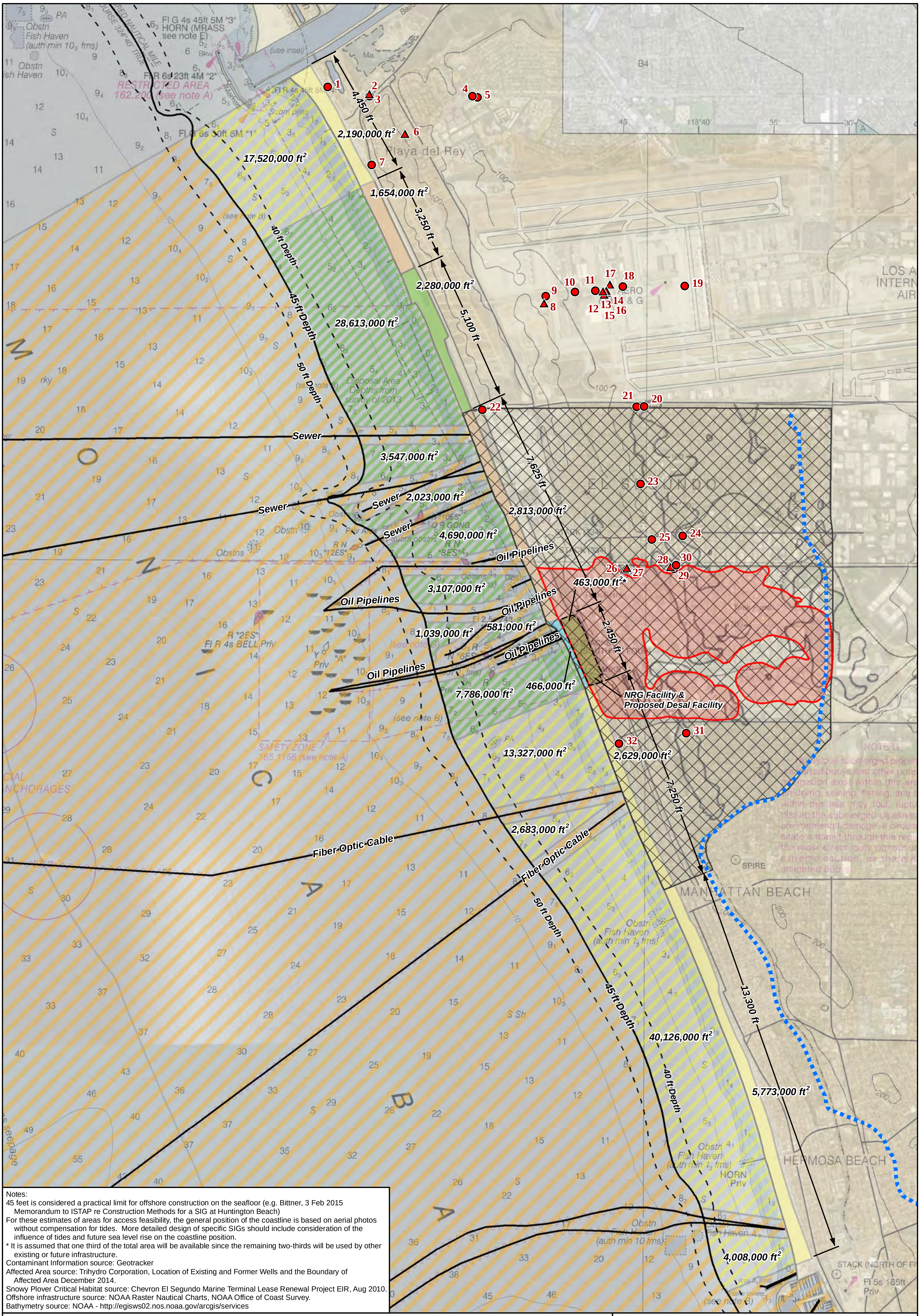
Evaluation Criteria

The feasibility of the SSI technologies depends on a variety of site-specific criteria. The following criteria were used for evaluation of the feasibility of SSI technology at the proposed El Segundo Desal Facility, in accordance with the factors listed in the Ocean Plan (2015).

- Hydrogeologic constraints
    - Hydraulic connection between SSIs and the ocean
    - Impacts on the water supply aquifers
    - Impact on the West Coast Basin Injection Barrier (Figure ES.5)
- Oceanographic constraints
    - Vulnerability to sea level rise
    - Sensitivity to beach stability
    - Sensitivity to seafloor stability (erosion/deposition)
- Geochemical and water quality constraints
    - Risk of adverse fluid mixing
    - Risk of clogging of the intake
    - Risk of high SDI water
    - Risk of drawing from contaminated groundwater (Figure ES.5)
    - Risk of drawing water from de-designated area (Figure ES.5)
- Land use and sensitive habitat
    - Residential property (Figure ES.5)
    - Snowy-plover habitat (Figure ES.5Able #x.1)
    - Risk of encountering undocumented buried infrastructure
- Maintenance
- Other technical and economic risk factors and uncertainties
    - Complexity of construction
    - Performance risk and degree of uncertainty of outcome
    - Reliability of the intake system
    - Economic viability



Notes:
45 feet is considered a practical limit for offshore construction on the seafloor (e.g. Bittner, 3 Feb 2015 Memorandum to ISTAP re Construction Methods for a SIG at Huntington Beach)
For these estimates of areas for access feasibility, the general position of the coastline is based on aerial photos without compensation for tides. More detailed design of specific SIGs should include consideration of the influence of tides and future sea level rise on the coastline position.
* It is assumed that one third of the total area will be available since the remaining two-thirds will be used by other existing or future infrastructure.
Contaminant Information source: Geotracker
Affected Area source: Trihydro Corporation, Location of Existing and Former Wells and the Boundary of Affected Area December 2014.
Snowy Plover Critical Habitat source: Chevron El Segundo Marine Terminal Lease Renewal Project EIR, Aug 2010.
Offshore infrastructure source: NOAA Raster Nautical Charts, NOAA Office of Coast Survey.
Bathymetry source: NOAA - http://egisws02.nos.noaa.gov/arcgis/services

Legend

- ▨ Potential Offshore Area
- ▨ Offshore Area In Front of Residential Properties
- ▨ Offshore Area Too Deep / Close to Infrastructure
- ⊠ Dedesignated Area
- 🟩 Potential Onshore Area
- 🟨 Onshore Area In Front of Residencial Properties
- 🟧 Onshore Area Snowy Plover Critical Habitat
- 🟦 Breakwater Area
- ▪▪▪ West Coast Basin Injection Barrier

Sites with Contaminated Groundwater

- ● Fuel Site
- ▲ Solvent Site
- ☐ Affected Area in Vicinity of Refinery

N

0 3,000 Feet

Infrastructure and Contaminants

Subsurface Seawater Intake Study
West Basin Municipal Water District

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Figure
ES.5

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Refined Site-Specific Evaluation of SSIs

The evaluation criteria assessed for each specific SSI technology are summarized in Table ES.1. The assessment is based on results of initial screening using the Guidance Tool, analyses of the site-specific data and field testing, groundwater modeling, relevant information compiled from other sources, such as the evaluation of feasibility of SSIs for the proposed desal facility at Huntington Beach[1] (ISTAP, 2014, 2015), and engineering judgment provided by expert advisors.

Vertical, Slant, and Radial Collector Wells

Refined evaluation of feasibility of vertical wells, slant wells and radial collector wells determined that they are not feasible because they would draw over 50% of the water from inland coastal margin aquifers, including contaminated groundwater and areas that are de-listed for beneficial use (Figure ES.5). Moreover, the pumping would impact the performance of the West Coast Basin Injection Barrier (Figure ES.5). Based on groundwater modeling conducted to evaluate feasibility of SSIs at the NRG Facility, the estimated maximum sustainable production capacity for vertical wells, slant wells and radial collector wells is below 20 MGD, significantly less than the design intake rate of 40 MGD. While wells could potentially be located outside the NRG Facility to increase capacity, these wells would face the same flaws related to drawing water from the inland coastal margin aquifers, as well as additional challenges posed by constructing in front of residential properties to the south and protected snowy-plover habitat to the north.

HDD Wells

HDD wells potentially provide better hydraulic connection to the ocean because they can be installed at relatively shallower depths and to greater distances offshore than other SSI well technologies. However, at El Segundo a low-permeability layer approximately 20 feet below the seabed poses significant challenges for HDD wells because it would limit the hydraulic connection with the ocean of HDD wells deeper than 20 feet, and would cause withdrawal of a portion of the water from inland sources. Groundwater modeling indicates that approximately 10% of the feed water provided by HDD wells below the 20-foot

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[1] An Independent Scientific Technical Advisory Panel (ISTAP) was engaged in 2014 and 2015 under the auspices of the California Coastal Commission and Poseidon Resources (Surfside) LLC to review feasibility of subsurface intakes for a desal facility proposed at Huntington Beach. The ISTAP review was convened and facilitated by Concur Inc. Reports by the ISTAP addressing feasibility of SSIs the proposed desal facility at Huntington Beach are referenced herein, and because of some similarities in the settings, some of the ISTAP findings and recommendations regarding feasibility of SSIs at Huntington Beach are applicable to SSI feasibility at El Segundo. However, the ISTAP review did not address feasibility of SSIs at El Segundo, and West Basin's investigation of SSI feasibility at El Segundo is independent of the investigation and ISTAP review of SSI feasibility conducted for Huntington Beach.

clay layer would originate from inland sources, including the injection barrier. The modeling also shows flow pathlines between the ocean and the coastal margin end of HDD wells follow a looping pathway under the NRG Facility where shallow groundwater is contaminated.

Model calculations indicate that the maximum production capacity for HDD wells with well heads inside the NRG Facility would be approximately 18 MGD, less than half of the design flow rate of 40 MGD. To meet the design capacity additional HDD wells would have to be located outside of the NRG Facility, and these wells would face the same flaws related to drawing water from the inland coastal margin aquifers, as well as additional challenges posed by constructing in front of residential properties to the south and protected snowy-plover habitat to the north. This is the same set of fatal flaws and challenges that applied to the vertical, slant, and radial collector wells:

- Impact on coastal water supply aquifers and on the West Coast Basin Injection Barrier,
- Drawing water from contaminated areas and from an area de-listed for municipal use, and
- Unable to provide the design intake rate with well heads located with the NRG Facility.

Thus, HDD wells completed deeper than 20 feet below the seafloor are technically infeasible.

An alternative approach would be to install the HDD wells above the 20-foot low-permeability layer, which would result in better hydraulic connection with the ocean and alleviate the fatal flaws described above. However, no known examples exist of HDD wells installed at depths shallower than 20 foot below the seafloor, and the presence of cobbles and gravel within the shallow seafloor sediments would likely prevent successful drilling and installation of HDD wells (Davis, 2008; Williams, 2008; Nielson et al., 2013).

Pilot testing of a single well could be performed in order to better assess the constructability and performance of shallow HDD wells, however, based on available information from borings and the geophysical survey, the presence of cobbles and gravel is localized, so a single pilot HDD well will not be representative of conditions and feasibility at other locations in the vicinity. Shallow HDD wells inside the closure depth[2] of 50 feet, which is reported to occur approximately 6,500 feet offshore (Jenkins, 2015—Appendix K to this report) would also be vulnerable to seafloor instability. Moreover, potential deposition of silts and clays on the Santa Monica Bay seafloor can occur with El

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[2] The closure depth represents the closest point to the shoreline where a stable seabed occurs.

Nino storms and decrease the performance yield and require difficult, expensive, and potentially damaging maintenance of the HDD wells (Missimer et al., 2013).

The high degree of construction and maintenance challenges, the technical risks posed during construction and operation, and the lack of a suitable precedence constitutes a fatal flaw for shallow HDD wells within sand with abundant local gravel and cobbles. The uncertain feasibility of the construction, maintenance and long term performance coupled with an estimated cost of $80M to $120M to drill and install the HDDs wells is an unacceptable technical and economic risk for West Basin to assume, as a public agency. Thus, HDD wells installed above the 20-foot low-permeability layer are not feasible.

Beach Infiltration gallery (BIG)

BIGs are designed to be located in the surf zone, such that they are self-cleaning due to the turbulence caused by breaking waves. Therefore a successful BIG should be located on a beach that is stable, with minimal erosion and deposition cycles. The high energy environment at El Segundo, due to location on the exposed open coast of the Southern California Bight, fully open to long period swells from the Gulf of Alaska winter storms (Appendix K), can lead to long-term patterns of coastal erosion. These cycles can quickly become exacerbated by extreme winters (such as those caused by El Nino events) where up to 400 cubic yards/yard of erosion has been documented during a single winter season along the beach in front of the NRG Facility (California State Lands Commission, 2010).

The erosion and nourishment cycles can result in migration of the beach and surf zone position, which can compromise the performance of a BIG. The 250 feet offset in the position of the coastal margin north and south of the jetty or rock groin adjacent to the NRG Facility (much wider beach north of the jetty) is evidence of substantial southward long-shore transport of sand and beach instability (Figure ES.1) (Google Earth, 2015; California State Lands Commission, 2010). BIGs have not been constructed in high-energy unstable beach settings such as at the El Segundo Desal Facility, and are considered technically infeasible.

Seafloor Infiltration gallery (SIG)

The optimal location for a SIG is at or beyond the “closure depth” where the change in seafloor bottom elevation with time due to coastal processes is essentially zero and the risk of the SIG becoming buried or eroded is minimal. Analysis of conditions at El Segundo indicates that the closure depth is approximately 50 feet, which is 6,500 feet offshore (Jenkins, 2015—Appendix K to this report). The 50 feet depth, coupled with the high-energy ocean environment and long-period ocean swells, would require specialized trestle or float-in construction methods that have previously been evaluated for a proposed desal facility at Huntington Beach and determined not to be economically viable for 50 MGD production capacity (ISTAP, 2015). Based on the Huntington Beach case and scaling for the El Segundo case, the capital costs to construct a SIG to provide feed water to the proposed desal facility at the NRG Facility are likely to exceed $774M.

In addition to the estimated cost in excess of $774M, construction of a SIG in the high-energy and relatively unprotected conditions offshore from the NRG Facility is unprecedented. By comparison, an existing SIG at Fukuoka on the north-west side of the island of Kyushu Japan is in a fetch-limited protected environment and is not exposed to the long-period open ocean swell waves that are present in the Santa Monica Bay. Similarly a small scale test SIG at Long Beach is located inside the breakwater system of the Long Beach/Los Angeles where it is completely sheltered from wave exposure (Appendix K). The higher energy environment at El Segundo further exacerbates the performance risk due to the lack of precedence.

Moreover, potential deposition of silts and clays on the Santa Monica Bay seafloor can occur with El Nino storms and decrease the performance yield and require difficult, expensive, and potentially environmentally damaging maintenance of a SIG.

The uncertainty of performance, coupled with the unacceptable construction cost, presents too much technical and economic risk for West Basin to assume as a public agency. Thus, a SIG is not a feasible SSI option for a desal facility at the NRG Facility.

Deep Infiltration Gallery (Water Tunnel)

DIGs or water tunnels are a range of conceptual offshore subsurface seawater collector systems without precedence for comparable conditions. For comparison, an existing DIG tunnel with lateral intakes at Alicante in Spain is located in a limestone aquifer with a significant network of karstic conduits (Rachman et al., 2014). DIGs are a novel idea, but not a proven technology for offshore marine alluvial settings. The extreme construction complexity coupled with potentially high technical risks and lack of precedence for comparable conditions, result in DIGs being deemed technically infeasible at the proposed El Segundo Desal Facility.

Conclusions

Extensive research, field testing, and analyses were conducted to evaluate the feasibility of seven SSI technologies for the proposed desal facility at the NRG Facility in El Segundo. The evaluation considered geotechnical data, hydrogeology, benthic topography, oceanographic conditions, presence of sensitive habitats, presence of sensitive species, impact on freshwater aquifers, existing infrastructure, design constraints (e.g., construction complexity), precedence (and associated technical risk), the Basin Plan, environmental and social factors, and economic viability.

The analysis determined that none of the seven SSI technologies are feasible for the design intake rate of 40 MGD at the NRG Facility, and that construction of SSIs outside of the NRG Facility would be subject to the same fatal flaws and challenges and are not feasible. In addition, due to the similar setting, many of the same fatal flaws and challenges would apply to construction of SSIs at the AES Facility at Redondo Beach, which was also considered by West Basin for the proposed desal facility.

Table ES.1: Subsurface Seawater Intake Summary Table

	Vertical Wells	Slant Wells	Radial Collector Wells	Horizontally Directionally Drilled Wells		Beach Infiltration Gallery	Seabed Infiltration Gallery	Deep Infiltration Gallery
				below 20 feet layer	above 20 feet layer			
Hydrogeologic Constraints								
Hydraulic connection to ocean	Moderate	Moderate	Moderate	Moderate	High	High	High	High
Impact on water supply aquifers	Yes	Yes	Yes	Yes	Unlikely	No	No	Unlikely
Impact on West Coast Basin Injection Barrier	Yes	Yes	Yes	Yes	Unlikely	No	No	Unlikely
Oceanographic								
Sensitivity to sea level rise	Possibly	Possibly	Possibly	No	Possibly	Possibly	No	No
Sensitivity to beach stability	Possibly	Possibly	Possibly	Possibly	Possibly	Yes	No	No
Sensitivity to seafloor stability	No	No	Possibly	Unlikely	Possibly	Possibly	Yes	Possibly
Geochemical and Water Quality Constraints								
Risk of adverse fluid mixing	High*	High*	Medium*	Unknown*	Unknown*	Low*	Low*	Low*
Risk of clogging	High*	Medium*	Medium*	High*	High*	Low*	Low*	Low*
Risk of high SDI production water	Low	Low	Low	Low	Low	High	Low	Low
Drawing contaminated water	Yes	Yes	Yes	Yes	Possibly	No	No	Unlikely
Drawing from aquifer area *de-designated* for municipal beneficial use	Yes	Yes	Yes	Yes	Unlikely	No	No	Possibly

	Vertical Wells	Slant Wells	Radial Collector Wells	Horizontally Directionally Drilled Wells		Beach Infiltration Gallery	Seabed Infiltration Gallery	Deep Infiltration Gallery
				below 20 feet layer	above 20 feet layer			
Land Use and Sensitive Habitat								
Need to construct in snowy-plover habitat and/or in front of residential property	Yes	Yes	Yes	Yes	Possibly	No	No	No
Need to perform O&M in snowy-plover habitat and/or in front of residential property	Yes	Yes	Yes	Yes	Possibly	No	No	No
Risk of encountering undocumented buried infrastructure	Low	Low	Low	Low	High	Low	Low	Medium
Maintenance								
Frequency of maintenance	High*	High*	Medium*	High*	High*	Medium / Unknown*	Medium / Unknown*	Low*
Complexity of maintenance	Low*	Medium*	Medium*	High*	High*	Medium*	High*	High*
Other Risk Factors								
Precedence at comparable scale and hydrogeologic / oceanographic conditions	No	No	Yes	No	No	No	No	No
Complexity of construction	Low*	Medium*	Medium*	Medium* / High	High	High*	High*	Very High*
Performance risk - degree of uncertainty of outcome	Low*	Medium*	Medium*	High*	High*	Medium*	Medium*	Unknown*
Reliability of intake system	High*	Medium / Unknown*	Medium*	Unknown*	Unknown*	Medium / Unknown*	Medium*	Unknown*
Economic viability	Medium	Medium	Medium	Low	Low	Medium	Low	Low

*Used information directly from ISTAP, 2014.

1 Background and Introduction

West Basin Municipal Water District (West Basin) provides imported drinking water and recycled water to nearly one million people in the coastal Los Angeles area. West Basin's Water Reliability 2020 Program aims to reduce dependence on imported water from 66% to 33% by 2020. To reduce dependency on imported water, and reduce the vulnerability of its water supply to drought, West Basin is striving to increase recycled water production, expand conservation efforts, and develop new sources of potable water, including ocean water desalination (desal) (Malcolm Pirnie - Arcadis, 2013).

For well over a decade, West Basin has conducted a step-wise investigation of desalination, which began with pilot testing from 2002 to 2009 at the NRG Generating Station site in El Segundo (NRG Facility). This pilot test involved operation of a 40 gallons per minute (gpm) facility that processed seawater through the use of micro-filtration (MF) and reverse osmosis (RO). Data and analytical results obtained from this pilot testing facility were used to develop a demonstration facility in Redondo Beach that was operated from 2010 to 2014 to research and test numerous methods and processes for all stages of operation of a desalination facility (intake, treatment, discharge). The goal of the demonstration facility was to gather information that could be used for full scale design simulations. This information included optimizing operating parameters, evaluating water quality impacts on design parameters, assessing the design options for environmentally-protective source intake methodologies, consistent with the recent desalination amendment to the California Ocean Plan, approved on 6 May 2015 by the State Water Resources Control Board (provided in Appendix A), and evaluating energy efficiency.

To identify the next steps for full scale development of ocean water desalination, West Basin completed an Ocean Water Desalination Program Master Plan (Desal PMP) (Malcolm Pirnie - Arcadis, 2013). This document identified an Environmental Impact Report (EIR) as the next step. One component of this EIR will be an evaluation of the feasibility of subsurface seawater intakes (SSIs) in compliance with the California State Water Board's updated Ocean Plan (2015), provided in Appendix A. Because screened ocean intakes can impact marine life, the use of SSIs is required to collect seawater when feasible. SSIs collect water from beneath the seafloor and coastal margin. However, if a site-specific evaluation determines that SSIs are not feasible, the Water Board may approve screened ocean intakes using best available technology to minimize entrainment and impingement. The feasibility definition in the context of the Ocean Plan (2015) is "*capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors*", which is also the feasibility definition in California Coastal Act of 1976 (California Coastal Commission, 2004). The same definition is used in the context of this study. Under the Ocean Plan, the Water Board shall consider the following factors in determining feasibility of SSIs; geotechnical data, hydrogeology, benthic topography, oceanographic conditions, presence of sensitive habitats, presence of sensitive species, energy use for the entire facility, design constraints (engineering, constructability), and project life cycle cost. These criteria are used in the evaluation of the SSIs performed in the context of this study (Section 4).

To support this effort, West Basin initiated an SSI study that was conducted by Geosyntec with assistance from expert advisors and reviewers in sub consultant roles including Gerry Filteau (Separation Processes, Inc.- SPI), Martin Feeney (Independent Consultant), Robert Bittner, (Bittner-Shen Engineering), and Jim Barry, (Sea Engineering). The SSI study includes the following components:

1. A literature study and overview of SSI technologies, along with a review of the current regulatory requirements in California applicable to permitting of a desalination facility in California. Results of this study are available in a technical memorandum, which is included as Appendix B to this report.
2. Developing an electronic, stand-alone computer-based general guidance tool for evaluating the technical feasibility of SSIs. Technical feasibility is one component of a feasibility assessment as specified in regulatory guidance documents, e.g. Ocean Plan and California Environmental Quality Act (CEQA). An overview of this guidance manual (Geosyntec, 2015) is provided in Section1.4.
3. Applying the guidance tool to assess technical feasibility of the SSIs for the potential West Basin desal facility at the NRG Facility.
4. Conducting additional evaluations of the subsurface and hydrogeologic conditions at the potential West Basin desal facility, including field testing and groundwater modeling of potential SSIs.
5. Evaluating feasibility of the SSIs at the potential West Basin desal facility considering economic, environmental, social, and technological factors, as specified in the amended Ocean Plan (2015).

This report summarizes the findings from steps three through five described above. The report is intended to be a component of an EIR for the West Basin desal facility and be used to address the evaluation of the feasibility of SSIs, in accordance with the amended Ocean Plan.

This report as well as the guidance tool, discussed in Section 1.4, was peer-reviewed by an Independent Advisory Panel (IAP) coordinated and facilitated by the National Water Research Institute (NWRI). The IAP consisted of four panel members with expertise in the fields of intake and well design, hydrogeology, coastal processes, evaluation of structures and vessels in the marine and coastal environment, development and implementation of alternate water supply projects (such as seawater desalination) at public agencies, and other areas relevant to the study (Appendix C).

Two public meetings were held at the Edward C. Little Water Recycling Facility in El Segundo, California on February 26 and April 14, 2015 on the guidance tool. After each meeting, the IAP issued a draft report summarizing IAP's review and comments on the Tool and the Tool was revised accordingly (Appendices C and D). A third meeting was held at the Edward C. Little Water Recycling Facility in El Segundo, California on November 16, 2015 on this report. After the meeting, the IAP issued a draft final report summarizing IAP's review and comments and the report was revised accordingly (Appendices C and D).

Overview of Proposed Desalination Facility

West Basin's Desal PMP includes evaluation of both local and regional water demands based on their 2010 Urban Water Management Plan (UWMP) (RMC, 2011) as well as system conveyance capacity to determine the desired desal facility capacity. Based on this analysis, West Basin developed conceptual system design and program requirements for 20 and 60 million gallons per day (MGD) facility options. In accordance with the Ocean Plan (2015), analysis of the need for desalinated water by West Basin is based on their 2010 UWMP and the Desal PMP. For a production capacity of 20 MGD, which is considered the minimum capacity for the project, the desal facility would require an ocean water intake (feed water) rate of approximately 40 MGD.

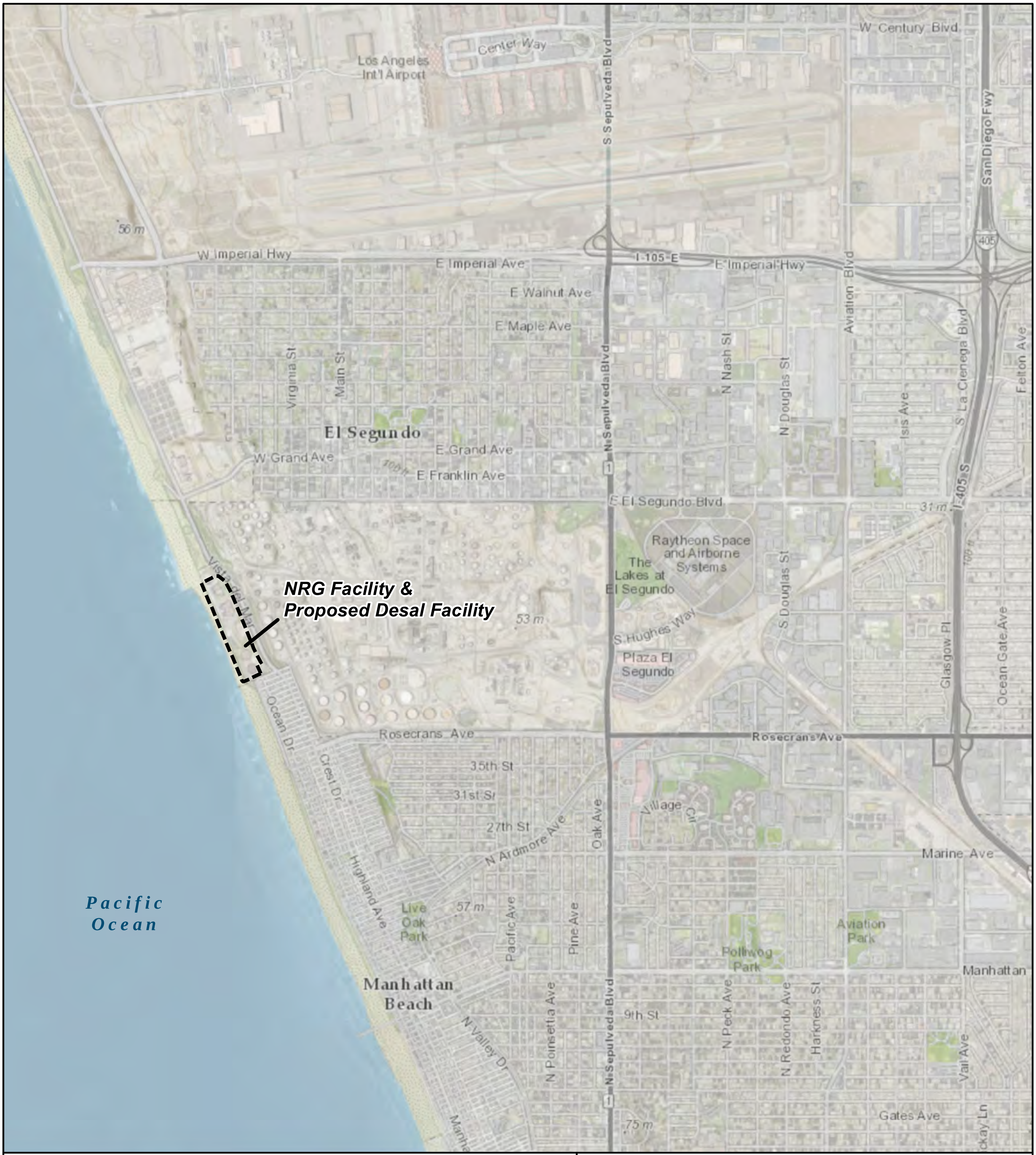
The currently proposed treatment process consists of the following process elements:

- Seawater intake
- Pretreatment processes
- Screening
- Coagulation
- Granular Media Filtration
- Low pressure membranes MF/UF
- Cartridge filters
- Reverse osmosis (single or two-pass process)
- Energy recovery
- Post-treatment

- Stabilization and corrosion control
- Disinfection
- Residuals handling and disposal
- Concentrate discharge/diffuser system

The Desal PMP includes evaluation of both subsurface and open surface intakes and various concentrate discharge alternatives.

After investigation of several potential locations, the NRG Facility in El Segundo is the site West Basin is considering for its proposed full scale desal facility. The site location is shown in Figure 1.1.



Legend

Site Location Map

Subsurface Seawater Intake Study
West Basin Municipal Water District

Geosyntec consultants

LA0324

December 2015

Figure

1.1

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1.1 Goals of the Report and Approach

The objective of this report is to evaluate the feasibility, taking into account economic, environmental, social, and technological factors, of SSI technologies to provide feed water for West Basin's proposed desal facility. The first task for achieving this objective was developing a framework for evaluating the technical feasibility of SSIs for any facility capacity at any proposed site. This framework was then developed into a more quantitative screening tool that underwent a formal peer review process to ensure its technical accuracy and defensibility. The decision tool incorporated geotechnical data, hydrogeologic characteristics, benthic topography, oceanographic conditions, impact on freshwater aquifers, and constructability constraints for assessing the technical feasibility of an SSI technology. The tool was then applied to West Basin's proposed El Segundo facility to provide a preliminary technical screening of SSIs. The initial screening with the guidance tool was conducted with no constraints on the siting of the SSI infrastructures; e.g., 8.2 miles of linear beach front, from Redondo (South) to Marina Del Ray (North), was assumed to be available for siting of the infrastructure in the guidance tool.

Following the initial screening, additional field studies including near-shore sand sampling and analysis, on-shore cone penetration test (CPT), and an off-shore seismic reflection survey were conducted to provide additional data needed to characterize the geology and hydrostratigraphy of the coastal margin in the vicinity of the NRG Facility and complete the assessment of technical feasibility of SSIs. Results of these studies were used to further assess design constraints (e.g., constructability and performance risk), and to develop numerical groundwater flow models for four of the considered SSIs. These models were used to evaluate anticipated yields from SSIs as well as to assess further the potential influence on inland freshwater aquifers, including drawing from nearby contaminated groundwater and interfering with the performance of the West Coast Basin Injection Barrier. Suitability of oceanographic conditions at the selected site for specific SSIs was also assessed by conducting a detailed littoral cell analysis.

Following the analysis of the technical feasibility of the SSIs for the proposed El Segundo site, the overall feasibility of each SSI was considered. This included incorporating social, environmental, and economic factors relevant to this site. Factors included the presence of residential properties and public beaches (social factors), and sensitive habitats and species (environmental factors) in the vicinity of the proposed site. Economic viability was also considered for SSIs considered technically feasible following the site-specific evaluation.

1.2 Overview of Subsurface Intake Technologies

The seven SSIs included in this analysis are listed below, along with short descriptions, and a schematic illustration of each technology is provided in Figure 1.2:

1. Vertical wells

   Vertical wells are identical to conventional groundwater production wells. Typically, a series of vertical wells are drilled along a beach location, and the number of wells is a function of the hydraulic conductivity of sediments or aquifer transmissivity (depending on the location of the screened interval) and the desired capacity of the desal unit.

2. Slant wells

   Slant wells are wells drilled at an angle from the shore toward the sea, with the well screen located beneath the seafloor. Several wells (typically two to four) can be drilled from a single location to create a cluster of wells.

3. Radial (Ranney) collector wells

   Radial collector wells (e.g. Ranney Wells^{TM}) include a central caisson that extends down into the sand, with a series of horizontal lateral wells fanning out from the caisson.

4. Horizontal directional-drilled (HDD) wells (sometimes called drains)

   HDD technologies can be used to install wells beneath the seafloor from the shoreline (or set back from the shoreline). The angle of the well can be adjusted gradually over the length of the well, allowing it to remain in the desired stratum and close to the seafloor. Similar to slant wells, groups of HDD wells (drains) can fan out from a common location inland of the beach.

5. Seabed infiltration gallery

   Water is pumped from the sea through seabed infiltration galleries (SIGs) installed over a large surface area and consisting of engineered sand and gravel fill placed within an excavation of the seabed. They typically consist of a network of perforated pipes placed beneath a series of sand layers that increase in grain size with depth. Seawater percolates through the sand into the pipes, which feed a single pumped collector pipe (Missimer at al., 2013).

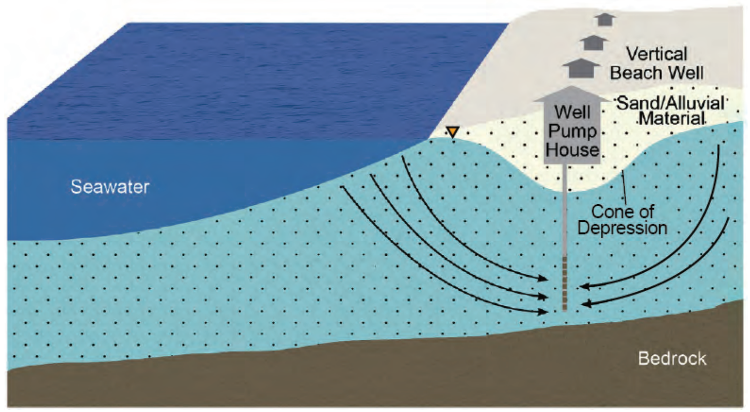
6. Beach (surf zone) infiltration gallery

Beach infiltration galleries (BIGs) are similar to SIGs, but are constructed in the surf zone, with the mechanical energy of the breaking waves used to continuously clean the face of the filter (Missimer et al., 2013).

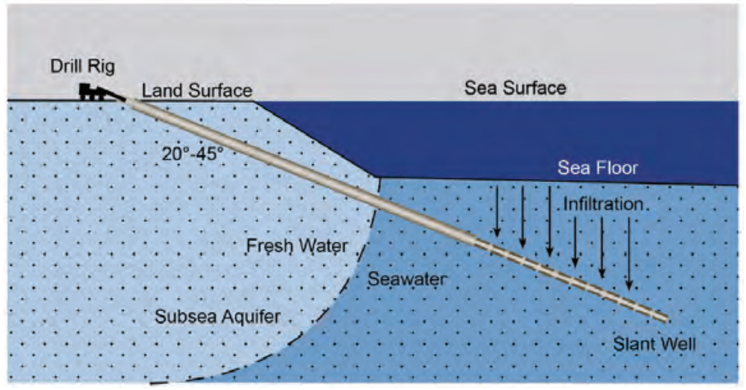
7. Deep infiltration gallery (water tunnel)

   A deep infiltration gallery (DIG) or water tunnel is a large pipe or tunnel beneath the seafloor that connects a series of vertical or radial collector wells to an onshore pump station.

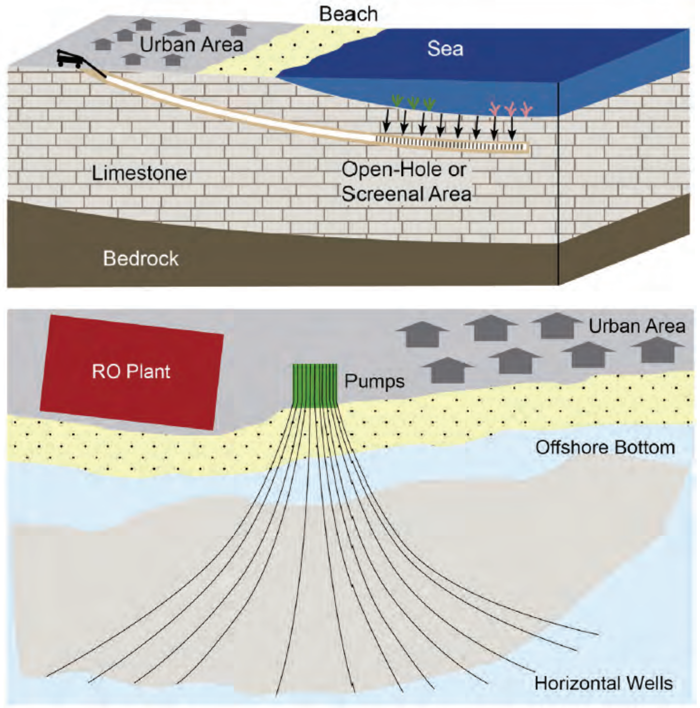
An overview of SSI technologies, including a summary of case studies of existing and proposed SSIs and a review of current regulatory requirements in California applicable to permitting of a desalination facility, is provided in the Technical Memorandum “Subsurface Seawater Intake Technology Overview” prepared by Geosyntec (Appendix A), as part of the “Ocean Water Desalination Subsurface Intake Study.”



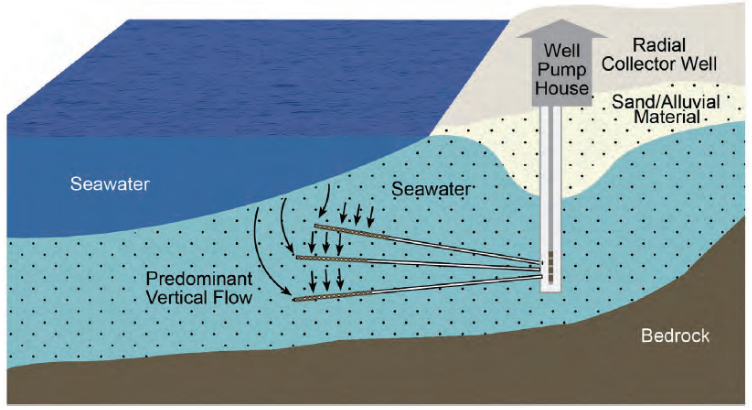
Schematic Representation of a Series of Vertical Wells Along a Beach.
(Adapted from Missimer et al., 2013)



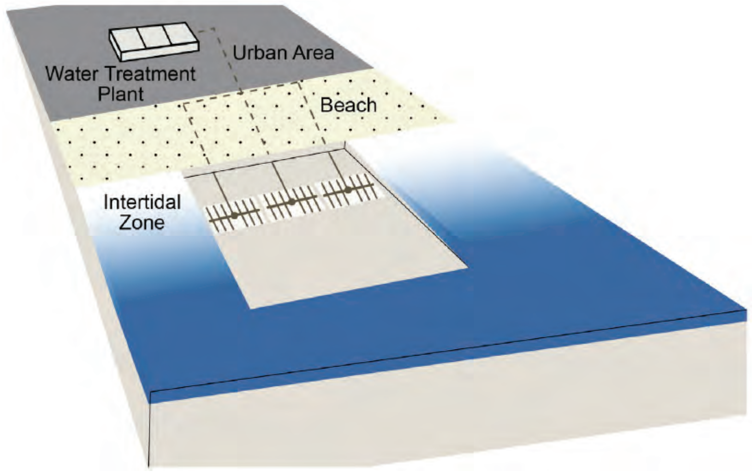
Schematic Representation of a Slant Well.
(Adapted from Missimer et al., 2013)



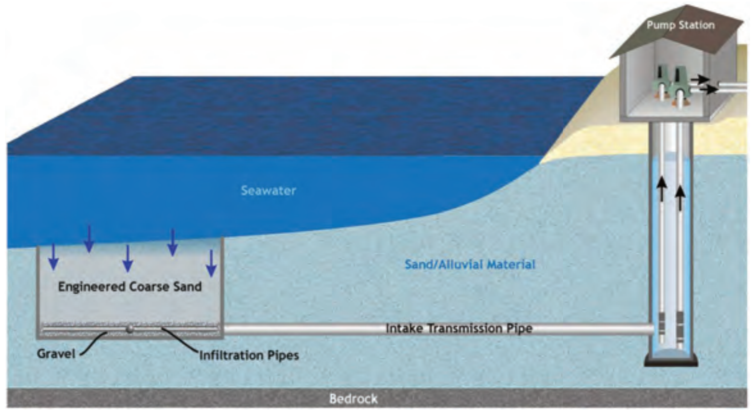
Schematic Representation of a Well Installation (Cross-Section)
and a Cluster of HDD Wells. (Adapted from Missimer et al., 2013)



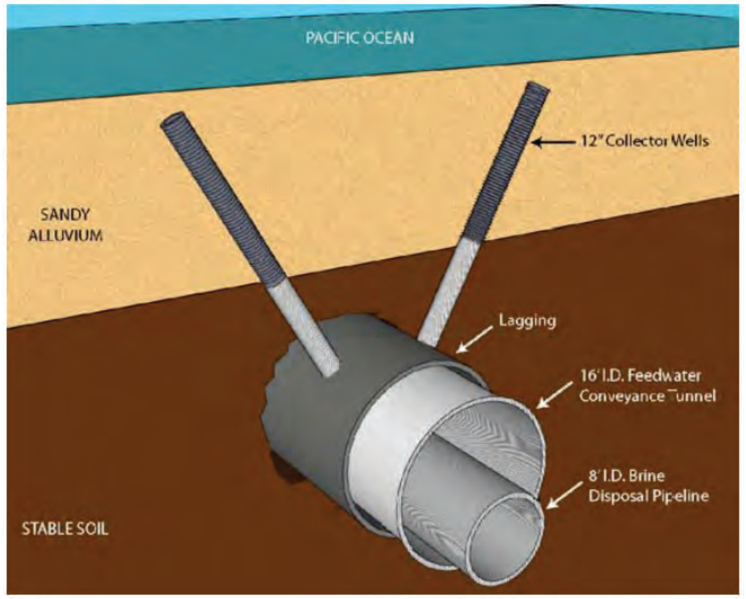
Schematic Representation of Radial Collector Wells.
(Adapted from Missimer et al., 2013)



Schematic Representation of a Beach Infiltration Gallery.
(Adapted from Missimer et al., 2013)



Schematic Representation of a Seabed Infiltration Gallery.
(Adapted from Missimer et al., 2013)



Schematic Representation of a Deep Infiltration Gallery.
(Adapted from ISTAP, 2014)

Schematic Illustrations of Subsurface Seawater Intake Technologies

Subsurface Seawater Intake Study
West Basin Municipal Water District

Geosyntec consultants

LA0324	December 2015	Figure 1.2

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1.3 Guidance Manual and Tool

An SSI Feasibility Screening Tool (Tool) was developed as part of this study in order to evaluate the technical feasibility of SSIs. The Tool is a screening level methodology to assess the potential technical feasibility of the seven different SSIs, listed in Section 1.3, to provide the necessary amount of feed water to meet the design desalination production capacity at a particular site along the California coastline. The scope of the Tool only addresses the technical feasibility of an SSI, defined as "*able to be built and operated using currently available methods*" (ISTAP, 2014)[3]. Additional analysis would be needed in order to determine feasibility for environmental, economic, and social considerations.

The intended users of this Tool are primarily water industry professionals and regulators who could evaluate technical feasibility of various types of SSIs based on site setting, conditions and production requirements. Other stakeholders involved in the decision-making process for desal projects might also use the Tool for assessing the technical feasibility of SSIs. The Guidance Tool was peer-reviewed by the IAP, which was coordinated and facilitated by NWRI.

The Tool is an Excel-based platform that will be available for download on the Bureau of Reclamation website (URL to be determined). The Guidance Manual for the Tool (Geosyntec, 2015) will also be provided on this website. The Tool consists of two steps: evaluation of potential fatal flaws and evaluation of potential challenges. For this evaluation, a fatal flaw is defined as a factor that cannot be reasonably mitigated and therefore the SSI is determined infeasible and eliminated from further consideration.
The Tool includes three general criteria that constitute fatal flaws:

1. Land type makes construction of the SSI infeasible;
2. Available coastline length is insufficient to construct the SSI; and
3. The area of available land (offshore and/or onshore) is insufficient to construct the SSI.

For those SSIs not eliminated by a fatal flaw (first step), the Tool utilizes a scoring system to characterize the technical features and potential challenges of

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[3] An Independent Scientific Technical Advisory Panel (ISTAP) was engaged in 2014 and 2015 under the auspices of the the California Coastal Commission and Poseidon Resources (Surfside) LLC to review feasibility of subsurface intakes for a desal facility proposed at Huntington Beach. The ISTAP review was convened and facilitated by Concur Inc. Reports by the ISTAP addressing feasibility of SSIs the proposed desal facility at Huntington Beach are referenced herein, and because of some similarities in the settings, some of the ISTAP findings and recommendations regarding feasibility of SSIs at Huntington Beach are applicable to SSI feasibility at El Segundo. However, the ISTAP review did not address feasibility of SSIs at El Segundo, and West Basin's investigation of SSI feasibility at El Segundo is independent of the investigation and ISTAP review of SSI feasibility conducted for Huntington Beach.

each SSI (second step). For the five following general categories, 18 criteria were identified as potential challenges affecting the technical feasibility of an SSI:

1. Construction of the SSI;
2. Operation of the SSI;
3. Operation of the treatment system;
4. Potential inland interference; and
5. Risk/uncertainty for project implementation.

The score generated with the Tool can be used to assess potential technical feasibility of each SSI by ranking the degree of challenges for different SSIs based on the 18 criteria within five categories listed above. As the 18 criteria are not considered fatal flaws, a low feasibility score would not result in the SSI being technically infeasible but would indicate that significant mitigation measures might be required to construct and/or operate the SSI. The Tool is based on 31 questions, which define both the intake scenario and the project setting. The user defines the quality of the input data as low, medium or high. The quality of the inputs is used to determine the uncertainty of the resulting scores. A description of the Tool development and setup is provided in the Guidance Manual for the Tool (Geosyntec, 2015).

The initial screening level assessment performed with the Tool is considered “Level 1” analysis. The Tool also provides a list of potential tests and analyses (Levels 2 and 3) that could be performed to obtain more data and improve understanding of site conditions for each of the evaluation criteria. Level 2 tests and analyses can generally be performed for $50,000-$200,000 and within a six month time frame. Level 3 are more in depth analyses that would typically require more time and money.

1.4 Report Organization

This remainder of the report is organized as follows:

- Section 2, *Initial Technical Feasibility Screening of SSI Technologies,* presents a description of the inputs used for preliminary application of the Tool, a description of the initial screening results and a summary of the preliminary footprint estimations.
- Section 3, *Hydrogeological Setting,* presents a description of the onshore and offshore hydrogeological setting of the proposed site, including existing data as well as data collected through field studies conducted as part of this project.

- Section 4, *Evaluation Criteria*, describes the criteria used to evaluate the feasibility, taking into account economic, environmental, social, and technological factors, of SSI technologies at the proposed site.
- Section 5, *Evaluation of SSI Technologies*, provides an evaluation of the overall feasibility of each technically feasible SSI for the proposed desal facility located at El Segundo. The evaluation mainly focuses on the criteria that represent fatal flaws for a given SSI technology, although other challenging criteria are also discussed.
- Section 6, *Conclusions*, summarizes the report findings.

2 Initial Technical Feasibility Screening of SSI Technologies

The Guidance Tool developed as part of this study (see Section 1.4 and Geosyntec, 2015) was applied to the El Segundo site to assess initial technical feasibility of the seven SSIs, and to identify the field investigations necessary to enhance the evaluation and conduct a technically defensible feasibility assessment for the selected site. This section presents the inputs and data sources used to apply the Tool as part of a Level 1 analysis, followed by the results of the initial screening.

2.1 Inputs for Initial Screening

There are 31 questions in the Tool for which inputs are needed to perform the screening evaluation. Default values are provided for all inputs. In addition, the quality of the data input needs to be quantified. The inputs and data quality qualifiers for the El Segundo site are provided in Appendix E and a discussion is provided below of the detailed data sources for inputs that were not based on default values in the Tool. The initial screening with the Tool was conducted with no constraints on the siting of the SSI infrastructures; e.g., 8.2 miles of linear beach front, from Redondo (South) to Marina Del Ray (North), was assumed to be available for siting of the infrastructure in the guidance tool. The Tool is used for screening purposes and as such the inputs were selected to provide screening level values.

Design intake rate for the project

The design intake rate for the project is 40 MGD, which corresponds to a treated water production rate of 20 MGD, which is the low end of the desired production capacity of the proposed facility (Section 1.1). Applying a contingency factor of 20%, a design intake rate of 48 MGD is used in the Tool.

Presence of cliff/inlet

There is no cliff or inlet at the El Segundo site.

Depth to bedrock

The depth to bedrock at the El Segundo site is not known, but existing borings have shown that unconsolidated sediments extends up to 200 feet below ground surface (bgs) (Haley & Haldrich, 2012; Appendix G of El Segundo Power, 2000).

Width of the beach

The average width of the beach for El Segundo site was estimated to be approximately 400 feet based on the general position of the coastline assessed using aerial photos (Google Earth, 2015) without compensation for tides.

Length of available beach front

The length of available beach front was estimated as 43,425 feet (8.2 miles), assuming that the beach front from Redondo (South) to Marina Del Ray (North) was available for construction of the SSIs. The available beach front is shown in Figure 2.1.

Area of available land onshore

The area of available onshore land was estimated to be 17,802,000 ft^2 (410 acres) using the length of available beach front and the general position of the coastline. The available onshore land is shown in Figure 2.1.

Area of available land offshore

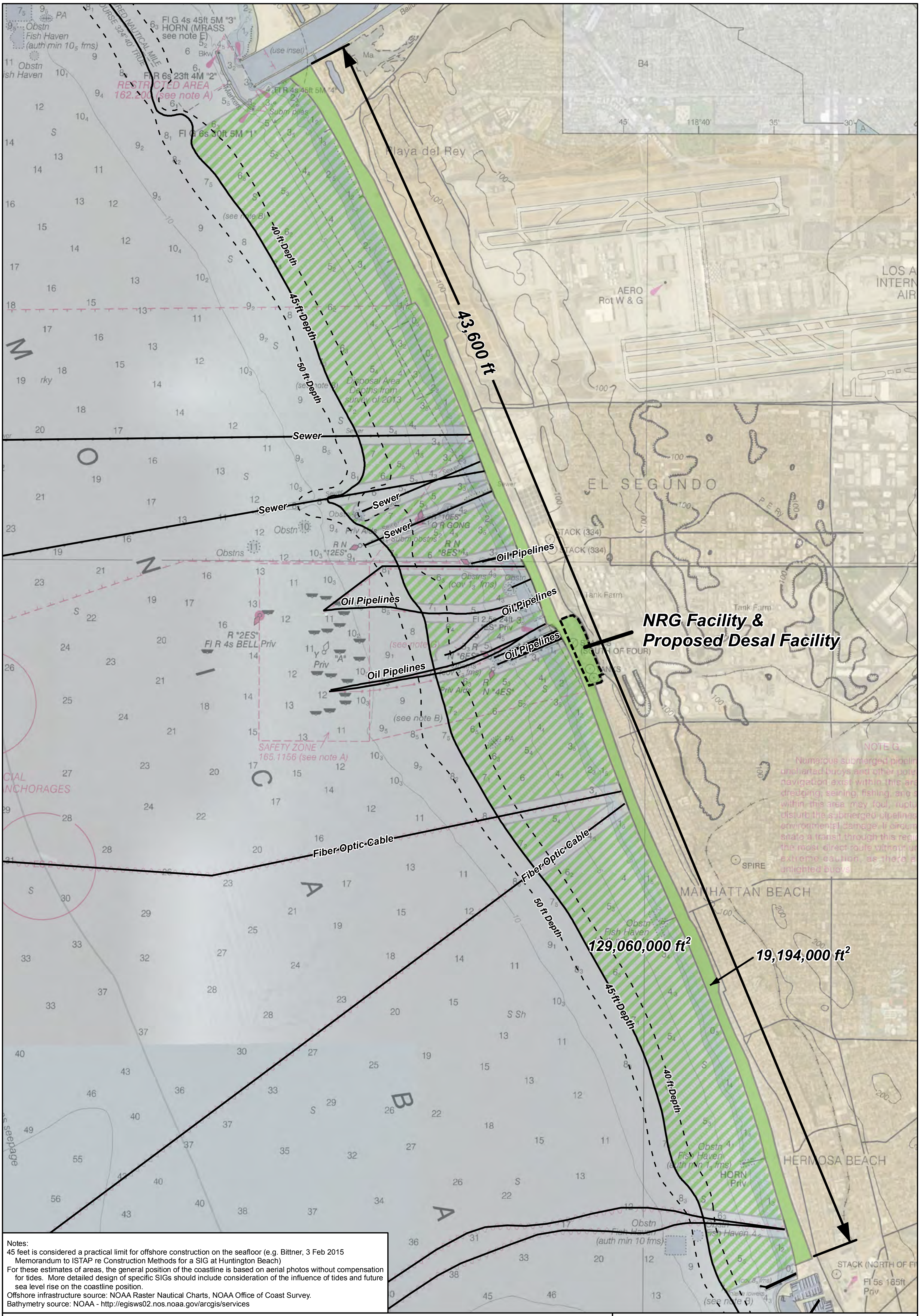
The area of available offshore land was estimated to be 125,042,000 ft^2 (2,900 acres) using the length of available beach front and the available offshore areas, defined as 1) shallower than 45 feet below sea level; and 2) 300 feet buffer distance from any of the existing offshore infrastructure, such as sewer discharge lines, oil pipelines, etc. The 45 feet below sea level limit is considered practical for offshore construction on the seafloor using the trestle approach (Bittner, 2015). The locations of the offshore infrastructure were obtained from the National Oceanic and Atmospheric Administration (NOAA) raster navigation charts (NOAA OCS, 2015). The available offshore area and the offshore infrastructure are shown in Figure 2.1.

Area available for drilling and staging equipment

The area is estimated to be 436,000 ft^2 (10 acres), which corresponds to the area of the NRG Facility that can be used for staging equipment.

Topography

The topography of the El Segundo site is generally flat. The average slope of the NRG Facility is four degrees, with locally steeper slopes between the NRG Facility and the beach (California State Lands Commission, 2010).



Notes:
45 feet is considered a practical limit for offshore construction on the seafloor (e.g. Bittner, 3 Feb 2015 Memorandum to ISTAP re Construction Methods for a SIG at Huntington Beach)
For these estimates of areas, the general position of the coastline is based on aerial photos without compensation for tides. More detailed design of specific SIGs should include consideration of the influence of tides and future sea level rise on the coastline position.
Offshore infrastructure source: NOAA Raster Nautical Charts, NOAA Office of Coast Survey.
Bathymetry source: NOAA - http://egisws02.nos.noaa.gov/arcgis/services

Legend

🟩 Onshore Area

▨ Offshore Area

— Offshore Infrastructure

N

0 3,000 Feet

Available Areas Used for Initial Technical Screening

Subsurface Seawater Intake Study
West Basin Municipal Water District

Geosyntec consultants

Figure 2.1

LA0324 | December 2015

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Slope of the seabed

The slope of the seabed in the Santa Monica Bay is low, approximately 0.5 degrees (California State Lands Commission, 2010).

Depth to seabed

The depth to seabed at the planned construction site was estimated to be 20 feet, which is the midpoint between the shore and the depth to seabed at the assumed practical limit of 45 feet.

Transmissivity of the sediments

The transmissivity of the sediments were estimated from former estimates of hydraulic conductivity and transmissivity values based on grain-size analysis, aquifer tests performed in the vicinity, percolation tests and numerical models developed for the regional area. For the different SSIs, the transmissivity values were estimated specifically as follows:

- Vertical wells were assumed to be screened in both the Gage and Silverado aquifers. The hydraulic conductivity of the Gage and Silverado aquifers in the vicinity of the El Segundo site is approximately 10 – 100 and 100 – 200 feet per day (ft/day), respectively, based on the numerical model developed for the West Basin Injection Barrier (Geoscience, 2009); the thickness is approximately 50 feet (Gage) and at least 100 feet (Silverado) (MWH, 2007). A transmissivity value of 130,000 gallons per day per foot (gpd/ft) (17,500 ft^2/day) was used in the Tool.
- Slant wells were also assumed to be screened in both the Gage and Silverado aquifers. Similarly to vertical wells, a transmissivity value of 130,000 gallons gpd/ft (17,500 ft^2/day) was used in the Tool.
- Radial collectors were assumed to be screened in the Gage aquifer only. A transmissivity value of 20,000 gpd/ft (2,500 ft^2/day) was used in the Tool.
- HDD wells were assumed to be screened 20 feet below the seafloor. Percolation rate tests performed on two samples of sand with gravel collected in one boring from depths of 13 and 29 feet in the vicinity of the NRG Facility indicated hydraulic conductivity between 1 and 6 ft/day (Appendix G of El Segundo Power, 2000). For screening purposes, an optimistically high transmissivity value of 5,000 gpd/ft (600 ft^2/day) was used in the Tool.
- A water tunnel is assumed to be installed 50 feet under the seabed. Similarly to HDD wells, a transmissivity value of 12,000 gpd/ft (1,500 ft^2/day) was used in the Tool.

Leakance of overlying the sediments

The leakance of the overlying sediments, which is the vertical hydraulic conductivity divided by thickness, is used to assess the hydraulic connection between the sediments and the ocean. The leakance values were estimated similarly to the transmissivity values. Specifically for the different SSIs, the leakance values were estimated as follows:

- For vertical wells, the vertical hydraulic conductivity of the Gage aquifer was assumed to be 1/10th of the horizontal hydraulic conductivity.4 A leakance value of 0.05 1/day was used in the Tool.
- Similarly for slant wells, a leakance value of 0.05 1/day was used in the Tool.
- Radial collectors are screened shallower than vertical wells and slant wells, so a leakance value of 0.1 1/day was used in the Tool.
- HDD wells were assumed to be screened 20 feet below the seabed. Based on the results of the percolation rate tests, a leakance value of 0.15 1/day was used in the Tool.
- Water tunnel is assumed to be installed 50 feet under the seabed. Similarly to horizontal wells, a leakance value of 0.06 1/day was used in the Tool.

Typical significant wave height

Average deep water wave heights offshore of the NRG Facility for the period 1980 to 2001 were 2.5 feet (California State Lands Commission, 2010) and this value was used in the Tool for the typical significant wave height.

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[4] Layered heterogeneity within sequences of alluvial deposits results in values of bulk anisotropy of horizontal to vertical hydraulic conductivity (Kh:Kv) that are commonly 100:1 or larger (e.g. Freeze and Cherry, 1979; Anderson et al., 2015). A Kh:Kv ratio of 10:1 provides an optimistically high hydraulic connection of SSIs through overlying sediments and the ocean.

Beach re-nourishment and mean sea levEl Shoreline

No direct information on beach re-nourishment was available for the El Segundo site. However, based on the fact that the beach in front of the NRG Facility has a high erosion potential (California State Lands Commission, 2010), and there is a large change in the position of the coastal margin north and south of the jetty or rock groin adjacent to the NRG Facility (much wider beach north of the jetty) (Google Earth, 2015; California State Lands Commission, 2010), the beach was defined as re-nourished in the past 10 years and a value of 20 feet was used for the annual mean sea levEl Shoreline change.

Inland groundwater level

Inland groundwater level of the coastal aquifer is above sea water level in the vicinity of the El Segundo site, as shown on groundwater contour maps of the area (MWH, 2007).

Contaminated groundwater in the vicinity

Contaminated groundwater is present below and in the vicinity of the NRG Facility (e.g. TriHydro, 2015), therefore, in the Tool, it is stated that a contaminant plume exists in the vicinity.

Sedimentation rate

Sedimentation rates are elevated in Santa Monica Bay, with estimates between 1.8 and 9.7 mm/year (Farnsworth and Warrick, 2007). A value of 6 mm/year was used in the Tool.

Source water turbidity

The water clarity within Santa Monica Bay is relatively high (California State Lands Commission, 2010), and feed water turbidity below 7 Nephelometric Turbidity Unit (NTU) was measured at the El Segundo pilot plant during operation between 2004 and 2009 (SPI, 2010), therefore a turbidity value of 5 NTU was used in the Tool for SSIs pumping seawater from below the Bay seabed (HDD wells, BIG, SIG and water tunnel).

Feed water Silt Density Index (SDI)

There is no information on feed water SDI but most of the seafloor within Santa Monica Bay consists of unconsolidated sediments, with a significant fraction of silt and clay (California State Lands Commission, 2010). Therefore a high SDI value of 3 was used in the Tool for SSIs pumping seawater from below the seafloor (HDD wells, BIG, SIG and a water tunnel).

Extremely impaired source

Because of the presence of contaminated groundwater in the vicinity, the feed water could include contribution from an extremely impaired source based on the California Water Resource Control Board Division of Drinking Water (DDW).

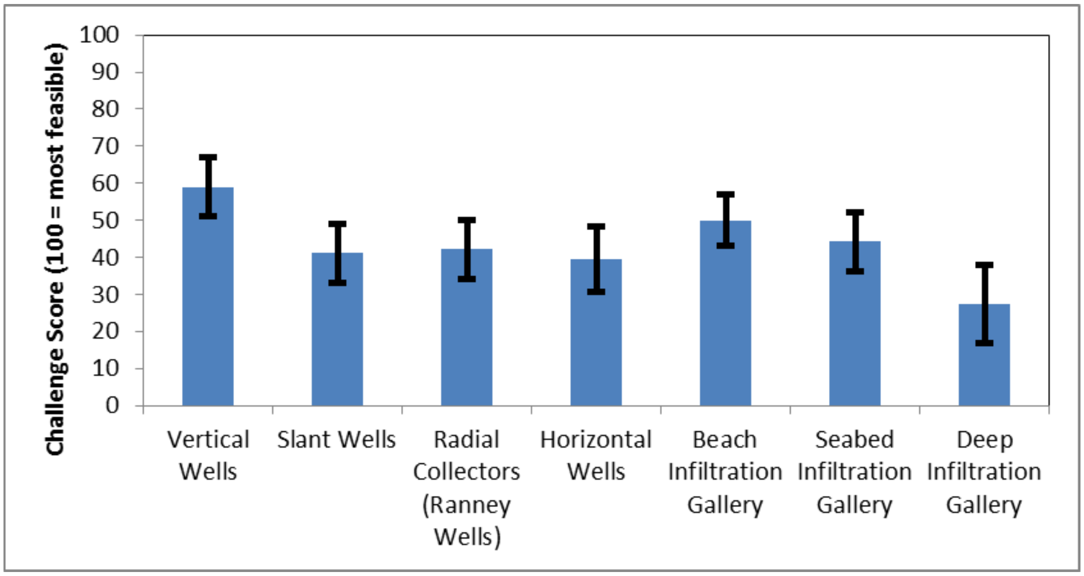
2.2 Initial Screening Results

The initial screening results are presented in Table 3.1. The detailed results for each SI are provided in Appendix E. All technologies were shown to be technically feasible under the assumption that there are no constraints on the siting of the SSI infrastructures. The beach front from Redondo (South) to Marina Del Ray (North) was assumed available. Two of the three fatal flaws are related to siting (available coastline and available areas onshore and offshore) and the initial screening was performed under the assumption that there are no constraints on the siting of the SSI infrastructures, therefore the initial screening results are conservative, as most favorable conditions were assumed. The scores with the error bars calculated based on the quality of the input data are illustrated in the graph below. The level of feasibility based on the scores is as follows (from most to least feasible): vertical wells > BIG, SIG, HDD wells, slant wells, radial collectors > DIG.

Table 2.1: Challenge Scores from Guidance Tool

Normalized Challenge Score 0=most challenging 100=most feasible							
	Vertical Wells	Slant Wells	Radial Collectors (Ranney Wells)	HDD Wells	BIG	SIG	DIG
Totals (100 = most feasible)[1]	**59**	**41**	**42**	**39**	**50**	**44**	**27**
Fatal Flaw	**No**	**No**	**No**	**No**	**No**	**No**	**No**

[1] The score is based on 18 criteria within five following general categories; constructability, operation of the SSI, operation of the treatment system, potential inland interference and technical risk/uncertainty for project implementation.



Vertical wells are the most technically feasible technology based on this initial screening. The main challenges for vertical wells are the beach instability, the clogging potential of the well screens, the potential inland interference, and the potential consideration of the water as an extremely impaired source. Based on the uncertainty associated with the result scores, BIG, SIG, HDD wells, slant wells and radial collector wells are all considered equally feasible. The main challenges for BIG are the beach instability, clogging potential of the gallery, and the potential consideration of the water as an extremely impaired source. In addition, a BIG suffers from lack of demonstrated success for facilities with similar capacities and in similar high energy wave environments. A SIG has similar challenges as a BIG, in addition to significant challenges for construction and maintenance. The main challenges for HDD wells, radial collectors and slant wells are beach instability, geological conditions (for HDD wells and radial collectors), potential consideration of the water as an extremely impaired source, and lack of demonstrated success for facilities with similar capacities. In addition, slant wells and HDD wells are also expected to be challenging to maintain, and a high clogging potential is anticipated for HDD wells.

Finally, a DIG is the least feasible technology, because of the complexity of construction, challenging maintenance, and lack of demonstrated success for similar capacity systems.

Based on the initial high-levEl Screening analysis (Level 1), since all technologies are technically feasible, they all are carried forward for additional analysis. Additional analysis includes “Level 2” investigations in the vicinity of the NRG Facility, as described in Section 3.2.

2.3 Preliminary Area Estimations Using Guidance Tool

The Tool used for the initial screening above also provided estimates of required linear beach front, onshore areas, and offshore areas as summarized in Table 2.2.

Table 2.2: Subsurface Seawater Intake Preliminary Calculations

	Vertical Wells	**Slant Wells**	**Radial Collector Wells**	**Horizontally Directionally Drilled Wells**	**Beach Infiltration Gallery**	**Seabed Infiltration Gallery**	**Deep Infiltration Gallery**
Yield estimate	1 MGD per well	5 MGD per three-well cluster	5 MGD per well	3 MGD per horiz. well	0.1 gpm/ft^2	0.1 gpm/ft^2	1.8 gpm/ft
Units required for 40 MGD with 20% safety factor	48 wells	10 three-well clusters	10 wells	16 horiz. wells	335,000 ft^2	335,000 ft^2	19,000 ft
Linear beachfront	4,700 ft	5,200 ft	3,000 ft	1,400 ft	1,100 ft	NA	NA
Onshore area	12,000 ft^2	48,000 ft^2	96,000 ft^2	minimal	minimal	minimal	minimal
Offshore area	NA	NA	NA	1,600,000 ft^{2*}	335,000 ft^2	335,000 ft^2	37,000 ft$^{2\wedge}$
Well heads likely required outside of NRG Facility	Yes	Yes	Yes	No	No	No	No

* The offshore area of HDD refers to the area of the seafloor under which HDD wells would be constructed (1,000 ft long wells and 100 ft spacing between wells).

^ The offshore area of a DIG is based on a tunnel type design (Appendix A).

Due to limitations of the linear beach front requirements, some technologies will likely require construction outside of the NRG footprint (2,450 feet of beach front), and this has construction-related disturbances and impacts either in front of residential property or in snowy plover habitat (see Sections 0 and 0). These implications are further discussed in Section 5.

The offshore area requirements for all SSI technologies can be satisfied through consideration of only the offshore area available directly in front of the NRG site (available offshore land area is 7,786,000 ft^2). Because of this, the available offshore areas for the El Segundo site are not considered to be a restriction for any SSI technology. However, the presence of buried offshore infrastructure does provide some challenges (see Section 4.4.3).

As described in Section 4, numerous criteria need to be considered when assessing the overall feasibility of different SSI technologies. Many of these are unique to specific sites and cannot adequately be assessed by the Tool, which was developed for general screening purposes. More detailed assessments of the specific intake technologies for the NRG Facility are provided in the following sections.

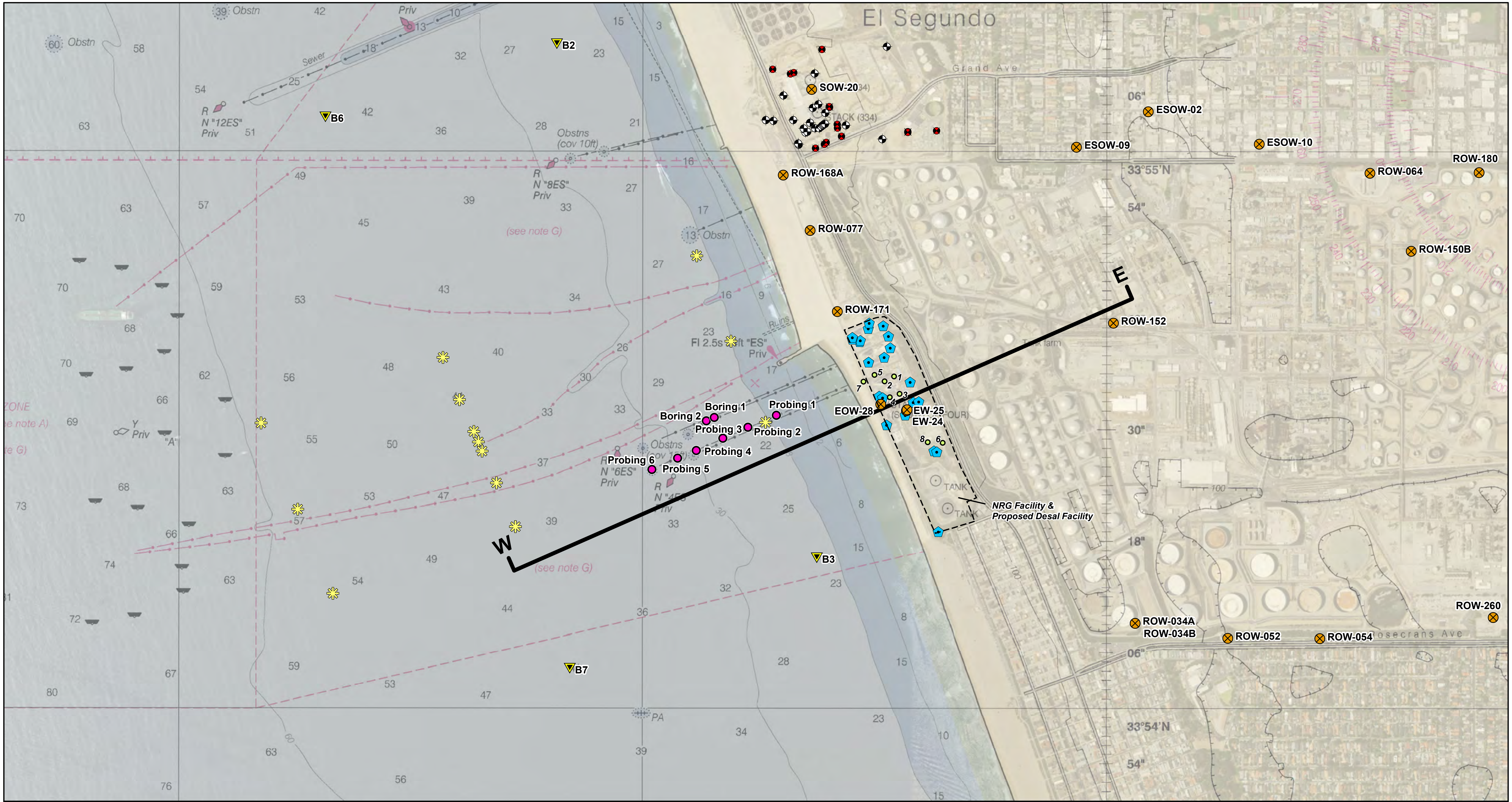
3 Hydrogeological Setting

The El Segundo site is located on the coastal edge of the West Coast Basin. The West Coast Basin is a major coastal groundwater basin and detailed studies of its hydrogeological setting have been conducted by the U.S. Geological Survey (USGS), California Department of Water Resources (DWR), Los Angeles County Flood Control District (LACFCD), California Department of Public Works (DPW), and several other agencies (e.g., DWR, 1961; LACFCD, 1957; USGS, 2003). The nearshore area of El Segundo is underlain by a thick, interbedded sequence of Quaternary (Holocene and Pleistocene) clays, silts, sands, and gravels (California State Lands Commission, 2010; Appendix G of El Segundo Power, 2000). This section summarizes existing hydrogeological data relevant to the installation and operation of SSIs, and describes the field investigations conducted to improve the accuracy of the hydrogeological information at the El Segundo site.

3.1 Review of Existing Hydrogeological Data

Available information about the hydrogeological characteristics of the shallow subsurface near the coastal margin in the vicinity of the proposed El Segundo desal facility is summarized below; Figure 3.1 shows the locations of borings, monitoring wells and sediment samples:

- Numerous borings and monitoring wells at the NRG and Chevron Refinery Facilities (e.g. CA RWQCB Geotracker website);
- Two offshore borings approximately 1,500 feet offshore to depths of ~40 feet below the seafloor (Dames and Moore, 1954 in Appendix G of El Segundo Power, 2000);
- Six offshore “probings” 800 to 2,500 feet offshore installed to depths of approximately 10 to 25 feet below the seafloor (Dames and Moore, 1962 in Appendix G of El Segundo Power, 2000); and
- 13 shallow seafloor samples 1,000 to 6,000 feet offshore (Fugro West 2004, 2007 in California State Lands Commission, 2010);



Legend

✳ Offshore Seafloor Sediment Sample Location
(State Lands EIR, Chevron El Segundo Refinery, 2010; Fugro West 2004, 2007.)

▼ **B7** Benthic Station Location*

○ **8** Dames & Moore Boring (1962)*

⊗ **ROW-052** Monitoring Well Location**

● **Probing 6** Boring (1954)/Probing (1962) Location*

◈ Scattergood Monitoring Well ***

● Decommissioned Scattergood Monitoring Well ***

⬟ El Segundo Energy Center Monitoring Well****

W — E Cross-Section

Source:
* El Segundo Power, II LLC, 2000. Application for Certification Submitted to the California Energy Commission, El Segundo Power Redevelopment Project. Appendix G.
** Geotracker, Chevron El Segundo Refinery, Site # SL372482441
*** Chevron Decommissioning Wells Report
**** Shaw Environmental, Groundwater Well Map

N

0 1,000 Feet

Former Investigation Locations

Subsurface Seawater Intake Study
West Basin Municipal Water District

Geosyntec consultants

Figure
3.1

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Based on review of these data, the subsurface near the coastal margin in the vicinity of the NRG Facility to depths of approximately 100 feet below sea level appears to have a generally consistent stratigraphy, which is described below in descending order and summarized in Table 3.1:

- The Old Dune Sand Aquifer includes Recent and Upper Pleistocene dune sands, and consists of well-sorted, fine- to medium-grained sand, along with discontinuous lenses of silt, coarse-grained sand, and gravel (California State Lands Commission, 2010). The Old Dune Sand Aquifer ranges in thickness from approximately 90 to 180 feet in the eastern portion of the Chevron Refinery, to approximately 55 feet in the vicinity of the NRG Facility.
- The Manhattan Beach Aquitard is a multi-layered assemblage of clay, silt, and very fine-grained sand of variable thickness and presence (California State Lands Commission, 2010). Although previous investigations have reported that the presence of the Manhattan Beach Aquitard is uncertain beneath the northern portion of the NRG Facility (California State Lands Commission, 2010; Appendix G of El Segundo Power, 2000; TriHydro, 2015), offshore borings and jet probes from 1954 and 1962 and the offshore geophysical survey conducted as part of this study show a thin fine-grained layer that appears to correlate with the Manhattan Beach Aquitard extending at least 1,500 feet north of the NRG Facility and approximately 2,000 feet offshore.
- The Gage Aquifer represents the Upper Pleistocene Lakewood Formation and consists of coarse poorly-graded sand with localized layers of silt and clay. The Gage Aquifer has a relatively constant thickness of 20 feet (California State Lands Commission, 2010). The Old Sand Dune and Gage Aquifers are reported to merge where the Manhattan Beach Aquitard is not present (California State Lands Commission, 2010; Appendix G of El Segundo Power, 2000; MWH, 2007).
- The El Segundo Aquitard is the uppermost unit of the lower Pleistocene San Pedro Formation, and consists of blue-gray to dark-gray laterally extensive, dense silty clay, containing abundant shells and wood fragments (California State Lands Commission, 2010; Appendix G of El Segundo Power, 2000; TriHydro, 2015). The thickness of the aquitard varies between 10 and 25 feet in the vicinity of the NRG facility (Appendix G of El Segundo Power, 2000; MWH, 2007).
- The Silverado Aquifer represents the lower Pleistocene San Pedro Formation and is bound below by the Pico Formation (California State Lands Commission, 2010). The Silverado Aquifer consists of fine- to coarse-grained sand and gravel with interbeds of pebbles; localized lenses

of silt and clays up to 10 feet thick are also observed (TriHydro, 2015). The thickness of the Silverado Aquifer is not documented in the vicinity of the NRG Facility (TriHydro, 2015), but is believed to be at least 105 to 125 feet (MWH, 2007). Based on the offshore geophysical survey, the Silverado Aquifer or similar material is estimated to extend to depths of approximately 600 feet.

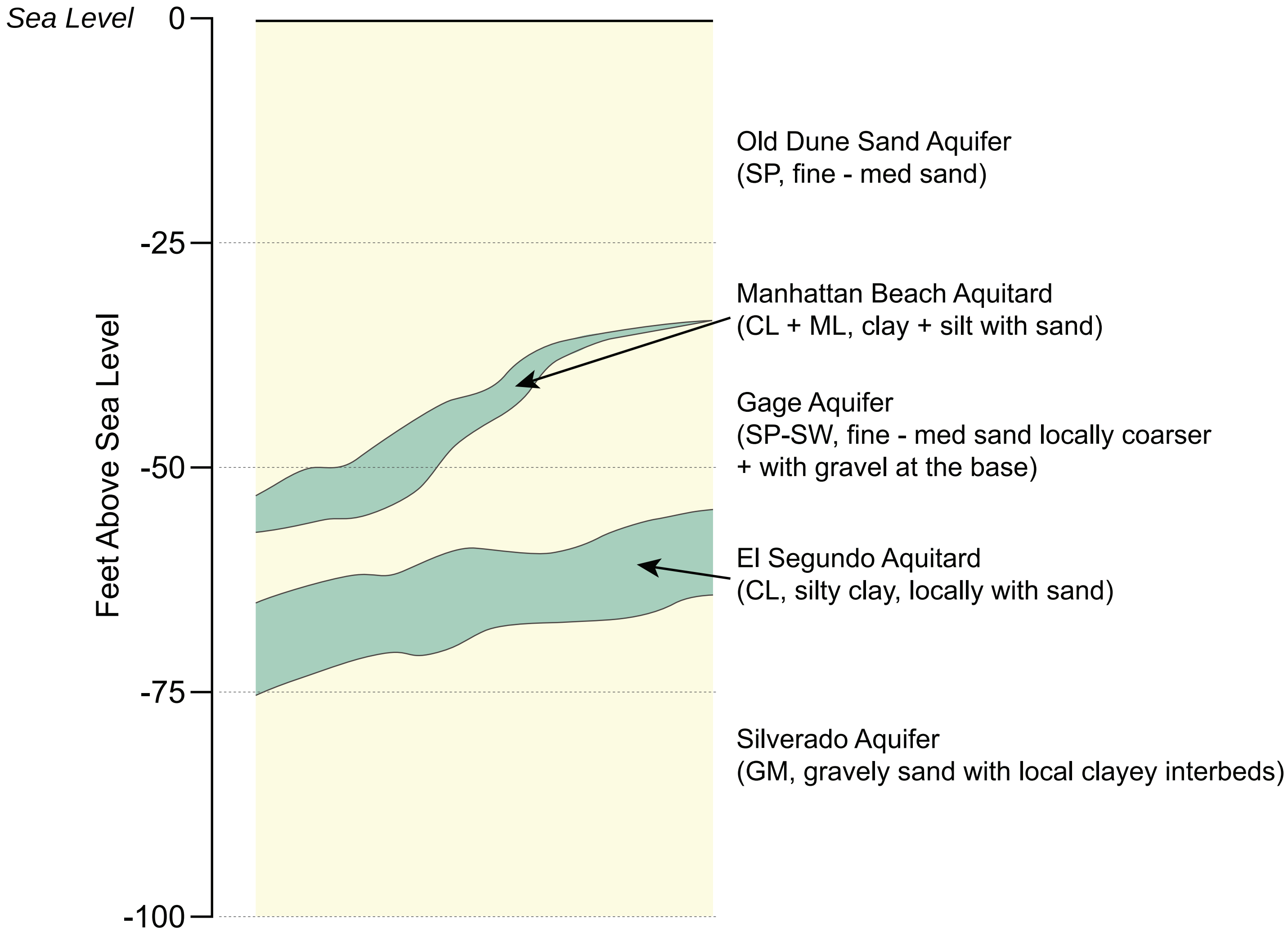
A schematic stratigraphic column is provided in **Figure 3.2**.

Table 3.1: Summary of Hydrostratigraphy in the Vicinity of the NRG Facility

Elevation of Top	Elevation of Bottom	Description	Name
Sea level and higher	35 to 50 feet bsl	Mainly fine-medium sand (SP), locally some gravel and cobbles; locally coarsening downward	Old Dune Sand Aquifer
35 to 50 feet bsl	40 to 60 feet bsl	Clay and Silt (CL & ML)	Manhattan Beach Aquitard
40 to 60 feet bsl	50 to 65 feet bsl	Fine-medium sand to gravelly sand (SP & SW)	Gage Aquifer
50 to 65 feet bsl	65 to 75 feet bsl	Clay and silty clay (CL)	El Segundo Aquitard
65 to 75 feet bsl	Bottom not defined by local borings, but estimated to extend to a depth of approximately 600 ft by the offshore geophysical survey.	Gravelly sand with silt with clayey interbeds (GM with CL)	Silverado Aquifer

feet bsl = feet below sea level

Based on the available geological data, a schematic cross-section of the hydrostratigraphy in the vicinity of the NRG Facility is provided in Figure 3.3.



Legend

🟨 Coarse Grained Material

🟩 Fine Grained Material

Schematic Stratigraphic Column
El Segundo Coastal Margin

Subsurface Seawater Intake Study
West Basin Municipal Water District

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Figure

3.2

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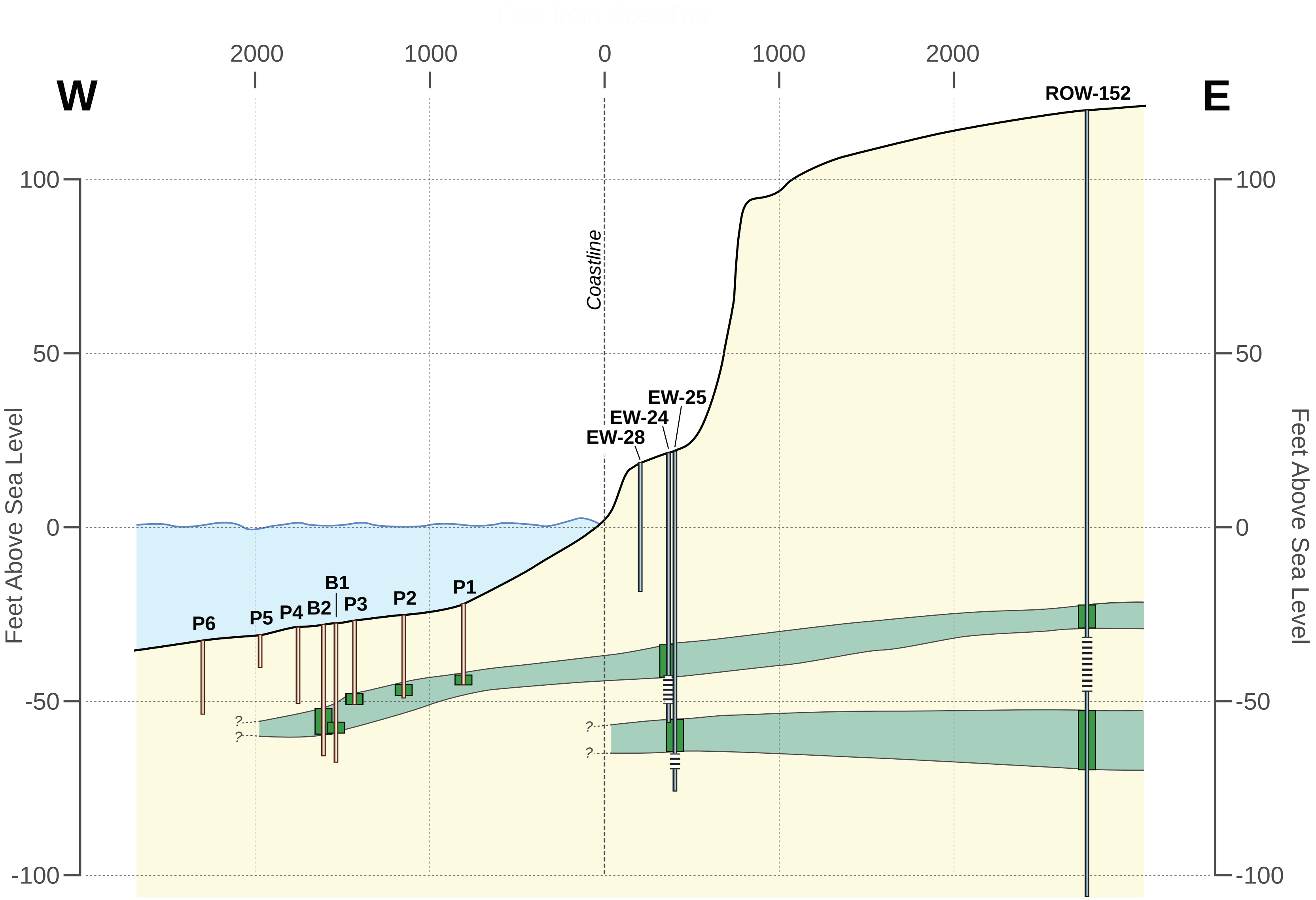

Legend

🟨 Coarse Grained Material

🟩 Fine Grained Material

B2

Soil Boring

Soil Log Indicating Fine Grained Material

EW-24

Extraction Well

Well Screen

Note:
Cross-section location shown on Figure 3.1.

Cross-Section
El Segundo Vicinity

Subsurface Seawater Intake Study
West Basin Municipal Water District

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Figure

3.3

The clayey interval, which begins at an elevation of approximately 40 to 50 feet below sea level (feet bsl), is an important factor in evaluating feasibility and conceptual design of HDD wells as intakes for the proposed desal facility at the NRG Facility. This clayey interval may correlate with the Manhattan Beach Aquitard, which occurs between the Old Dune Sand and Gage Aquifers. However, some reports (e.g. TriHydro, 2015; Shaw 2007; El Segundo Power, 2000) indicate that the Manhattan Beach Aquitard may not be present near coastline portion of the Chevron Refinery or beneath the northern portion of the NRG Facility. Alternatively, this clayey interval may correlate with the El Segundo Aquitard, in which case the overlying sand may correlate with both the Old Dune Sand and Gage Aquifers. The El Segundo Aquitard is reported to range in thickness from 5 to 15 feet with its basal elevation ranging from 35 to 55 feet bsl (Appendix G of El Segundo Power, 2000).

Although the stratigraphic correlation is uncertain, this low permeability clayey interval was encountered in five borings 800 to 1,600 feet offshore of the NRG Facility at depths of approximately 20 to 25 feet below the seafloor; based on onshore borings it may be 5 to 10 feet thick. Based on typical hydraulic conductivity values for sandy and clayey material (e.g. Anderson et al., 2015), the vertical hydraulic conductivity of the clayey interval is likely to be at least 100 to 1,000 times lower than the horizontal hydraulic conductivity of the overlying very fine sand, which was estimated in the order of 1 to 50 ft/d (see Section 3.2.1 below). As this shallow clayey interval may be a key limitation in the hydraulic connection between the ocean and SSIs completed beneath it, additional investigations were performed to delineate this layer and estimate its hydraulic conductivity (Section 3.2).

Grain-size distribution for five samples of seafloor sand collected between distances of approximately 1,000 and 6,000 feet offshore along the Chevron Terminal Pipeline just north of the NRG Facility (see locations in **Figure 3.1**) show that the seafloor consists of very fine to fine sand in this area (California State Lands Commission, 2010). Additional evaluation of the grain-size distribution of these five samples is provided in Section 3.2.1.

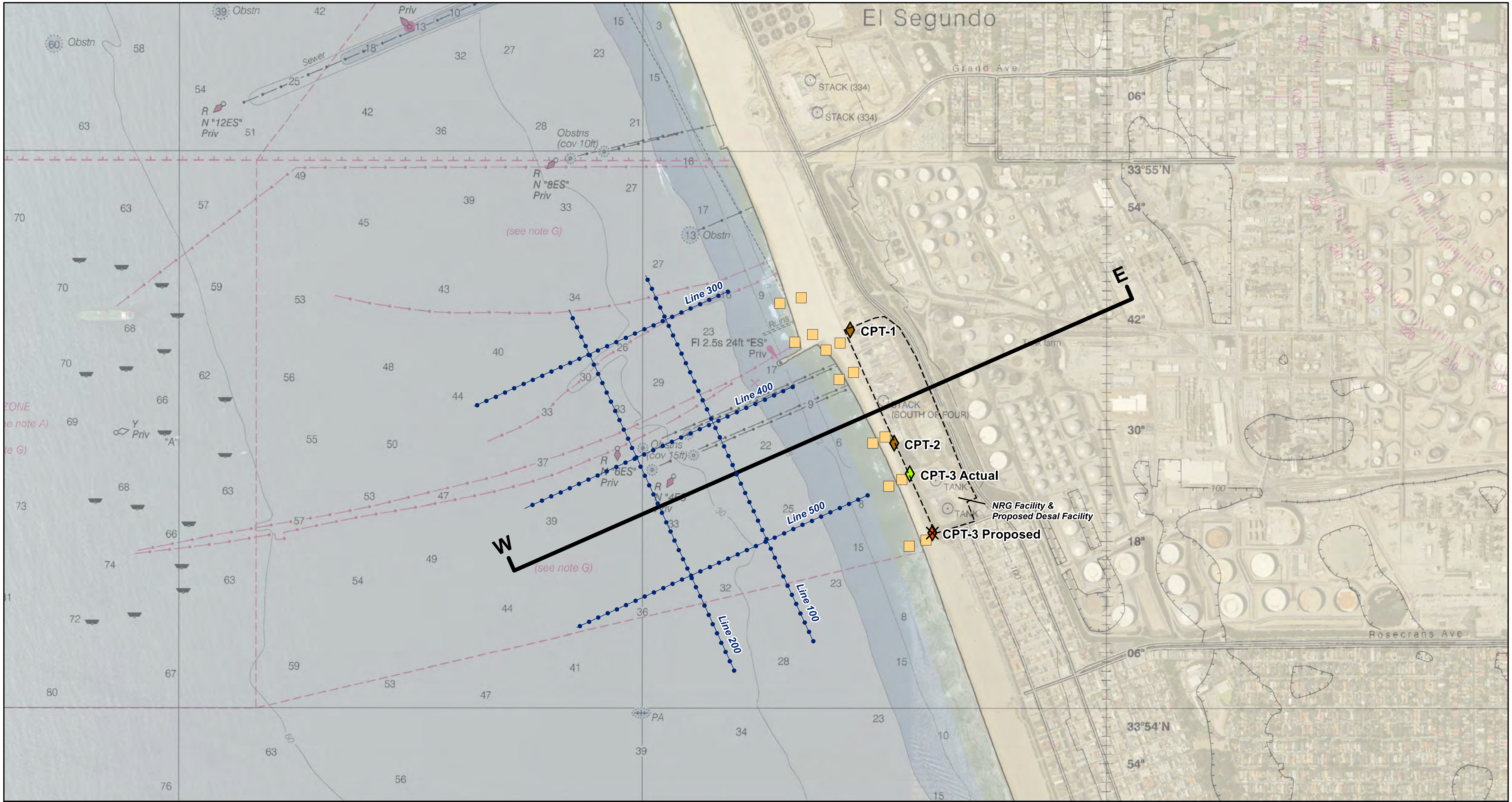
3.2 Field Testing

Site-specific field investigations and testing were conducted to better characterize the shallow sediments near the coastal margin in the vicinity of the NRG Facility and to delineate the extent of the shallow clay layer identified based on existing data. A field testing and sampling plan was prepared and is provided in Appendix F. Locations of field investigations conducted as part of this study are shown on Figure 3.4 and included the following:

- Grain size analysis of samples collected on the beach and at the surf zone to estimate hydraulic conductivity of the shallow sediments;

- Cone penetrometer testing (CPT) borings along the coastal margin in the NRG Facility to characterize the subsurface stratigraphy, and pore-pressure dissipation testing to measure permeability of the subsurface sediments; and
- Offshore sub-bottom profiling and multi-channel seismic reflection geophysical surveys to characterize the shallow offshore stratigraphy, specifically the extent and continuity of the clay interval.

These investigations are considered “Level 2” analyses and tests, as defined in Section 1.4, and were selected to refine the initial feasibility screening.
Field testing and results are described in details below.



Legend

◆ Refusal at 27 ft bgs

◆ Refusal at 81 ft bgs

☒ Unable to access with CPT rig

🟧 Beach and Surf-Zone Sand Sample (July 2015)

•-• Seismic Reflection Lines

W — E Cross-Section

Note:
ft bgs - feet below ground surface

N

0 1,000 Feet

Field Testing Locations

Subsurface Seawater Intake Study
West Basin Municipal Water District

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Figure 3.4

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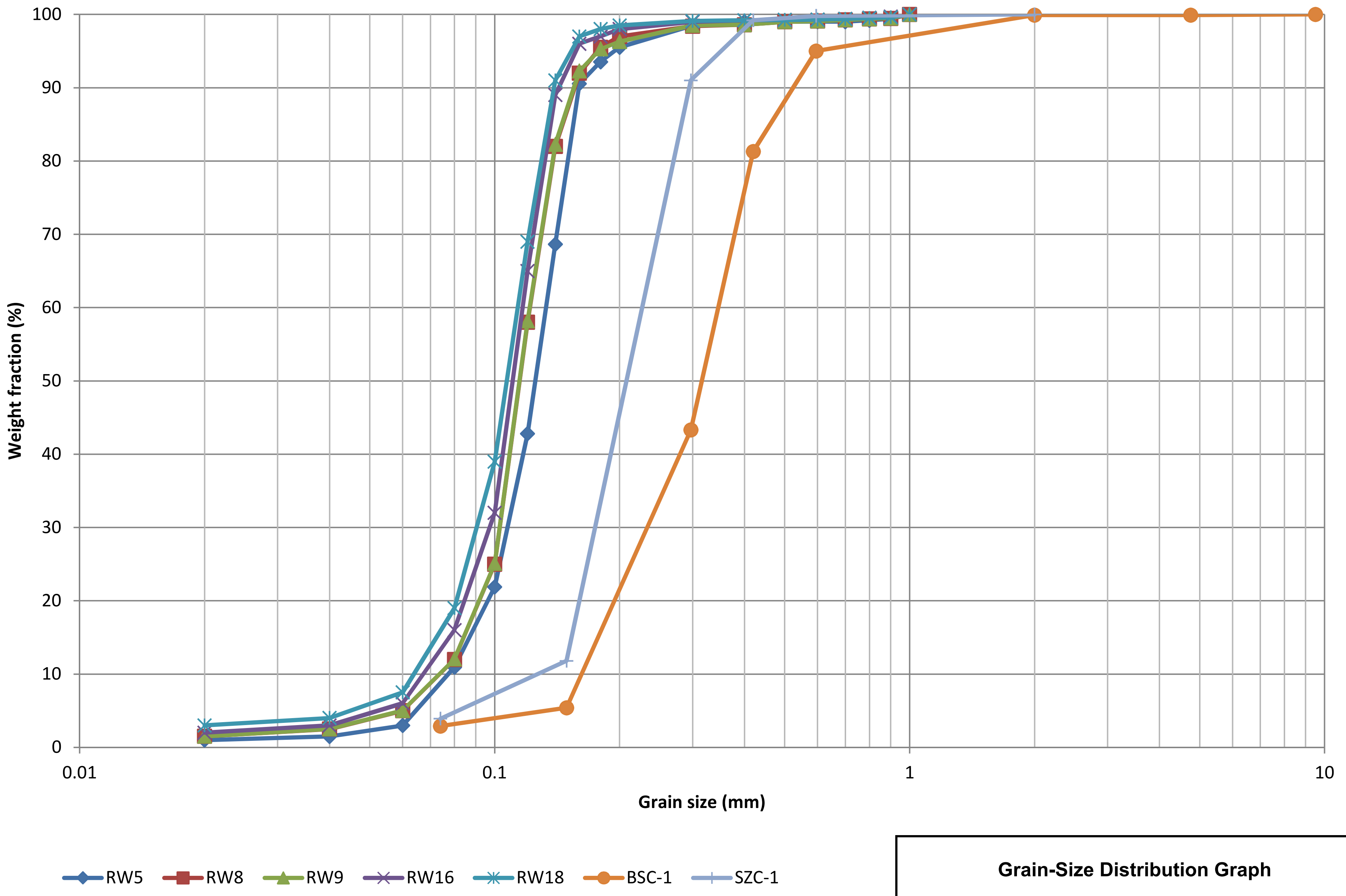
3.2.1 Grain-Size Analysis

Five samples of seafloor sand (RW5, RW8, RW9, RW16, and RW18) were previously collected (prior to 2007) between distances of 1,000 and 6,000 feet offshore and between depths of 20 and 60 feet along the Chevron Terminal Pipeline north of the NRG Facility. Grain-size analyses of these seafloor samples are included in the Public Draft Environmental Impact Report for the Chevron El Segundo Marine Terminal (California State Lands Commission, 2010). On 8 July 2015, seven surf zone sand samples and seven beach sand samples were collected by Geosyntec personnel. These samples were combined to form one composite sample for the surf zone (SZC-1) and one composite sample for the beach sand (BSC-1). The sample locations are shown in Figure 3.4. The two composite samples were sent to Cooper Testing Laboratory for analysis.

The grain-size data of the beach and seafloor samples are shown in Figure 3.5. Grain-size distribution for the seafloor samples show consistent fine to very fine sand. The majority of the beach samples are fine sand, and SZC-1 is finer than BSC-1. Hydraulic conductivities for the seafloor sand samples calculated from the grain-size data are listed in Table 3.2. The values range from 2 to 29 ft/day for a porosity of 0.3, and from 3 to 49 ft/day for a porosity of 0.26, and show decreasing hydraulic conductivity as offshore distance increases.

A permeability test was also performed by Cooper Testing Laboratory on SZC-1 sample. The resulting measured hydraulic conductivity value (46 ft/day) is consistent with the hydraulic conductivity estimated using grain-size distribution for this sample (29 – 49 ft/day). The details of the calculations of hydraulic conductivity values based on grain-size distribution and the accompanying laboratory report are provided in Appendix G.



Note:
Grain-size data for RW5, RW8, RW9, RW16, and RW18 are adapted from California State Lands Commission, 2010.

Grain-Size Distribution Graph

Subsurface Seawater Intake Study
West Basin Municipal Water District

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Figure 3.5

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L:\Task 4 Final Reporting\Figures\[Fig3.5_DRAFT Grain-Size Distribution Graph.xlsx]

Table 3.2: Seafloor Sediment and Beach Sand Samples Grain-Size Analysis

				Estimated Hydraulic Conductivity (ft/day)			
				Porosity = 26%		Porosity = 30%	
Location	**Date**	**Depth (feet bsl)**	**Cross-Shore Distance (ft)**	**Barr method[1]**	**Fair and Hatch method[2]**	**Barr method[1]**	**Fair and Hatch method[2]**
BSC-1	7/8/2015	0	0	19.0	28.5	32.6	49
SZC-1	7/8/2015	0	0	10.0	15.3	17.2	26.3
RW-5	--	20	1,000	3.6	5.1	6.2	8.8
RW-8	--	40	4,000	3.0	4.4	5.1	7.5
RW-9	--	40	4,000	2.9	4.4	5.1	7.5
RW-16	--	60	6,000	2.5	3.9	4.2	8.8
RW-18	--	60	6,000	2.0	3.5	3.5	8.8

[1] Evaluated with the Barr method (Barr, 2001).

[2] Evaluated with the Fair and Hatch method (Fair and Hatch, 1933).

ft = feet

bsl = below sea level

-- = Not available

BSC = Beach at shoreline line

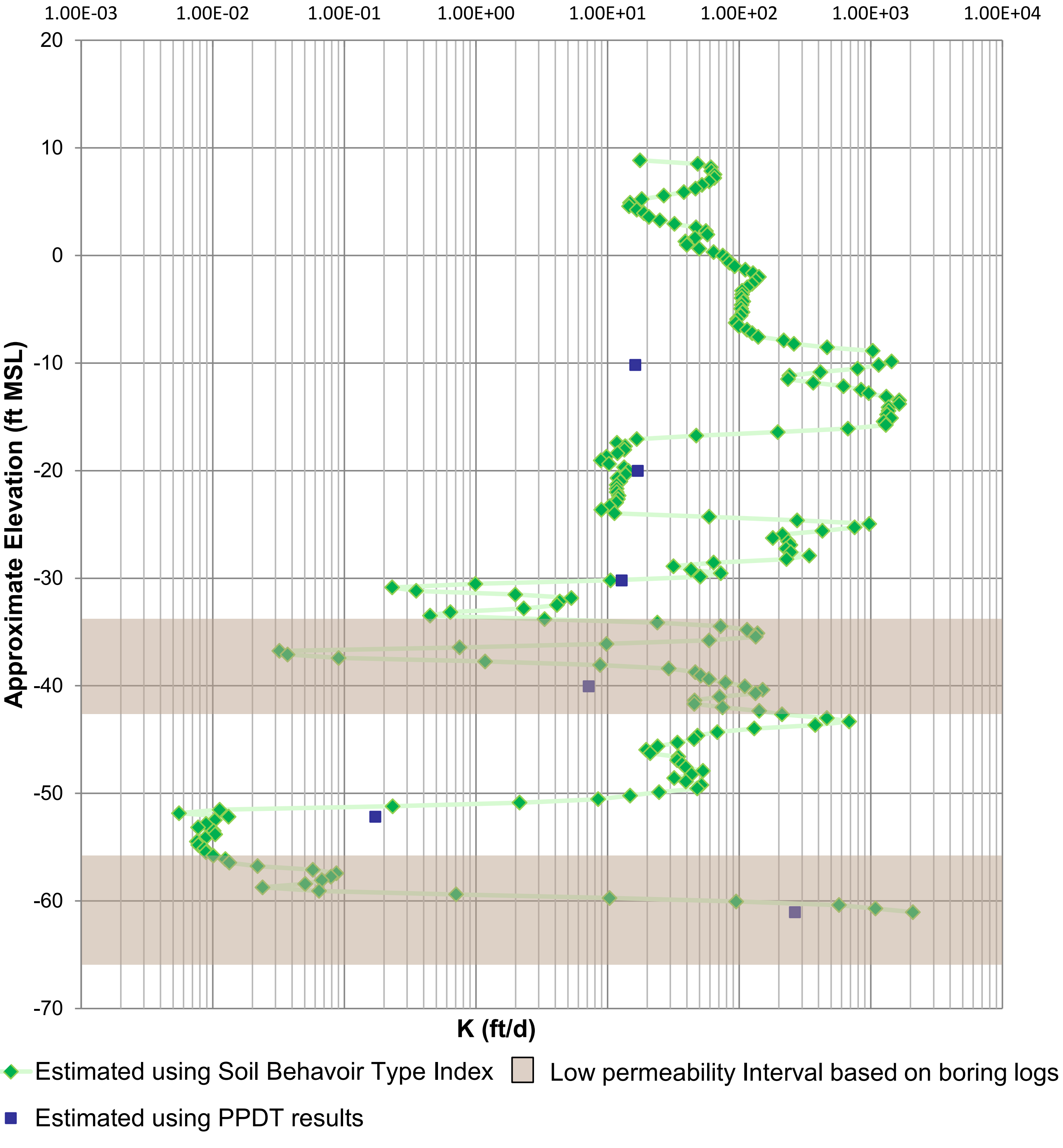
SZC = Surf zone

3.2.2 Onshore CPT

CPT borings were advanced on 31 August 2015 at three locations within the NRG Facility, as shown in Figure 3.4. A fourth location was proposed south of the NRG Facility but access was not possible with the CPT rig (Figure 3.4). CPT-1 and CPT-2 were advanced to a depth of 27 feet, at which refusal was encountered, likely due to the presence of cobbles. CPT-3 was advanced to a depth of 81 feet, before hitting refusal.

At CPT-3 location, pore pressure dissipation tests were performed at 30, 40, 50, 60, 70, 72 and 81.2 feet bgs. Hydraulic conductivity values were estimated based on CPT Normalized Soil Behavior Type (SBT) Indicies and pore pressure dissipation results. The CPT data for the CPT-3 location show two low permeability depth intervals: the upper between -30 and -38 feet mean sea level (msl), and the lower between -50 and -60 feet msl. Figure 3.6 shows a profile of the calculated hydraulic conductivity values at the CPT-3 location. The hydraulic conductivity values calculated from the SBT data are considered more reliable than the pore dissipation test data because, except for the test elevation at approximately -20 feet msl, the pore pressure dissipation tests appear to be at depths that straddle high and low permeability intervals. The details of the CPT results and calculations are provided in Appendix H

Estimated Hydraulic Conductivity from CPT data (ft/day)



Notes:
The estimated values of hydraulic conductivity values (K) calculated from the CPT soil behavior type (SBT) data capture detailed trends of local stratigraphic variation of K, but may be inaccurate as to absolute values (e.g. Robertson and Cabal, 2014).

The K values calculated from the SBT data are considered more reliable than the pore dissipation test data, because with the exception of the test at approximately -20 ft MSL, the pore pressure dissipation tests appear to be at depths that straddle high and low permeability intervals.

All data and results are provided in appendix H.

Estimated Hydraulic Conductivity (K) from CPT/PPDT Data

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Figure

3.6

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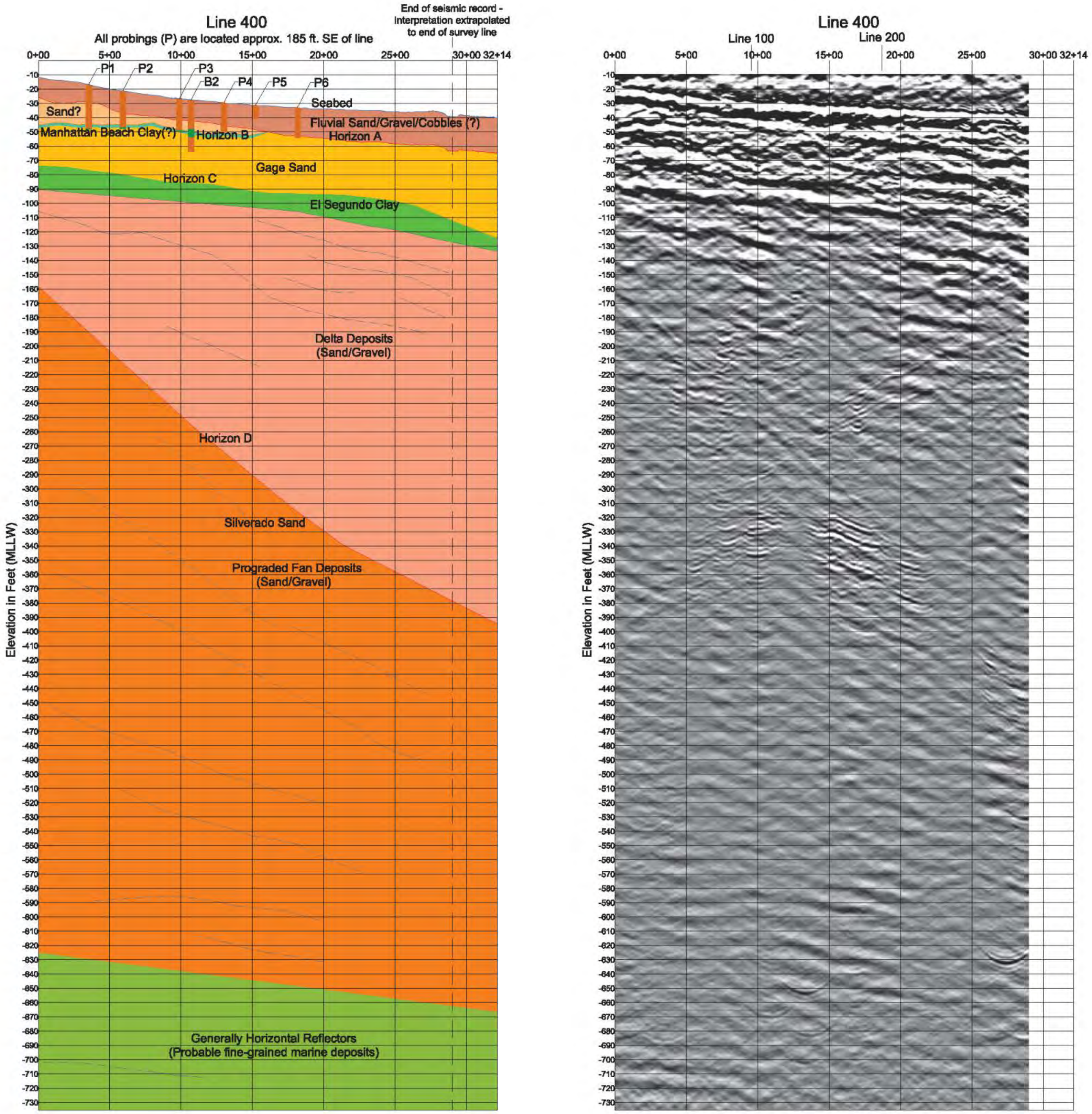
3.2.3 Seismic Reflection Survey

Offshore seismic reflection geophysical surveys were conducted offshore of the NRG Facility on 3 September 2015 along three lines perpendicular to the shoreline, and two lines parallel to the shoreline. The locations of the survey lines are shown in Figure 3.4. The lines perpendicular to the shoreline extended approximately 3,800 feet offshore and were separated by 1,200 and 1,400 feet, respectively. The two lines parallel to the shoreline were approximately 930 feet apart, with the first line located approximately 1,500 feet from the shoreline.

The geophysical surveys included both single-channEl Sub-bottom profiles (SBP) using an EdgeTech full-spectrum SB-512i Chirp system, and multi-channel common point depth (CDP) seismic reflection profiles employing a single-plate Boomer system. The Chirp system SBP provides high resolution of shallow subsurface features, and the multi-channEl Survey with the higher energy boomer source provides deeper penetration and imaging to approximately 700 feet. Due to the nature of the shallow sediments and interference by the seabed multiple, the SBP penetration and interpretable features were generally limited to less than 45 feet below the seafloor, however, the multi-channel Boomer survey was used to supplement the SBP Chirp data and provided penetration of the upper 700 feet of sediment. The details of the geophysical survey data processing and results are provided in Appendix I. The interpreted geological profile along Line 400, which is the central line perpendicular to the shore (see location in Figure 3.4), is provided in Figure 3.7. The main findings are summarized below:

- Gravel and/or cobbles are present locally beneath the seafloor to depths of 10 to 15 feet.
- The SBP Chirp data show a clear horizon, identified as Horizon A on the geophysical profiles at depths of 10 to 15 feet below the seafloor. This is interpreted to be a transition from the shallow interbedded sand, gravel and cobbles to relatively uniform sand below.
- The upper clay layer is present at a sub-seabed depth of approximately 20-25 feet (corresponding to an elevation of approximately -40 to -50 feet msl). Fugro reported that the SBP Chirp data do not clearly image this clay layer, but the Boomer data show a reflector that is interpreted to be the upper clay, which is identified as Horizon B on the geophysical profiles. The thickness of the clay layer is uncertain based on seismic reflection data because it is less than the resolution of the Boomer imaging; in places it may be as thin as 1 or 2 feet. Horizon B (the upper clay layer) appears to be continuous and nearly horizontal shoreward of survey line 200 (~2,200 feet offshore). Beyond 2,200 feet offshore, the interpreted geophysical profiles show Horizon B (the upper clay layer) truncated by Horizon A, which is likely an erosional unconformity. The upper clay may correlate with the Manhattan Beach Clay, or it may be an upper extension of the El Segundo Clay, which may interfinger with the Gage Sand.

- The top of the lower clay layer is imaged by a Boomer reflector at a depth of approximately 50 to 60 feet below the seafloor (-80 to -110 feet msl) and is identified as Horizon C on the interpreted geophysical profiles. This clay layer correlates well with the El Segundo Clay and is contiguous to at least 3,800 feet offshore. It is estimated to be 10 to 15 feet thick and roughly parallels the seafloor.
- Based on the interpreted geophysical survey, the Silverado Sand Deposits below the El Segundo Clay are more than 500 feet deep, extending to approximately -600 feet msl.
- It is likely that fine-grained marine deposits underlie the Silverado Sands below approximately -600 feet msl.



Notes: All data and results are provided in Appendix I.

Interpreted Profile from Seismic Reflection Survey

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West Basin Municipal Water District

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Figure 3.7

3.2.4 Updated Hydrostratigraphy

The data collected and analyses conducted as part of the field testing (Section 3.2) have improved the conceptual understanding of the hydrogeology and stratigraphy at the Site and addressed the gaps identified based on review of the existing data (Section 3.1).

The current understanding of the hydrostratigraphy beneath the coastal margin adjacent to the NRG Facility is summarized below:

- The shallow sediments, mostly very fine to fine sand in the upper portion of the sediments, extend approximately 20-30 feet deep. Based on grain-size testing hydraulic conductivity of seafloor sand decreases from 30-40 ft/day on the beach to 1-4 ft/day several thousand feet offshore.[2] Gravel and cobbles are also present in these shallow sediments, both onshore and offshore.
- The upper clay layer located below these shallow sediments extends approximately 2,200 feet offshore. The thickness of the clay layer is uncertain, but in places it may be as thin as 1 or 2 feet. Based on CPT data, the vertical hydraulic conductivity of this fine-grained material is estimated to be in the range 0.005 to 0.01 ft/day.
- The Gage Aquifer, located between the upper and lower clay layers is approximately 35-40 feet thick and consists of fine-medium sand to gravelly sand. Based on localized measurements in one CPT boring, the horizontal hydraulic conductivity is in the range 10 to 1,000 ft/day.[5]
- The lower clay layer, correlating with the El Segundo Aquitard, is located 50-60 feet below the seafloor and is contiguous to at least 3,800 feet offshore. This layer is approximately 10-15 feet thick and the estimated vertical hydraulic conductivity is in the range 0.001 to 0.01 ft/day.
- The Silverado Aquifer or similar sandy deposits extend to depths of approximately 600 feet bsl (over 500 feet thick) based on the geophysical survey.

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[5] Note that large scale hydraulic conductivity of heterogeneous alluvial sediments can differ substantially from localized measurements of hydraulic conductivity, including laboratory permeameter tests, grain-size analyses, and estimates from CPT data. Moreover, vertical hydraulic conductivity (Kv) of heterogeneous alluvial deposits is generally at least an order of magnitude lower than horizontal hydraulic conductivity (Kh), and Kh:Kv ratio can be several orders of magnitude for layered assemblages of alluvial deposits (e.g. Freeze and Cherry, 1979; Anderson et al., 2015).

3.3 Potential Additional Field Testing and Analysis

As discussed in Section 3.2, the existing data and the field testing and analyses have better characterized the hydrogeological setting in the vicinity of the NRG Facility. Additional field testing and analyses may be conducted if there is a need to further characterize the hydrostratigraphy, delineate the extent of the fine-grained interval in greater detail, and/or refine estimates of the hydraulic properties of the shallow sediments above this fine-grained interval.

Potential additional field testing and analysis are provided below and cost estimates for these additional measures are provided in Table 3.3:

- Additional characterization of the offshore shallow sediments to refine estimates of hydraulic conductivity. The hydraulic conductivity of these sediments controls the connection between the ocean and SSIs completed beneath, such as HDD wells completed above the shallow fine-grained material. Such characterization would better delineate the extent and depth of the gravel/cobbles identified previously in this shallow layer. Testing and analysis could include:
    - Collection of additional sea-floor samples and grain-size analysis;
    - Video survey of the seafloor along transect lines; and
    - Collection of vibracore samples from offshore locations to depth of approximately 20-25 feet.
- Additional characterization of onshore subsurface to refine hydrostratigraphy and estimates of hydraulic properties. Testing and analysis could include:
    - Advancement of additional onshore CPTs. This might be challenging given the presence of shallow cobbles and gravel, and the high risks for hitting refusal at shallow depths;
    - Advancement of onshore borings using alternative drilling techniques such as mud-rotary, air rotary casing hammer, or sonic drilling to prevent refusal at shallow depths and collection of samples for grain size analysis or permeability testing; and
- Additional characterization of the offshore extent and depth of the fine-grained layer and sediments beneath it. This shallow fine-grained interval may be a key limitation in the hydraulic connection between the ocean and the SSIs completed beneath it, such as HDD wells, slant wells or radial collectors completed in the layer below the fine-grained interval. Testing and analysis could include:

  - Advancement of deep offshore borings and collection of samples for grain size analysis or permeability testing. This will likely require a barge and a crane and is therefore considered “Level 3” analysis; and
  - Advancement of offshore CPTs. Similarly to onshore CPTs, it might be challenging due to the presence of shallow cobbles and gravel and the high risks for hitting refusal at shallow depths. In addition, offshore CPTs will likely require a large barge with piers, and are therefore considered “Level 3” analysis.

In addition, pumping tests at existing or newly installed coastal margin wells would provide additional site-specific characterization of subsurface hydraulic properties. However, SSI technologies that would benefit from these additional characterizations (vertical wells, slant wells and radial collectors) are not considered feasible at the site, as explained in detail in Section 5.

Finally, pilot testing of potentially feasible SSIs would help to assess construction feasibility and challenges, as well as anticipated capacity. Based on the feasibility assessment conducted as part of this study, a pilot test for a shallow HDD well completed above the fine-grained material to assess constructability and capacity and/or completed below the fine-grained material to assess hydraulic connection to the ocean and capacity would represent a potential “Level 3” analysis. Note however, based on available information from borings and the geophysical survey (Section 3.2), the presence of cobbles and gravel is localized so a single pilot HDD well will not be representative of conditions and feasibility at other locations in the vicinity. Moreover, no known examples exist of HDD wells installed at depths shallower than 20 foot below the seafloor, and the presence of cobbles and gravel within the shallow seafloor sediments would likely prevent successful drilling and installation of HDD wells (Davis, 2008; Williams, 2008; Nielson et al., 2013).

Table 3.3: Additional Field Testing and Analysis Cost Estimates

Location	Testing/Analysis	Tasks	Number of tests/borings	Cost Estimates	Comments
Offshore	Hydraulic Conductivity	Collection of additional seafloor samples and grain-size analysis	6-8	$15,000	In conjunction with vibracores
			6	$27,000	In a separate mobilization
			15	$22,000	Divers - including laboratory analytical fees
		Video survey along transect lines			
		Collection of vibracore samples to depth of approximately 20-25 feet	6-8	$75,000	Problems likely due to cobbles
	Extent, Depth and Properties of the Fine-Grained Layer and Sediments	Advancement of offshore vibracores 25-30 feet deep and collection of samples for grain size analysis	6-8	$160,000	Problems likely due to cobbles
		Advancement of offshore CPTs	6-8	$400,000	Requires self-elevating barge. Problems likely due to cobbles.
Onshore subsurface	Hydrostratigraphy and Hydraulic Properties	Advancement of additional CPTs	3	$15,000	Risk of hitting refusal before reaching target depths
		Advancement of borings using sonic drilling and collection of samples for grain size analysis or permeability testing	4	$45,000	
Coastal Margin	Subsurface Hydraulic Properties	Pumping Test (install test well and use existing MWs to record response to pumping)	8-hr-test	$155,000	8-inch well, 500 gpm, temp storage in twelve 20,000 gallon baker tanks on site, treatment before discharge.
General	Construction Feasibility and Challenges and Anticipated Capacity	Pilot Testing of HDD Well	1	$1-3M	This cost will depend on actual design of the HDD well used for pilot test (length, depth), permitting requirements and pilot testing activities.

4 Evaluation Criteria

The feasibility of the SSI technologies depends on a variety of site-specific criteria. This section describes criteria developed for evaluation of the feasibility of SSI technology at the proposed El Segundo Desal Facility. The application of these criteria and additional analysis to the proposed El Segundo Desal Facility is presented in the next section (Section 5).

4.1 Hydrogeologic Constraints

4.1.1 Hydraulic Connection to Ocean

The objective of an SSI is to produce large volumes of filtered seawater for treatment at the desal facility. The ability of the SSI to extract seawater is dependent on the hydraulic connection of the intake works to the ocean (Water Research Foundation, 2011). Poor hydraulic connection to the ocean may result in limited intake capacity and/or result in withdrawing a substantial amount of water from inland sources, instead of seawater. Hydraulic connection to the ocean might be limited by the presence of low permeability layers between the seafloor and the SSI. These layers would impact the vertical infiltration rate of seawater to the intake works and either limit the SSI capacity, or result in higher horizontal flow from inland groundwater sources. HDD wells, slant wells, vertical wells, and radial collectors may be affected by these low permeability layers, depending on the depth of completion of the SSIs and the locations and depths of these layers.

4.1.2 Water Supply Aquifers

The proposed project site is located on the western edge of the West Coast Basin, in which groundwater provides 20% of the water demand of approximately eleven cities and unincorporated areas of Los Angeles County via more than 50 production wells located throughout the West Coast Basin (Intera, 2015; West Basin, 2015). The proposed site overlies the western portion of the Silverado Aquifer, which is the principle source of groundwater supply for numerous production water wells throughout the West Coast Basin, with approximately 90% of water supply production in the West Coast Basin occurring from the Silverado Aquifer (MWH, 2007). In addition, production wells are also completed in the Gage Aquifer overlying the Silverado Aquifer (e.g. Geoscience, 2009).

Large-scale subsurface pumping in the vicinity of the shoreline would result in abstraction of inland groundwater from the West Coast Basin, which would adversely impact the water budget of the basin and cause additional drawdowns (e.g. ISTAP, 2014). SSI technologies that would be expected to withdraw a substantial amount of water from inland sources and thus impact the inland water supply aquifers are considered fatally flawed, as illustrated in Section 5.

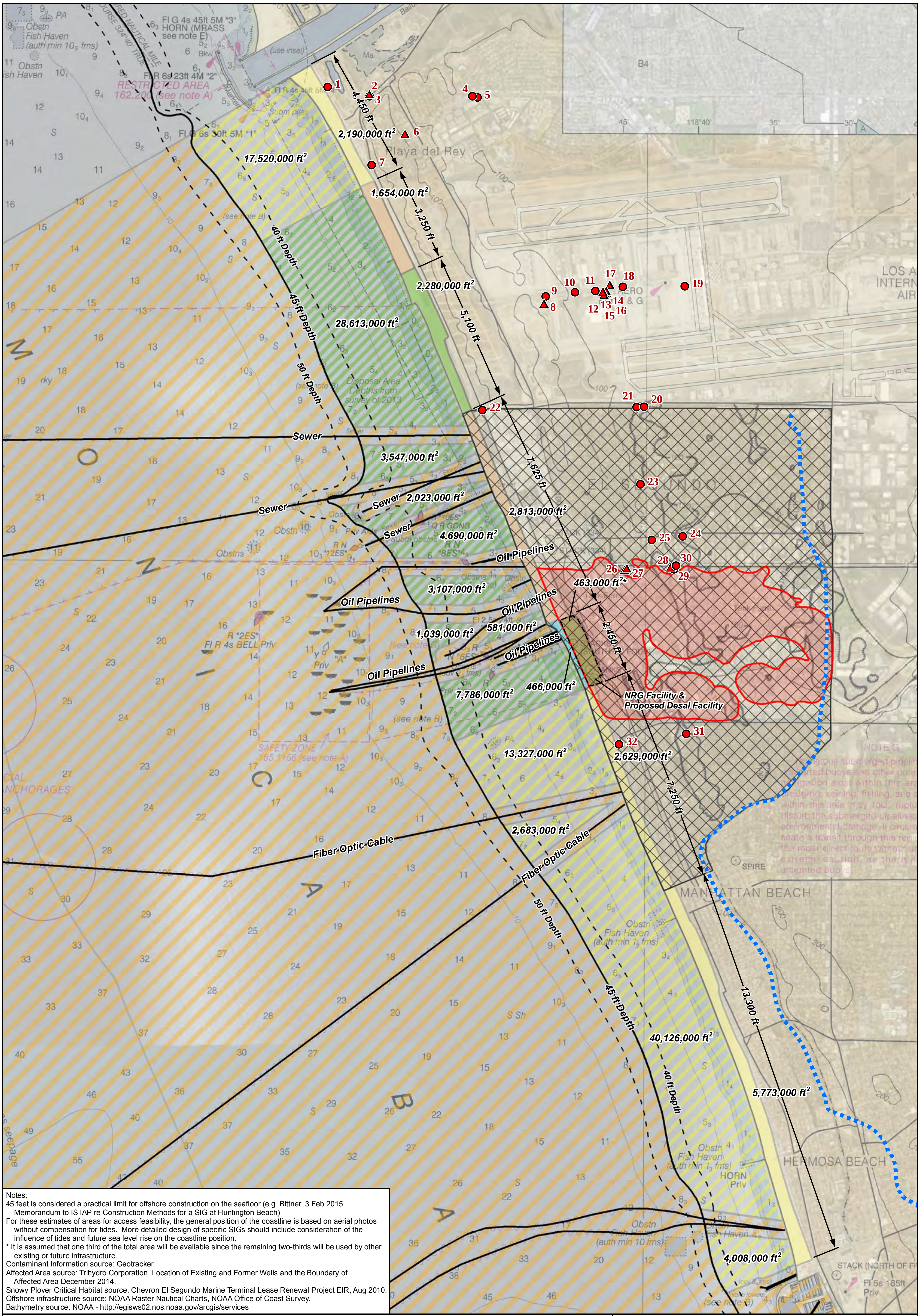
4.1.3. West Coast Basin Injection Barrier

The West Coast Basin Barrier Project was established to protect the West Coast Groundwater Basin from seawater intrusion. A mix of highly treated recycled water and imported potable water is injected into a series of 153 wells in the West Coast Basin near the Santa Monica Coastline (Figure 4.1) (e.g., Intera, 2015). The injection replenishes the West Coast Basin aquifers and protects them from seawater intrusion by maintaining hydraulic head well above sea level at the injection wells. Operation of the West Coast Basin Barrier Project began in 1952. Since 2007, up to 20 MGD of water has been injected into the barrier, with injection consisting of up to 80% treated recycled water (Geoscience, 2009; Intera, 2015).

West Basin provides annual reports to the Los Angeles Regional Water Quality Control Board (LARWQCB) that present operational status of the injection barrier and groundwater model predictions for the fate and transport of the injected recycled water, including travel time to production wells (e.g. Intera, 2015).

Injection wells are screened in the Gage, Silverado, and Lower San Pedro Aquifers (LACDPW, 2015). Between 2006 and 2010, the injected water distribution was 10% in the Gage Aquifer, 65% in the Silverado Aquifer and 25% in the Lower San Pedro Aquifer, and approximately 15,000 acre-feet per year (corresponding to an average of 13 MGD) were recharged to these aquifers (Geoscience, 2011). The average percentage of recycled water in the injected water between 2006 and 2010 was 55% (Geoscience, 2011).

The operation of SSIs that withdraw water from inland sources would interfere with performance of the injection barrier, as illustrated in Section 5. The potential for interfering with groundwater recharge provided by the injection barrier would need to be addressed in the EIR, and likely constitutes a fatal flaw for some SSI options.



Notes:

45 feet is considered a practical limit for offshore construction on the seafloor (e.g. Bittner, 3 Feb 2015 Memorandum to ISTAP re Construction Methods for a SIG at Huntington Beach)

For these estimates of areas for access feasibility, the general position of the coastline is based on aerial photos without compensation for tides. More detailed design of specific SIGs should include consideration of the influence of tides and future sea level rise on the coastline position.

* It is assumed that one third of the total area will be available since the remaining two-thirds will be used by other existing or future infrastructure.

Contaminant Information source: Geotracker

Affected Area source: Trihydro Corporation, Location of Existing and Former Wells and the Boundary of Affected Area December 2014.

Snowy Plover Critical Habitat source: Chevron El Segundo Marine Terminal Lease Renewal Project EIR, Aug 2010.

Offshore infrastructure source: NOAA Raster Nautical Charts, NOAA Office of Coast Survey.

Bathymetry source: NOAA - http://egisws02.nos.noaa.gov/arcgis/services

Legend

- ▨ Potential Offshore Area
- ▨ Offshore Area In Front of Residential Properties
- ▨ Offshore Area Too Deep / Close to Infrastructure
- ☒ Dedesignated Area
- 🟩 Potential Onshore Area
- 🟨 Onshore Area In Front of Residencial Properties
- 🟧 Onshore Area Snowy Plover Critical Habitat
- 🟦 Breakwater Area
- ▪▪▪ West Coast Basin Injection Barrier

Sites with Contaminated Groundwater

- ● Fuel Site
- ▲ Solvent Site
- 🟥 Affected Area in Vicinity of Refinery

N

0 3,000 Feet

Infrastructure and Contaminants

Subsurface Seawater Intake Study
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Figure 4.1

P:\GIS\WestBasinMWD\Project\2015Oct\Fig4_1_InfrastructureAndContaminants.mxd 10/13/2015 2:45:49 PM

4.2 Oceanographic Constraints

Oceanographic constraints address the potential change in coastal and seafloor environments. Three constraints are discussed in this section: sea level rise and beach stability as they affect the position of the beach and the infrastructure, and seafloor stability as it affects the infrastructure located beneath it.

4.2.1 Seafloor Stability (Erosion/Deposition)

Sea level rise can pose a threat to SSI infrastructure (e.g., well heads) if said infrastructure is located beneath the elevation that sea level is projected to rise during the expected life of the infrastructure, which is considered to be 40 years from project initiation. 40 years include 8 years for planning and permitting, 2 years for construction, and 30 years for operation, as suggested by the IAP (Appendix C-2). Estimates of sea level rise at the project location are 0.13 to 0.98 feet by 2030 and 0.39 to 2.0 feet by 2050 (CO-CAT, 2013). These values are consistent with other estimates indicating that sea level will rise 0.63 to 1.23 in the Los Angeles area (NRC, 2012). While these increases would not lead to the inundation of SSI infrastructure under normal conditions, they would increase the risk of inundation during extreme conditions (such as a storm surge coupled with spring tides).

This risk can be mitigated if the SSI onshore infrastructure can be set back from the coast, or contained within a constructed vestment or sea wall. In the present study, the existing sea wall at the NRG Facility and existing breakwater provide opportunities to mitigate these risks, provided there is enough room within the site to house all required well heads and other infrastructure.

SIGs and BIGs, though designed to be inundated, may also be negatively affected by sea level rise because of changes to the erosion/deposition equilibrium that may be associated with changes in sea level. This equilibrium is a critical element of the design of SIGs and BIGs and equilibrium changes could have negative long term impacts to their long term functionality.

4.2.2 Beach Stability (Erosion/Deposition)

Beach instability can pose a threat to SSI infrastructure located on the beach (e.g., vertical wells, slant wells, HDD wells or radial collectors) or at the shoreline (e.g., BIG). Beach instability is characterized by either erosion or deposition. Both might compromise the stability of the infrastructure located on the beach, and could impact well performance and integrity (WateReuse, 2011). Beach instability can be mitigated if the SSI onshore infrastructure could be located further away from the shoreline, however this might result in lower hydraulic connection with the ocean and therefore increase the portion of freshwater extracted by the intake. As a result, wells that are better suited to being set back from the beach (e.g., slant wells, HDD wells) provide more opportunity to mitigate this technical risk (Missimer et al., 2013). In addition, beach instability and migration of the shoreline could be a fatal flaw for the installation of BIG.

Beach erosion would result in a BIG that would be located too far offshore from the surf zone and would impact the self-cleaning function, while beach deposition could result in dewatering of the BIG (Missimer et al., 2013; ISTAP, 2015).

4.2.3 Seafloor Stability (Erosion/Deposition)

Seafloor instability could pose a threat to SSI infrastructure located beneath the seafloor (e.g., HDD wells, SIG). High sedimentation rate would result in deposition of fine-grained material (silt and clay) on the seabed and decrease hydraulic connection between HDD wells and the ocean, or it could decrease the infiltration rate of the SIG and necessitate frequent rehabilitation (e.g., scraping of the seabed surface) (Missimer et al., 2013). Generally, high sedimentation rates are associated with river, stream or sewer discharge into the sea (Missimer et al., 2013). Elevated sedimentation rates have been observed in Santa Monica Bay because of the accumulation of fine sediment in the vicinity of the wastewater outfalls in this area (Farnsworth and Warrick, 2007).

In contrast, scouring of the seafloor can exhume the SSI infrastructure that are located too shallow beneath the seafloor and could impact their performance (Water Research Foundation, 2011). Scouring of the seafloor occurs generally in high-energy environments, such as at El Segundo, and is exacerbated during extreme winters by large waves associated with El Nino (California State Lands Commission, 2010). Analysis of coastal processes and seafloor stability in the vicinity of the El Segundo NRG Facility indicates a closure depth of 50 feet, which occurs approximately 6,500 feet offshore (Jenkins, 2015, Appendix K herein).[6] The closure depth represents the closest point to the shoreline where a stable seabed occurs. Shallow offshore SSIs inside the closure depth are vulnerable to seafloor instability.

4.3 Geochemical and Water Quality Constraints

Geochemical conditions (redox conditions, concentrations of iron or manganese, alkalinity) and water quality of the source water in the vicinity and within the subsurface intakes are significant criteria in the evaluation of reliability and long-term performance of SSIs, since challenging conditions might result in loss of performance and decreased capacity of the system (Missimer et al., 2013; ISTAP, 2014). In addition, desal facilities use RO technology, which requires feed water with low suspended solids concentration, low concentration of clogging organic compounds, and stable water chemistry (ISTAP, 2014). The lifespan and

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[6] Profiles of seafloor bathymetry for different times typically would converge at the depth of closure. However, some of the bathymetric profiles shown on Figures 4.7 and 4.8 of Jenkins, 2015, which is provided as Appendix K, diverge near the reported depth of closure. The divergence of some of the profiles near the reported depth of closure could be due to inaccurate orientation or location of some of the surveys. Periodic updates to the bathymetric profiles with data from the NRG bathymetric surveys, which began in 2011, are recommended but are not expected to influence the analysis of feasibility of SSIs at El Segundo.

performance of RO membranes are therefore strongly dependent on the feed water quality (Bartak et al., 2012).

4.3.1 Seafloor Stability (Erosion/Deposition)

The quality of the feed water can be impacted by mixing of different water sources in the SSI intake. For example, mixing of anoxic and oxic water, or mixing of freshwater and seawater, can lead to precipitation of iron oxides, manganese oxides, calcium carbonate or elemental sulfur. Such precipitation would result in clogging of the intake works (which would decrease intake capacity or necessitate rehabilitation) and/or fouling of the filters and membranes of the treatment system (Missimer et al., 2013, 2015). Risks of adverse fluid mixing is highest in those SSIs which extract water from different sources, i.e., vertical wells, radial collectors and slant wells extracting a mix of seawater and freshwater, and SSIs drilled through zones of varying oxidation conditions, i.e., HDD wells with screens between 1,000 and 2,000 feet offshore (Missimer et al., 2013). SSIs with the lowest risks are infiltration galleries, which produce water mainly by vertical infiltration (ISTAP, 2014). At the El Segundo site, elevated concentrations of both iron and manganese exist in the groundwater in the vicinity of the NRG Facility (MWH, 2007). These concentrations might impact the performance of the intake works for SSIs extracting groundwater, and might also require additional pretreatment at the desal facility (MWH, 2007).

4.3.2 Clogging

Clogging (also referred to as plugging) of the SSI will result in decreased intake capacity, loss of performance, and would require rehabilitation of the intake. Therefore it is of greatest concern as a feasibility criteria for SSIs with complex and expensive rehabilitation requirements, e.g., slant wells, HDD wells and SIG (see Section 4.5.2) (ISTAP, 2014). Clogging of the intake works can be caused by chemical, biological and physical processes (ISTAP, 2014). Geochemical processes, e.g., mineral precipitation, result mainly from adverse fluid mixing as described above (Section 4.3.1). Bacterial growth on the well screen or on the seabed surface would result in clogging that could affect the intake capacity and performance (Water Research Foundation, 2011). In addition, clogging of the seabed surface might occur via deposition of fine-grained material (silt and clay) in a low-energy environment, where wave movement is not sufficient, or under high sedimentation conditions (Bartak et al., 2012; Missimer et al., 2013). Clogging of the seabed surface would affect performance of infiltration galleries, as deposition of fine-grained sediments on the surface of the engineered fill would reduce the infiltration rate of the engineered fill. Clogging of the seabed surface would reduce hydraulic connection to the ocean of HDD wells and other SSIs. Specifically for HDD wells, the intake rates would be significantly reduced with clogging of the seabed surface. Sedimentation rates in Santa Monica Bay are relatively high because of the accumulation of fine sediment in the vicinity of the wastewater outfalls in this area (Farnsworth and Warrick, 2007), as discussed in Section 4.2.3.

4.3.3 High SDI Water

Silt Density Index (SDI) of the feed water is a parameter used in desal facility design to determine the potential for RO membrane fouling and the need for additional pretreatment and/or filtration prior to the RO system (Bartak et al., 2012; ISTAP, 2014). Seawater SDI typically exceeds 10, and values of 2-3 are desirable for RO desalination, with values below 4-5 being acceptable (Bartak et al., 2012; Missimer et al., 2013; Rachman et al., 2014). SSI systems provide water filtration and are able to improve feed water quality in order to reduce the need for additional pretreatment (Missimer et al., 2013). But the degree of filtration and improvement of the feed water quality, relative to the source water, depends on the SSIs as well as site-specific considerations, such as the travel time to the intake system; longer travel time potentially provides better filtration and feed water of higher quality (Rachman et al., 2014). Vertical wells generally provide feed water with an SDI value of 0.3-1 (Bartak et al., 2012), and were shown to provide feed water of better quality than other SSIs (Rachman et al., 2014). HDD wells have been shown to be less efficient and generally provide feed water with higher SDI (Rachman et al., 2014). SDI values for SIG have been reported below 2 for the full-scale system in Japan (Missimer et al., 2013) and between 4 and 5 for the pilot scale system in Long Beach, California (Missimer et al., 2013).

4.3.4 Contaminated Groundwater

The presence of contaminated groundwater in the vicinity of the SSIs is of concern with regard to those SSI technologies which partially withdraw water from inland sources, such as vertical wells, slant wells or radial collectors. The operation of these SSIs could cause movement of potential contaminants seaward. The potential for mobilizing contaminated groundwater plumes would be evaluated under CEQA, and could constitute a fatal flaw. In addition, withdrawing contaminated groundwater could result in the need for additional treatment, and the potential for the source water to be considered an extremely impaired source by the by the California Water Resource Control Board Division of Drinking Water (DDW) and to require additional permitting (California Department of Health Services, 1997).

Information about potential groundwater contamination in the vicinity of the proposed El Segundo Desal Facility is available from the California Water Resources Control Board Geotracker site. Contaminated soil and groundwater is present underneath both the Chevron refinery and the NRG Facility, and in the surrounding areas. The extent of the affected area is shown in Figure 4.1. In addition, multiple sites contaminated with fuel constituents or solvents are identified in the vicinity of the proposed El Segundo Desal Facility, as illustrated in Figure 4.1.

4.3.5 De-Designated Area

Due to contamination of groundwater associated with the Chevron El Segundo Refinery and the terminal and other industrial facilities, in order to prevent interference with hydraulic gradients needed to maintain the barrier and to allow injection of recycled water in the injection barrier, the aquifers in the vicinity of El Segundo between the injection barrier and the coast (see Figure 4.1) were formally de-designated for municipal water supply by the Los Angeles Regional Water Quality Control Board in November 1998 by Resolution No. 98-18, which amended the Water Quality Control Plan for the Los Angeles Basin (Basin Plan). SSI technologies such as vertical wells, slant wells or radial collectors that withdraw groundwater from inland aquifer sources in this de-designated area would be in violation of this amended Basin Plan.

4.4 Land Use and Sensitive Habitat

4.4.1 Residential Property

Locating SSI permanent infrastructure or temporary construction staging on the beach in front of residential properties increases the risk for active public opposition to the project.

Manhattan Beach residential beach front properties are adjacent to the southern margin of the site, Hermosa and Redondo residential beach front properties are located further south, and additional residential beach front properties begin three miles north of the site. Based on the feasibility definition that takes into account economic and social factors, public opposition may constitute a significant challenge for locating SSI infrastructure and/or staging construction, operations and maintenance in front of these homes. This could limit the potential areas in which many of the SSIs could be located and constructed thereby limiting the available footprint for onshore SSIs and potentially being an impediment for offshore SSIs that require shoreline area for construction staging. Public opposition could potentially be mitigated by burying well heads, but this would increase the risk of damage caused by sea level rise, and may still be an issue for residents, due to the need for well and infrastructure maintenance. Locating SSI infrastructure in front of residential property would need to be addressed in the EIR.

4.4.2 Snowy-Plover Habitat

There are two areas of critical western snowy plover habitat just north of the proposed project site totaling approximately 44 acres (see Figure 4.1). The Pacific coast population of the western snowy plover was listed as threatened on 5 March 1993 under provisions of the Endangered Species Act of 1973. Its nesting season runs from March 1 to September 1, during which time the plover lays its eggs above the high tide line on coastal beaches (USFW, 2007).

Therefore, any development, construction staging, or maintenance of SSIs within these areas would be subject to review by several permitting agencies to ensure that these activities would not cause a disturbance to the snowy plover. This could potentially make it prohibitive to locate permanent SSI infrastructure in the snowy plover habitat, or at a minimum, it would cause delays in construction since construction could not take place during the nesting season from March through August and in maintenance operations since maintenance could not take place during the nesting season. Likewise, for SSIs that could be located outside of snowy plover habitat (e.g., BIG and SIG) but require construction or maintenance staging in the critical habitat area, scheduling would be similarly restricted. Locating SSI infrastructure within the designated critical habitat may not be allowed and would need to be addressed in the EIR.

4.4.3 Existing Buried Infrastructure

There is a variety of buried offshore infrastructure in the vicinity of the proposed project site, including sewer lines, oil pipelines, and fiber optic cables (see Figure 4.1). While there is enough area between these offshore infrastructure to situate and construct an SSI (i.e., SIG, DIG, and HDD) on or under the seafloor, there are likely to be additional undocumented/abandoned buried infrastructure as a result of historic and/or industrial activities. Existing subsurface infrastructure could pose significant technical risks during construction, including delays and cost overruns due to encountering the unknown infrastructure.

Furthermore, due to the abundance of oil pipelines in the area there is a risk of leaking pipes introducing oil to the desal facility via seepage through sand.

In addition to offshore infrastructure, there are buried infrastructure onshore, and particularly within the NRG Facility where there is a 36-inch gas line running parallel to the western boundary. This may complicate construction for onshore SSIs. First, any buried infrastructure would need to be located accurately. Then, either the placement of the SSI and associated construction activities would have to be designed to avoid these infrastructures, or the infrastructure would have to be temporarily or permanently relocated. Such relocation could be costly, and could also interfere with the operation of the NRG Generating Station.

4.5 Maintenance

Optimum performance of SSIs requires maintenance activities such as well rehabilitation, scraping of seabed surface, or pump replacement.

4.5.1 Frequency of Maintenance

The frequency of maintenance activities that would be required depends on both the SSI technology and site-specific conditions. For example, the presence of fine-grained material in the source water might increase the potential for screen clogging of vertical wells, slant wells, radial collectors or HDD wells (Missimer et al., 2013). Similarly, precipitation of iron or manganese oxides due to mixing of different sources of water might result in screen clogging (Missimer et al., 2013). For infiltration galleries, the frequency of maintenance might be controlled by the sedimentation rates on the seabed, or scouring of the seabed that might disturb the engineered fill and produce filter clogging (Missimer et al., 2013).

4.5.2 Complexity of Maintenance

Complexity of maintenance addresses both the technical challenges associated with potential maintenance activities and the logistical issues that might make maintenance more complex. For example, rehabilitation of slant and HDD wells is much more complex than that of vertical wells, because such maintenance may require specialized equipment, the screen is located a long distance from the shoreline, and there is a risk of damaging the screen due to cleaning equipment lying on the lower part of the screen (Water Research Foundation, 2011; Missimer et al., 2013). Although potential maintenance of seafloor infiltration galleries is technically simple (e.g., scraping or dredging of the seabed surface), it can be relatively challenging to perform offshore (ISTAP, 2014), and potentially environmentally damaging.

4.6 Other Risk Factors and Uncertainties

In addition to technical constraints related to site setting and subsurface conditions, additional factors (including complexity of construction, performance uncertainty and reliability) contribute to the uncertainty of cost and the probability of successful long-term reliability of SSIs.

4.6.1 Precedence

Precedence refers to the existence of intake systems operating in similar settings and at similar capacity to the intake under consideration. Lack of precedence increases the performance risk and decreases the reliability of the intake system. It also means that the ability to find contractors capable of designing and/or constructing the intake system might be limited. When precedent systems exist, it is important to consider any issues encountered during construction and/or operation, and whether and how they were mitigated. Existing systems at similar capacity (40 MGD) include vertical well systems in Oman and Spain (Missimer et al., 2013) and HDD wells in Spain (Missimer et al. 2013). However, the Oman facility is located in a karst aquifer, a very productive aquifer containing cavities and fractures (Missimer et al., 2015). Similarly, the Spain facility is located in a limestone aquifer containing unlithified sediments (Missimer et al., 2015). In addition, both of which have experienced lower capacity than expected and have reported water quality issues (Rachman et al., 2014). Even for these existing systems, limited data have been available to assess actual performance and long term operating efficiency.

4.6.2 Complexity of Construction

Construction complexity refers to issues that could increase cost, extend the construction schedule, or increase the technical risk of successful project completion, which would contribute to the feasibility of a specific SSI option.

These issues are generally inherent to the type of SSI, i.e., the construction of a SIG or water tunnel would be much more complex than other SSIs such as vertical wells, although complexity depends on specific site conditions. Issues may include:

- Difficulties in finding construction contractors available and/or capable of performing the work required to install SSI;
- Difficulties in obtaining construction permits and/or the length of time required to obtain permits;
- Onshore and offshore constrained construction schedules due to seasonal restrictions on beach access from public use;
- Offshore constrained construction schedules due to seasonal sea conditions;
- Difficulties in offshore construction because of:
    - Water depth as complexity and cost of construction increase directly with water depth;
    - Wave and wind energy as complexity and cost of construction increase geometrically with increased levels of wave energy;
    - Weather predictability as construction risk and cost increase with decrease in predictability; and
    - Stability of seabed during construction
- Potential environmental impacts resulting from construction (ISTAP, 2014).

Specific complexities involved with each SSI at the proposed project site are discussed in Section 5.

4.6.3 Performance Risk / Uncertainty of Outcome

Performance risk is the potential for the intake system not to meet project performance expectations in terms of intake rate and/or water quality. Because of the significant costs associated with the construction of SSI and the desal facility, there must be confidence that the selected intake system can satisfactorily perform over the lifespan of the desal plan, generally a 30-year minimum (ISTAP, 2014). This means that the selected intake method should provide at least the design intake rate at the expected water quality for which the desal facility is designed. A high degree of uncertainty about the outcome might jeopardize the ability of the desal facility to provide the desired water supply.

Performance risk is higher for intakes or site conditions for which it is difficult to implement a pilot test to assess intake capacity, capacity sustainability and feed water quality. This is the case for specific SSIs, such as a water tunnel or SIG, which are challenging to pilot test, or for heterogeneous site conditions, in which the results of a pilot test might not be scalable to a full-sized system. In addition, the inability to rely on operational history of comparable systems constructed in similar geologies and site conditions also contributes to the uncertainty with regard to the likelihood of successful implementation.

4.6.4 Reliability of Intake System

The reliability of an intake system refers to the ability of the intake to maintain acceptable performance, in terms of both capacity and water quality, over the designed lifespan of the desal facility, generally a 30-year minimum (but longer lifespan might be considered). Normal operation and maintenance activities for the intake system are not considered to affect the reliability of the intake system in cases where they can be readily performed using standard methods, and where they would be able to restore the system capacity without long-term damages or extensive delays. For example, vertical wells are expected to require periodic rehabilitation for which standard methods can be used. However, challenging (or uncertain) source water quality might impact the reliability of the intake system, including vertical wells, and could increase the required frequency of rehabilitation.

In addition, evaluation of the reliability of some SSIs is difficult because of the absence of operational history of comparable systems constructed in similar geologies and site conditions. For example, some long-term performance data is available for the SIG located in Japan (Missimer et al., 2013; Pankratz, 2014), but this information is difficult to transfer to a high energy environment such as El Segundo, which possesses very different conditions from the calm sea setting of the SIG in Japan (Appendix K) and therefore cannot be used to comprehensibly assess reliability of SIGs. Similarly, due to the relatively recent development of the technology for SSIs, data are not available for the long-term performance of HDD and slant wells, and whether they can be rehabilitated to original conditions after years of operation.

5 Evaluation of SSI Technologies

The evaluation criteria discussed in Section 4 were applied to each specific SSI technology for the proposed desal facility as summarized in Table 5.1. For this assessment the desired production capacity of the proposed desal facility is 20 MGD, corresponding to a desired intake rate of 40 MGD. A production capacity of 20 MGD for the proposed desal facility lies at the low end of the expected production capacity outlined in the West Basin Desal PMP (between 20 and 60 MGD) (Section 1.1), and is considered the minimum capacity for the proposed desal facility.

This assessment is based on results of initial screening using the Guidance Tool as described in Section 2, analyses of the site-specific data and field testing described in Section 3, groundwater modeling, which is presented in Appendix J and discussed below, relevant information compiled from other sources, such as the evaluation of feasibility of SSIs for the proposed desal facility at Huntington Beach (ISTAP, 2014, 2015), and engineering judgment provided by expert advisors and reviewers.[7]

Additional discussion is provided below for each of the specific SSIs. Emphasis is on the criteria that represent fatal flaws for the SSI technology, although other challenging criteria are also discussed.

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[7] The expert advisors and reviewers included Michael Kavanaugh, Ph.D., P.E. (Geosyntec Consultants, Inc.), Gerry Filteau (SPI), Martin Feeney, P.G., C.E.G., C.H.G. (Independent Consultant), Robert Bittner, P.E., (Bittner-Shen Engineering), and Jim Barry, P.E., (Sea Engineering).

Table 5.1: Subsurface Seawater Intake Summary Table

	Vertical Wells	Slant Wells	Radial Collector Wells	Horizontally Directionally Drilled Wells		Beach Infiltration Gallery	Seabed Infiltration Gallery	Deep Infiltration Gallery
				below 20 feet layer	above 20 feet layer			
Hydrogeologic Constraints								
Hydraulic connection to ocean	Moderate	Moderate	Moderate	Moderate	High	High	High	High
Impact on water supply aquifers	Yes	Yes	Yes	Yes	Unlikely	No	No	Unlikely
Impact on West Coast Basin Injection Barrier	Yes	Yes	Yes	Yes	Unlikely	No	No	Unlikely
Oceanographic								
Sensitivity to sea level rise	Possibly	Possibly	Possibly	No	Possibly	Possibly	No	No
Sensitivity to beach stability	Possibly	Possibly	Possibly	Possibly	Possibly	Yes	No	No
Sensitivity to seafloor stability	No	No	Possibly	Unlikely	Possibly	Possibly	Yes	Possibly
Geochemical and Water Quality Constraints								
Risk of adverse fluid mixing	High*	High*	Medium*	Unknown*	Unknown*	Low*	Low*	Low*
Risk of clogging	High*	Medium*	Medium*	High*	High*	Low*	Low*	Low*
Risk of high SDI production water	Low	Low	Low	Low	Low	High	Low	Low
Drawing contaminated water	Yes	Yes	Yes	Yes	Possibly	No	No	Unlikely
Drawing from aquifer area *de-designated* for municipal beneficial use	Yes	Yes	Yes	Yes	Unlikely	No	No	Possibly

	Vertical Wells	**Slant Wells**	**Radial Collector Wells**	**Horizontally Directionally Drilled Wells**		**Beach Infiltration Gallery**	**Seabed Infiltration Gallery**	**Deep Infiltration Gallery**
				below 20 feet layer	**above 20 feet layer**			
Land Use and Sensitive Habitat								
Need to construct in snowy-plover habitat and/or in front of residential property	Yes	Yes	Yes	Yes	Possibly	No	No	No
Need to perform O&M in snowy-plover habitat and/or in front of residential property	Yes	Yes	Yes	Yes	Possibly	No	No	No
Risk of encountering undocumented buried infrastructure	Low	Low	Low	Low	High	Low	Low	Medium
Maintenance								
Frequency of maintenance	High*	High*	Medium*	High*	High*	Medium / Unknown*	Medium / Unknown*	Low*
Complexity of maintenance	Low*	Medium*	Medium*	High*	High*	Medium*	High*	High*
Other Risk Factors								
Precedence at comparable scale and hydrogeologic / oceanographic conditions	No	No	Yes	No	No	No	No	No
Complexity of construction	Low*	Medium*	Medium*	Medium* / High	High	High*	High*	Very High*
Performance risk - degree of uncertainty of outcome	Low*	Medium*	Medium*	High*	High*	Medium*	Medium*	Unknown*
Reliability of intake system	High*	Medium / Unknown*	Medium*	Unknown*	Unknown*	Medium / Unknown*	Medium*	Unknown*
Economic viability	Medium	Medium	Medium	Low	Low	Medium	Low	Low

* Used information directly from ISTAP, 2014.

5.1 Vertical Wells

The use of vertical wells at the proposed El Segundo Desal Facility is not feasible due to the fact that vertical wells withdraw a substantial amount of water from inland sources. At the NRG Facility the withdrawal of water from inland sources would impact the inland water supply aquifers (see Section 4.1.2) and compromise performance of the West Coast Basin Injection Barrier (see Section 4.1.3). For example, groundwater modeling[8] indicates that more than 50% of the feed water would originate from inland sources, including the injection barrier (Appendix J). Moreover, the vertical wells would draw water from contaminated sites (see Section 4.3.4) and from within the area that was de-designated for municipal beneficial use (see Section 4.3.5). These factors constitute fatal flaws for the use of vertical wells for the proposed desal facility.

In addition to the fatal flaws described above, there are other substantial challenges in using vertical wells. Groundwater modeling indicates that the maximum production capacity of vertical wells located inside the NRG Facility footprint would be between 10 and 20 MGD,[9] significantly less than the design intake rate of 40 MGD. Additional wells would need to be located outside of the NRG Facility either in front of residential property (Section 4.4.1) to the south, or in snowy plover habitat (Section 0) to the north in order to achieve the design flow rate.

Vertical wells located outside of the NRG Facility would be subject to the same fatal flaws as outlined above: to the north of the NRG Facility, vertical wells would withdraw water from freshwater aquifer and from contaminated sites (Figure 4.1), and to the south of the NRG Facility, vertical wells would withdraw water from the injection barrier, which is located even closer to the coastline in this area. Additionally, vertical wells located outside the seawall of the NRG Facility may be more susceptible to sea level rise and beach erosion (Sections 4.2.1 and 4.2.2). Due to the fatal flaws and other significant challenges, the use of vertical wells is not considered technically feasible to achieve the design flow rate for the proposed El Segundo Desal Facility.

5.2 Slant Wells

Slant wells for the purpose of SSIs are intended to provide more direct connection to the ocean than vertical wells, but the benefit of slant wells is limited because the intakes are likely to be 100 to 200 feet below the seafloor due to set-back

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[8] Groundwater modeling was conducted for wells located within the NRG Facility. Results for wells located to the north or south of the NRG Facility will produce similar results due to the hydrogeological similarities along the 8-mile area of study.

[9] Depth of vertical wells was assumed to be approximately 200 feet. Production capacity would be higher for deeper wells, but proportion of seawater pumped would be even less.

requirements and angle drilling limitations, angle of 20° being considered the minimum. The groundwater model represents slant wells drilled at an angle of 20° from NRG facility, with screened intervals located between 35 and 170 feet bsl, for a lineal length of 600 feet (Appendix J). At the ocean margin the well screen is more than 100 feet below sea level.

As a consequence of the depth of the slant wells beneath the seafloor and shallow clay layers, slant wells are subject to the same fatal flaws as vertical wells since they draw a substantial amount of water from inland sources. Specifically, the use of slant wells would impact the inland water supply aquifers (see Section 4.1.2) and compromise performance of the West Coast Basin Injection Barrier (see Section 4.1.3). Groundwater modeling[10] indicates that over 50% of the feed water would originate from inland sources, including the injection barrier (Appendix J), and that water would be drawn from contaminated sites (see Section 4.3.4) and from within the area that was de-designated for municipal beneficial use (see Section 4.3.5).

In addition, groundwater modeling indicates that the maximum production capacity of slant wells located inside the NRG footprint would be approximately 16 MGD, significantly less than the design intake rate of 40 MGD. Additional well heads would need to be located outside of the NRG Facility, thus encroaching into areas in front of residential property and/or snowy plover habitat, as well as requiring additional mitigation to provide protection from sea level rise and beach erosion. Slant wells located outside of the NRG Facility would be subject to the same fatal flaws as outlined above; to the north of the NRG Facility, slant wells would withdraw water from freshwater aquifer and from contaminated sites (Figure 4.1), and to the south of the NRG Facility, slant wells would withdraw water from the injection barrier, which is located even closer to the coastline in this area. Finally, slant wells are more complex to construct, have less information on long-term reliability, and require more complex maintenance than vertical wells.

In addition to the water quality concerns indicated above, slant wells would draw water from multiple incompatible sources, i.e., inland groundwater and seawater from multiple depths. This could lead to the mixing of anoxic water, containing dissolved iron and/or manganese and oxygenated water such as seawater. Oxidation of the iron and manganese would result in precipitation of minerals that would require filtration prior to reverse osmosis. At El Segundo, elevated concentrations of iron and manganese (up to 49 and 10 mg/L respectively) exist in shallow groundwater in the vicinity of the NRG Facility (MWH, 2007). Similar issues have been encountered at the demonstration slant well operated at Dana Point, California between 2010 and 2012. The slant well drew “old marine groundwater” which was high in iron and manganese (11 mg/L and 5 mg/L,

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[10] Groundwater modeling was conducted for wells located within the NRG Facility. Results for wells located to the north or south of the NRG Facility will produce similar results due to the hydrogeological similarities along the 8-mile area of study.

respectively) (MWDOC, 2014), and resulted in concerns about eventual mixing with oxic seawater.

Due to these fatal flaws and other challenges, the use of slant wells is not technically feasible to achieve the design flow rate for the proposed El Segundo Desal Facility.

5.3 Radial Collectors Wells

Radial collector wells suffer from the same fatal flaws as vertical and slant wells because they too would draw a substantial amount of water from inland sources (Table 5.1). Specifically, the use of radial collector wells would impact the inland water supply aquifers (see Section 4.1.2), compromise the performance of West Coast Basin Injection Barrier (see Section 4.1.3), and draw water from contaminated sites (see Section 4.3.4) and from within the area that was de-designated for municipal beneficial use (see Section 4.3.5). Groundwater modeling[11] also indicates that unreasonable drawdown would be occurring in the direct vicinity of the radial collector screens.

In addition, groundwater modeling indicates that the maximum production capacity for radial collector wells with well head caissons located inside the NRG footprint would be less than 10 MGD (Appendix J), significantly less than the design intake rate of 40 MGD. Additional well head caissons would need to be located outside of the NRG Facility, thus encroaching into areas in front of residential property and/or snow-plover habitat, as well as requiring additional mitigation to provide protection from sea level rise and beach erosion. Radial collector wells located outside of the NRG Facility would be subject to the same fatal flaws as outlined above; to the north of the NRG Facility, wells would withdraw water from freshwater aquifer and from contaminated sites (Figure 4.1), and to the south of the NRG Facility, wells would withdraw water from the injection barrier, which is located even closer to the coastline in this area.

In addition to the water quality concerns indicated above, the redox state of the pumped water could be critical for radial collector wells, because of the caisson that would allow air to come in contact with the pumped water (Missimer et al., 2013). At El Segundo, elevated concentrations of iron and manganese (up to 49 and 10 mg/L respectively) exist in shallow groundwater in the vicinity of the NRG Facility (MWH, 2007). Oxidation of the iron and manganese would change it to a form which has minimal solubility, resulting in a precipitant that might impact the performance of the intake and would require filtration prior to reverse osmosis. In addition, the presence of hydrogen sulfide in the pumped water, which can be anticipated in shallow subsurface benearth the sea floor, could result

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[11] Groundwater modeling was conducted for wells located within the NRG Facility. Results for wells located to the north or south of the NRG Facility will produce similar results due to the hydrogeological similarities along the 8-mile area of study.

in the precipitation of elemental sulfur, which could also foul the filters and membranes (Missimer et al., 2013).
Due to these fatal flaws and other challenges, the use of radial collector wells is not technically feasible to achieve the design flow rate for the proposed El Segundo Desal Facility.

5.4 Horizontally Directionally Drilled Wells

Compared to other well technologies, HDD wells have a higher level of construction complexity, higher performance risk, less known reliability, and higher frequency and complexity of maintenance. At El Segundo these factors will likely be compounded by the presence of gravel and cobbles that may prevent successful horizontal directional drilling.

The advantage HDD wells present is that that they generally provide a better hydraulic connection to the ocean than other well technologies because of the shallower depth of the intakes below the seafloor. However, at El Segundo a low-permeability layer approximately 20 feet below the seabed (as identified in Section 3) poses significant challenges for the HDD technology. Positioning of the HDD wells below this layer would limit the hydraulic connection with the ocean, and would cause withdrawal of a portion of the water from inland sources, thereby impacting water supply aquifers (see Section 4.1.2) and the injection barrier (see Section 4.1.3). Groundwater modeling[12] indicates that approximately 8% of the feed water would originate from inland sources, including the injection barrier. Moreover, groundwater modeling shows flow pathlines between the ocean and the costal margin end of HDD wells follow a looping pathway under the NRG facility where shallow groundwater is contaminated (Appendix J).

Additionally, groundwater modeling indicates that the maximum production capacity for HDD wells originating inside the NRG Facility footprint would be approximately 18 MGD, significantly less than the design intake rate of 40 MGD. Additional HDD wells would have to be located outside of the NRG Facility. This is the same set of fatal flaws and challenges that applied to the vertical, slant, and radial collector wells; impact on water supply aquifers and on the West Coast Basin Injection Barrier, drawing water from contaminated areas and from an area de-listed for beneficial use and unable to provide the design flow rate with well heads located within the NRG Facility. Thus, the HDD wells positioned deeper than 20 feet below the seabed are not feasible as SSIs for the proposed Desal Facility.

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[12] Groundwater modeling was conducted for HDD well heads located within the NRG Facility, and with the wells located immediately offshore from the NRG Facility. Results for wells located to the north or south of the NRG Facility will produce similar results due to the hydrogeological similarities along the 8-mile area of study.

An alternative approach would be to install the HDD wells above the 20-foot low-permeability layer. This would likely result in much better hydraulic connection with the ocean, alleviating the fatal flaws described above. However, there are no precedents for shallow HDD installations in coastal marine settings with similar geological conditions, and the presence of cobbles and gravel within the shallow seafloor sediments would likely prevent successful drilling and installation of HDD wells, as is supported by excerpts from publications below:

> *"cobbles and boulders in the case of horizontal directional drilling could prove to be disastrous, as any percentage of gravel, cobbles, or boulders greater than 50% of the total by weight would make horizontal directionally drilled installation a NO GO scenario."* (Davis, 2008)
>
> *"horizontal directional drilling does not work well in the presence of loose unconsolidated cobbles or boulders. These types of materials tend to steer the drilling bit off course, and make it difficult to maintain an open borehole."* (Williams, DWR 2008)
>
> *"HDD construction through soil deposits containing large-size particles is challenging and avoided where possible. Cobbles and boulders can deflect the pilot bore from being installed on proper line and grade and can obstruct the reaming of the pilot bore and the pullback of the pipe string."* (Nielson et al., 2013).

In addition, there is a risk of encountering undocumented buried infrastructure (e.g., abandoned pipes) within the upper portion of the seabed (Section 4.4.3). Pilot testing of a single well could be performed in order to better assess the constructability and performance of shallow HDD wells in the challenging conditions present at the proposed El Segundo Desal Facility (Section3.3). Note however, based on available information from borings and the geophysical survey (Section3.2), the presence of cobbles and gravel is localized so a single pilot HDD well will not be representative of conditions and feasibility at other locations in the vicinity. Shallow HDD wells inside the reported closure depth[13] of 50 feet, which occurs approximately 6,500 feet offshore (Jenkins, 2015—Appendix K to this report) would also be vulnerable to seafloor instability. Moreover, potential deposition of silts and clays on the Santa Monica Bay seafloor can occur with El Nino storms and decrease the performance yield and require difficult, expensive, and potentially damaging maintenance of the HDD wells (Missimer et al., 2013).

In addition to the challenges listed above, HDD wells would draw water from zones of sediments potentially containing varying oxidation conditions along the axis of the well. This could lead to the mixing of anoxic water, containing dissolved iron, manganese or hydrogen sulfide and an oxic source, such as sea

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[13] The closure depth represents the closest point to the shoreline where a stable seabed occurs.

water. Oxidation of the iron, manganese and hydrogen sulfide would change it to a form which has minimal solubility, resulting precipitation of minerals that might impact performance of the intake and require additional maintenance and would require filtration prior to reverse osmosis. At El Segundo, elevated concentrations of both iron and manganese exist in the groundwater in the vicinity of the NRG Facility at up to 49 and 10 mg/L, respectively (MWH, 2007). There is no data available on hydrogen sulfide concentrations, but hydrogen sulfide is common in the shallow subsurface beneath the sea floor.

The high degree of construction and maintenance challenges, the technical risks posed during construction and operation, and the lack of a suitable precedence constitutes a fatal flaw for shallow HDD wells within sand with abundant local gravel and cobbles. The uncertainty of the construction, maintenance and long term performance coupled with the estimated cost of \$80M to \$120M[14] to drill and install the wells presents too much technical and economic risk for West Basin to assume, as a public agency. Thus, HDD wells installed above the 20-foot low-permeability layer are not feasible.

Much deeper directionally drilled wells in rock are common in some oil fields. A project, known as the Proposed E&B Oil Drilling and Production Project, proposed the utilization of directional drilling of 34 wells to access the oil and gas reserved in the tidelands and in an onshore area known as the uplands in the City of Hermosa Beach (Marine Research Specialists, 2014).[15] The directional drilling wells were proposed to be constructed between 600 and 3,000-4,000 feet depth, which is very different than how HDD wells for SSIs would be constructed. The proposed project was rejected due to public opposition in March 2015.

5.5 Beach Infiltration Gallery

BIGs are designed to be located in the surf zone, such that they are self-cleaning due to the turbulence caused by breaking waves. Therefore a successful BIG should be located on beaches that are stable, with minimal erosion and deposition cycles (Section 4.2.2). This is not the case at El Segundo where the high energy environment, due to location on the exposed open coast of the Southern California Bight, fully open to long period swells from the Gulf of Alaska winter storms (Appendix K), can lead to long-term patterns of coastal erosion. These cycles can quickly become exacerbated by extreme winters (such as those caused by El Nino events) where up to 400 cubic yards/yard of erosion has been observed in a winter season along the beach in front of the NRG Facility (California State Lands Commission, 2010).

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[14] Preliminary cost estimates provided by Intake Works and HDD Company (9/24/2015). Based on assumed 1 MGD to 2 MGD per well.

[15] The final EIR for the Proposed E&B Oil Drilling and Production Project is available at http://www.hermosabch.org/index.aspx?page=738.

Beach nourishment activities replace sand lost due to erosion, but these typically occur infrequently (i.e., on cycles of several years). In the vicinity of Marina Del Rey harbor the US Army Corps of Engineers perform significant dredging and nourishment activities every 3 to 5 years (Appendix K). The erosion and nourishment cycles can result in the beach and surf zone position migrating considerably over periods of several years, which makes it difficult to construct a BIG that remains in the surf zone. The large change in the position of the coastal margin north and south of the jetty or rock groin adjacent to the NRG Facility (much wider beach north of the jetty) is evidence of substantial southward long-shore transport of sand and beach instability (Figure 3.1) (Google Earth, 2015; California State Lands Commission, 2010). BIGs have not been constructed in high-energy unstable beach settings such as at the El Segundo Desal Facility, and are considered technically infeasible.

5.6 Seabed Infiltration Gallery

The optimal location for SIGs is at or beyond the “closure depth” where the change in sedimentation due to coastal processes is essentially zero and the risk of the SIG becoming buried or eroded is minimal. Recent analysis by Dr. Scott Jenkins (2015), which is provided in Appendix K, indicates that the closure depth is approximately 50 feet (15 m) and is located 6,500 feet offshore.

The 50 feet depth, coupled with the high-energy ocean environment and long-period ocean swells, would require specialized trestle or float-in construction methods identified for Huntington Beach that were found to be not economically viable for the 50 MGD production capacity (ISTAP, 2015). El Segundo is a comparable site to Huntington Beach because of the general similarity in terms of wave exposure (Appendix K), bathymetry and high energy ocean environment (Appendix K; Section 4.2.3). Therefore El Segundo is subject to the same constraints and challenges as Huntington Beach for construction of a SIG. A detailed cost estimate and economic analysis was not conducted for the smaller proposed desal facility at the NRG Facility, but a comparison of some key parameters in Table 5.2 indicates that capital costs are likely to exceed $774M. Moreover, the unit costs (i.e., cost per acre-foot) are likely to be greater for the NRG Facility site due to reduced economies of scale, and as such the same arguments will likely indicate that a SIG is not economically viable at the NRG Facility.

Table 5.2: Comparison of NRG Facility and Huntington Beach

	Huntington Beach (ISTAP, 2015)	NRG Facility, El Segundo
Closure depth (feet)	42	50
Offshore distance to closure depth (feet)	3,400	6,500
Intake Production Capacity (MGD)	106	40
Estimated capital cost of SIG ($M)	1,936 – 2,347	> 774*

* Assuming a simplistic scaling based upon intake production capacity. Actual costs likely to be higher due to reduced economies of scale, fixed mobilization costs, and greater closure depth. The closure depth represents the closest point to the shoreline where a stable seabed occurs (see Jenkins, 2015—Appendix K to this report).

In addition to economic arguments, the construction of a SIG in the high-energy and relatively unprotected conditions offshore from the NRG Facility is unprecedented. By comparison, the Fukuoka SIG on the north-west side of the island of Kyushu Japan is in a fetch-limited environment and is not exposed to the long-period open ocean swell waves that are present in the Santa Monica Bay (Appendix K). Similarly the small scale test SIG at Long Beach is located inside the breakwater system of the Long Beach/Los Angeles where it is completely sheltered from wave exposure (Appendix K). This substantially increases the complexity of construction (see Section 4.6.2). The high energy environment at El Segundo further exacerbates the performance risk and uncertainty of outcome (Section 4.6.3) due to the lack of precedence (Section 4.6.1).

Moreover, erosion of massive amounts of sediments from the watershed, which can occur as a consequence of El Nino winter storms, has the potential to deposit silts and clays on the Santa Monica Bay seafloor that would cover the surface of a SIG (Appendix K). Deposition of fine-grained sediment would substantially decrease the performance yield and/or require difficult, expensive, and potentially environmentally damaging maintenance (Section 4.5.2).

The uncertainty of performance with time coupled with the estimated cost in excess of $774M to build a SIG, presents too much technical and economic risk for West Basin to assume as a public agency. Thus, SIGs are not technically feasible at the NRG Facility.

5.7 Deep Infiltration Gallery

DIGs or water tunnels are a range of conceptual offshore subsurface seawater collector systems without precedence for comparable conditions. Accordingly, information is not available on performance risk and reliability.

One DIG concept is a large pipe or tunnel beneath the sea floor that connects a series of vertical or radial collector wells to an onshore pump station. One conceptual design for the tunnel consists of two concentric pipelines with the inner pipeline serving for brine discharge. A different conceptual DIG design consists of a single tunnel connecting a series of vertical wells completed both above and beneath the tunnel with access to the wells provided by ports in seafloor.

A one kilometer long offshore DIG tunnel with lateral intakes was constructed to provide a portion of 34.3 MGD of feed water for a Desal Facility in Alicante, Spain. However, the DIG tunnel in Alicante is apparently constructed in limestone rock (Rachman et al., 2014, not in unconsolidated alluvium. DIGs are a novel idea, but not a proven technology for offshore marine unconsolidated alluvial settings.

The extreme construction complexity (e.g., may require ground freezing [ISTAP, 2014]), coupled with potentially high technical risks and lack of precedence at comparable conditions, result in DIGs being deemed technically infeasible at the proposed El Segundo Desal Facility.

6 Conclusions

Extensive research, field testing, and analyses were conducted to evaluate the overall feasibility of seven SSI technologies to provide 40 MGD of feed water for the proposed desal facility at the NRG Facility in El Segundo.[16]

The evaluation considered geotechnical data, hydrogeology, benthic topography, oceanographic conditions, presence of sensitive habitats, presence of sensitive species, impact on freshwater aquifers, existing infrastructure, design constraints (e.g., construction complexity), precedence (and associated technical risk), environmental and social factors, and economic viability.

The analysis determined that none of the seven SSI technologies are feasible for the intake rate of 40 MGD at the NRG Facility as a result of technical, social, environmental, and economic factors. The main limiting factors are summarized below. Higher intake rates would not feasible because of the same fatal flaws.

Vertical, slant, radial collector, and HDD wells constructed below the 20-foot depth low-permeability layer would have limited hydraulic connection to the ocean and as such have the following flaws:

- Impact on water supply aquifers;
- Impact on West Coast Basin Injection Barrier;
- Drawing contaminated water and mobilizing contaminant plumes;
- Drawing groundwater from an area de-designated for municipal beneficial use; and
- Unable to provide the required flow rate with SSI facilities located within the NRG Facility.

These constitute fatal flaws, and render each of the above SSI options infeasible at the NRG Facility. In addition, in order to meet production capacity requirements, well heads would need to be located outside the NRG Facility, which would require

- Construction in front of residential property or in snowy plover habitat;
- Installation of required infrastructure to support SSIs – power, controls, piping, access roads; and
- Performance of routine operation and maintenance activities in front of residential property or in snowy plover habitat.

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[16] 40 MGD is the approximate feed water intake rate required for a potable water production capacity of 20 MGD, which is considered the minimum capacity for the project.

More importantly, vertical, slant, radial collector, and HDD wells (constructed below the 20-foot depth low-permeability layer) located outside of the NRG Facility would be subject to the same fatal flaws as outlined above:

- To the north of the NRG Facility the wells would withdraw water from inland adjudicated aquifers that locally are de-designated for municipal use and are contaminated; and
- To the south of the NRG Facility the wells would withdraw water from the injection barrier, where it is located even closer to the coastline.

Additional challenges for these SSIs include risk of mixing of different water sources in the SSI intakes and risk of clogging (as discussed within the report).

The remaining SSI technologies (i.e., BIGs, SIGs, DIGs, and HDD wells constructed above the 20-foot depth low-permeability layer) would have better hydraulic connection to the ocean and are therefore unlikely to impact inland groundwater. However, these technologies lack precedence at sites with comparable hydrogeologic and oceanographic conditions, require complex construction techniques, and lack sufficient information on reliability and performance risk at the scale matching the desired production capacity, as summarized below:

- HDD constructed above the 20-foot depth low-permeability layer
    - Presence of cobbles and gravel would likely prevent successful drilling and installation;
    - Lack of precedence of shallow installation in unconsolidated sand with gravel and cobbles beneath the seafloor;
    - Potential for subsequent deposition of fine-grained sediment (e.g., from El Nino winter storms) on seafloor, thereby decreasing performance or requiring maintenance; and
    - Risk of encountering undocumented buried infrastructure.
- BIG
    - Lack of precedence of construction and performance in high-energy ocean environments subject to long-period ocean swells; and
    - Lack of beach stability and/or sea level rise resulting in migration of surf zone away from a BIG.

- SIG
    - Lack of precedence of construction and performance in high-energy ocean environments subject to long-period ocean swells;
    - Complex and expensive construction methods;
    - Potential for subsequent deposition of fine-grained sediment (e.g., from El Nino winter storms) on constructed gallery, thereby decreasing performance or requiring maintenance; and
    - Demonstrated not to be economically viable at a similar setting (Huntington Beach).
- DIG
    - Lack of precedence of construction in offshore unconsolidated alluvial sediments;
    - Lack of precedence and performance in high-energy ocean environments subject to long-period ocean swells;
    - Complex and expensive construction methods; and
    - Not a proven technology.

All of the above factors pose significant construction and performance risks. Coupled with high capital costs, the assumed technical and economic risk is unacceptable for West Basin. Thus, all SSI technologies are infeasible at the NRG Facility, and construction of SSIs outside of the NRG Facility would be subject to the same fatal flaws and challenges and are not feasible. In addition, due to the similar hydrogeologic setting, many of the same fatal flaws and challenges would apply to construction of SSIs at the AES Facility at Redondo Beach, which was also considered by West Basin for the proposed desal facility.

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APPENDIX A
Ocean Plan 2015

Draft Final Amendment to the Water Quality Control Plan for Ocean Waters of California
Addressing Desalination Facility Intakes, Brine Discharges, and Incorporating Other
Nonsubstantive Changes.

This May 5, 2015 draft reflects changes circulated on April 24, 2015 in blue single underline and ~~red single strikethrough~~**.** Additional changes since April 24, 2015, including changes in Change Sheet #1 and Change Sheet #2 circulated on May 1, 2015 and May 4, 2015 respectively, are reflected in blue double underline and ~~red double strikethrough~~. Text that has been moved, but not changed, is reflected in green double underline and ~~green double strikethrough~~.

[NOTE: the proposed Desalination Amendment, if adopted, will be inserted into chapter III.M, not L, of the Ocean Plan.]

M. Implementation Provisions for Desalination Facilities*

1. Applicability and General Provisions

   a. Chapter III.~~L~~ M applies to desalination facilities* using seawater.* Chapter III.~~L~~M.2 does not apply to desalination facilities* operated by a federal agency. Chapter III.~~L~~M.2, ~~L~~M.3, and ~~L~~M.4 do not apply to portable desalination facilities* that withdraw less than 0.10 million gallons per day (MGD) of seawater* and are operated by a governmental agency. These standards do not alter or limit in any way the authority of any public agency to implement its statutory obligations. The Executive Director of the State Water Board may temporarily waive the application of chapter III.~~L~~ M to desalination facilities* that are operating to serve as a critical short term water supply during a state of emergency as declared by the Governor.

   b. Definitions of New, Expanded, and Existing Facilities:

      (1) For purposes of chapter III.~~L~~M, "existing facilities" means desalination facilities* that have been issued an NPDES permit and all building permits and other governmental approvals necessary to commence construction for which the owner or operator has relied in good faith on those previously-issued permits and approvals and commenced construction of the facility beyond site grading prior to [effective date of this Plan]. ~~Existing facilities do not include a facility for which permits and approvals were issued and construction commenced after January 1, 1977, but for which a regional water board did not make a determination of the best site, design, technology, and mitigations measures feasible, pursuant to Water Code section 13142.5, subdivision (b) (hereafter Water Code section 13142.5(b)).~~

      (2) For purposes of chapter III.~~L~~M, "expanded facilities" means existing facilities for which, after [effective date of the Plan], the owner or

operator does either of the following in a manner that could increase intake or mortality of all forms of marine life * beyond that which was originally approved in any NPDES permit or Water Code section 13142.5, subdivision (b) (hereafter Water Code section 13142.5(b)) determination:* 1) increases the amount of seawater* used either exclusively by the facility or used by the facility in conjunction with other facilities or uses, or 2) changes the design or operation of the facility. To the extent that the desalination facility* is co-located with another facility that withdraws water for a different purpose and that other facility reduces the volume of water withdrawn to a level less than the desalination facility's* volume of water withdrawn, the desalination facility* is considered to be an expanded facility.

(3) For purposes of chapter III.~~L~~M, "new facilities" means desalination facilities* that are not existing facilities or expanded facilities.

c. Chapter III.~~L~~M.2 (Water Code §13142.5(b) Determinations for New and Expanded Facilities: Site, Design, Technology, and Mitigation Measures) applies to new and expanded desalination facilities* withdrawing seawater.*

d. Chapter III.~~L~~M.3 (Receiving Water Limitation for Salinity*) applies to all desalination facilities* that discharge into ocean waters* and wastewater facilities that receive brine* from seawater* desalination facilities* and discharge into ocean waters.*

e. Chapter III.~~L~~M.4 (Monitoring and Reporting Programs) applies to all desalination facilities* that discharge into ocean waters.* Chapter III.~~L~~M.4 shall not apply to a wastewater facility that receives brine* from a seawater* desalination facility* and discharges~~ing~~ a positively buoyant commingled effluent through an existing wastewater outfall that is covered under an existing NPDES permit as long as the owner or operator monitors for compliance with the receiving water limitation set forth in chapter III.~~L~~M.3. For the purposes of chapter III.~~L~~M.4, a positively buoyant commingled effluent shall mean that the commingled plume rises when it enters the receiving water body due to salinity* levels in the commingled discharge being lower than the natural background salinity.*

f. References to the regional water board include the regional water board acting under delegated authority. For provisions that require consultation between regional water board and State Water Board staff, the regional water board shall notify and consult with the State Water Board staff prior to making a final determination on the item requiring consultation.

g. All desalination facilities must comply with all other applicable sections of the Ocean Plan.

2. Water Code section 13142.5(b) Determinations for New and Expanded Facilities: Site, Design, Technology, and Mitigation Measures Feasibility Considerations

   a. General Considerations

      (1) The owner or operator shall submit a request for a Water Code section 13142.5(b) determination to the appropriate regional water board as early as practicable. This request shall include sufficient information for the regional water board to conduct the analyses described below. The regional water board in consultation with the State Water Board staff may require an owner or operator to provide additional studies or information if needed, including any information necessary to identify and assess other potential sources of mortality to all forms of marine life. All studies and models are subject to the approval of the regional water board in consultation with State Water Board staff. The regional water board may require an owner or operator to hire a neutral third party entity to review studies and models and make recommendations to the regional water board.

      (2) The regional water board shall conduct a Water Code section 13142.5(b) analysis of all new and expanded desalination facilities.* A Water Code section 13142.5(b) analysis may include future expansions at the facility. The regional water board shall first analyze separately as independent considerations a range of feasible* alternatives for the best available site, the best available design, the best available technology, and the best available mitigation measures to minimize intake and mortality of all forms of marine life.* Then, the regional water board shall consider all four factors collectively and determine the best combination of feasible* alternatives to minimize intake and mortality of all forms of marine life.* The best combination of alternatives may not always include the best alternative under each individual factor because some alternatives may be mutually exclusive, redundant, or not feasible* in combination.

      (3) The regional water board's Water Code section 13142.5(b) analysis for expanded facilities may be limited to those expansions or other changes that result in the increased intake or mortality of all forms of marine life,* unless the regional water board determines that additional measures that minimize intake and mortality of all forms of marine life* are feasible* for the existing portions of the facility.

      (4) In conducting the Water Code section 13142.5(b) determination, the regional water boards shall consult with other state agencies involved in the permitting of that facility, including, but not limited to: California Coastal Commission, California State Lands Commission, and California Department of Fish and Wildlife. The regional water board

shall consider project-specific decisions made by other state agencies; however, the regional water board is not limited to project-specific requirements set forth by other agencies and may include additional requirements in a Water Code section 13142.5(b) determination.

(5) A regional water board may expressly condition a Water Code section 13142.5(b) determination based on the expectation of the occurrence of a future event. Such future events may include, but are not limited to, the permanent shutdown of a co-located power plant with intake structures shared with the desalination facility* or a reduction in the volume of wastewater available for the dilution of brine.* The regional water board must make a new Water Code section 13142.5(b) determination if the foreseeable future event occurs.

  (a) The owner or operator shall provide notice to the regional water board as soon as it becomes aware that the expected future event will occur, and shall submit a new request for a Water Code section 13142.5(b) determination to the regional water board at least one year prior to the event occurring. If the owner or operator does not become aware that the event will occur at least one year prior to the event occurring, the owner or operator shall submit the request as soon as possible.

  (b) The regional water board may allow up to five years from the date of the event for the owner or operator to make modifications to the facility required by a new Water Code section 13142.5(b) determination, provided that the regional water board finds that 1) any water supply interruption resulting from the facility modifications requires additional time for water users to obtain a temporary replacement supply or 2) such a compliance period is otherwise in the public interest and reasonably required for modification of the facility to comply with the determination.

  (c) If the regional water board makes a Water Code section 13142.5(b) determination for a desalination facility* that will be co-located with a power plant, the regional water board shall condition its determination on the power plant remaining in compliance with the Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling.

b. Site is the general onshore and offshore location of a new or expanded facility. There may be multiple potential facility design configurations within any given site. For each potential site, in order to determine whether a proposed facility site is the best available site feasible* to minimize intake and mortality of all forms of marine life,* the regional water board shall require the owner or operator to:

(1) Consider whether subsurface intakes* are feasible.*

(2) Consider whether the identified need for desalinated* water is consistent with an applicable adopted ~~county general plans, integrated regional water management plans, or~~ urban water management plan~~s~~ prepared in accordance with Water Code section 10631, or if no urban water management plan is available, other water planning documents such as a county general plan or integrated regional water management plan~~if these plans are unavailable~~.

(3) Analyze the feasibility of placing intake, discharge, and other facility infrastructure in a location that avoid impacts to sensitive habitats* and sensitive species.

(4) Analyze the direct and indirect effects on all forms of marine life* resulting from facility construction and operation, individually and in combination with potential anthropogenic effects on all forms of marine life* resulting from other past, present, and reasonably foreseeable future activities within the area affected by the facility.

(5) Analyze oceanographic geologic, hydrogeologic, and seafloor topographic conditions at the site, so that the siting of a facility, including the intakes and discharges, minimizes the intake and mortality of all forms of marine life.*

(6) Analyze the presence of existing discharge infrastructure, and the availability of wastewater to dilute the facility's brine* discharge.

(7) Ensure that the intake and discharge structures are not located within a MPA or SWQPA* with the exception of intake structures ~~without~~ that do not have marine life mortality associated with the construction, operation, and maintenance of the intake structures ~~related marine life mortality~~ (e.g. slant wells). Discharges shall be sited at a sufficient distance from a MPA or SWQPA* so that the salinity* within the boundaries of a MPA or SWQPA* does not exceed natural background salinity.* To the extent feasible,* surface intakes shall be sited so as to maximize the distance from a MPA or SWQPA.*

c. Design is the size, layout, form, and function of a facility, including the intake capacity and the configuration and type of infrastructure, including intake and outfall structures. The regional water board shall require that the owner or operator perform the following in determining whether a proposed facility design is the best available design feasible* to minimize intake and mortality of all forms of marine life:*

(1) For each potential site, analyze the potential design configurations of the intake, discharge, and other facility infrastructure to avoid impacts to sensitive habitats* and sensitive species.

(2) If the regional water board determines that subsurface intakes* are not feasible* and surface water intakes are proposed instead, analyze potential designs for those intakes in order to minimize the intake and mortality of all forms of marine life.*

(3) Design the outfall so that the brine mixing zone* does not encompass or otherwise adversely affect existing sensitive habitat.*

(4) Design the outfall so that discharges do not result in dense, negatively-buoyant plumes that result in adverse effects due to elevated salinity* or hypoxic conditions occurring outside the brine mixing zone.* An owner or operator must demonstrate that the outfall meets this requirement through plume modeling and/or field studies. Modeling and field studies shall be approved by the regional water board in consultation with State Water Board staff.

(5) Design outfall structures to minimize the suspension of benthic sediments.

d. Technology is the type of equipment, materials,* and methods that are used to construct and operate the design components of the desalination facility.* The regional water board shall apply the following considerations in determining whether a proposed technology is the best available technology feasible* to minimize intake and mortality of all forms of marine life*:

(1) Considerations for Intake Technology:

(a) Subject to ~~Section~~ chapter ~~L~~M.2.a.(2), the regional water board in consultation with State Water Board staff shall require subsurface intakes* unless it determines that subsurface intakes* are not feasible* based upon a comparative analysis of the factors listed below for surface and subsurface intakes.* A design capacity in excess of the need for desalinated* water as identified in chapter III.~~L~~M.2.b.(2) shall not be used by itself to declare subsurface intakes* as not feasible.*

i. The regional water board shall consider the following factors in determining feasibility of subsurface intakes:* geotechnical data, hydrogeology, benthic topography, oceanographic conditions, presence of sensitive habitats,* presence of sensitive species, energy use for the entire facility;~~ impact on freshwater aquifers, local water supply, and existing water users; desalinated* water conveyance, existing infrastructure, ~~design constraints (engineering, constructability), and project life cycle cost. Project life cycle cost shall be determined by evaluating the total cost of planning, design, land acquisition, construction, operations, maintenance, mitigation, equipment replacement and disposal over the lifetime of the facility, in addition to the cost of decommissioning the facility. Subsurface intakes* shall not be determined to be economically infeasible solely because subsurface intakes* may be more expensive than surface intakes. Subsurface intakes* may be determined to be economically infeasible if the additional costs or lost profitability associated with subsurface intakes,* as compared to surface intakes, would render the desalination facility* not economically viable. In addition, the regional water board may evaluate other site- and facility-specific factors.

ii. If the regional water board determines that subsurface intakes* are not feasible* for the proposed intake design capacity, it shall determine whether subsurface intakes* are feasible* for a reasonable range of alternative intake design capacities. The regional water board may find that a combination of subsurface* and surface intakes is the best feasible* alternative to minimize intake and mortality of marine life and meet the identified need for desalinated water as described in chapter III.M.2.b.(2).

(b) Installation and maintenance of a subsurface intake* shall avoid, to the maximum extent feasible,* the disturbance of sensitive habitats* and sensitive species.

(c) If subsurface intakes* are not feasible,* the regional water board may approve a surface water intake subject to the following conditions:

i. The regional water board shall require that surface water intakes be screened. Screens must be functional while the facility is withdrawing seawater.*

ii. In order to reduce entrainment, all surface water intakes must be screened with a 1.0 mm (0.04 in) or smaller slot size screen when the desalination facility* is withdrawing seawater.*

iii. An owner or operator may use an alternative method of preventing entrainment so long as the alternative method results in intake and mortality of eggs, larvae, and juvenile organisms that is less than or equivalent to a 1.0 mm (0.04 in) slot size screen. The owner or operator must demonstrate the effectiveness of the alternative method to the regional water board. The owner or operator must conduct a study to demonstrate the effectiveness of the alternative method, and use an Empirical Transport Model* (ETM)/ Area of Production Forgone* (APF) approach* to estimate entrainment. The study period shall be at least 12 consecutive months. Sampling for environmental studies shall be designed to account for variation in oceanographic or hydrologic conditions and larval abundance and diversity such that abundance estimates are reasonably accurate. Samples must be collected using a mesh size no larger than 335 microns and individuals collected shall be identified to the lowest taxonomical level practicable. The ETM/APF analysis* shall evaluate entrainment for a broad range of species, species morphologies, and sizes under the environmental and operational conditions that are representative of the entrained species and the conditions at the full-scale desalination facility.* At their discretion, the regional water boards may permit the use of existing entrainment data to meet this requirement.

iv. In order to minimize impingement, through-screen velocity at the surface water intake shall not exceed 0.15 meters per second (0.5 feet per second).

(2) Considerations for Brine* Discharge Technology:

(a) The preferred technology for minimizing intake and mortality of all forms of marine life* resulting from brine* discharge ~~disposal~~ is to commingle brine* with wastewater (e.g., agricultural, municipal, industrial, power plant cooling water, etc.) that would otherwise be discharged to the ocean. The wastewater must provide adequate dilution to ensure salinity* of the commingled discharge meets the receiving water limitation for salinity* in chapter III.M.3. ~~is less than or equal to the natural background salinity,* or the commingled discharge shall be discharged through multiport diffusers.*~~ Nothing in this section shall preclude future recycling of the wastewater.

(b) Multiport diffusers* are the next best method for disposing of brine* when the brine* cannot be diluted by wastewater and when there are no live organisms in the discharge. Multiport diffusers* shall be engineered to maximize dilution, minimize the size of the brine mixing zone,* minimize the suspension of benthic sediments, and minimize mortality of all forms of marine life.*

(c) Brine* discharge ~~disposal~~ technologies other than wastewater dilution and multiport diffusers,* ~~such as flow augmentation,*~~ may be used if an owner or operator can demonstrate to the regional water board that the technology provides a comparable level of intake and mortality of all forms of marine life* as wastewater dilution if wastewater is available, or multiport diffusers* if wastewater is unavailable. The owner or operator must evaluate all of the individual and cumulative effects of the proposed alternative discharge method on the intake and mortality of all forms of marine life*, including (where applicable); intake-related entrainment, osmotic stress, turbulence that occurs during water conveyance and mixing, and shearing stress at the point of discharge. When determining the ~~level of protection provided by~~intake and mortality associated with a brine* discharge ~~disposal~~ technology or combination of technologies, the regional water board shall require the owner or operator to use empirical studies or modeling to:

i. Estimate intake entrainment impacts using an ETM/APF approach.*

ii. Estimate degradation of all forms of marine life* from elevated salinity* within the brine mixing zone,* including osmotic stresses, the size of impacted area, and the duration that all forms of marine life* are exposed to the toxic conditions. Considerations shall be given to the most sensitive species, and community structure and function.

iii. Estimate the intake and mortality of all forms of marine life* that occurs as a result of water conveyance, in-plant turbulence or mixing, and waste* discharge.

iv. Within ~~three years~~18 months of beginning operation, submit to the regional water board an empirical study that evaluates intake and mortality of all forms of marine life* associated with ~~flow augmentation*~~the alternative brine* discharge technology. The study must evaluate impacts caused by any augmented intake volume, intake and pump technology, water conveyance, waste brine* mixing, and effluent discharge. Unless demonstrated otherwise, organisms entrained by ~~flow augmentation*~~ the alternative brine* discharge technology are assumed to have a mortality rate of 100 percent. The study period shall be at least 12 consecutive months. If the regional water board requires a study period longer than 12 months, the final report must be submitted to the regional water board within 6 months of the completion of the empirical study.

v. If the empirical study shows that ~~flow augmentation*~~the alternative brine* discharge ~~disposal~~ technology ~~is less protective of~~ results in more intake and mortality of all forms of marine life* than a facility using wastewater dilution or multiport diffusers,* then the facility must either (1) cease using ~~flow augmentation*~~ the alternative brine* discharge technology and install and use wastewater dilution or multiport diffusers* to discharge brine* waste, or (2) re-design the ~~flow augmentation*~~the alternative brine* discharge technology system to minimize intake and mortality of all forms of marine life* to a level that is comparable with wastewater dilution if wastewater is available, or multiport diffusers* if wastewater is unavailable,* subject to regional water board approval.

(d) Flow augmentation* as an alternative brine* discharge technology is prohibited with the following exceptions:

i. At facilities that use subsurface intakes* to supply augmented flow water for dilution. Facilities that use subsurface intakes* to supply augmented flow water for dilution are exempt from the requirements of chapter III.M.2.d.(2)(c) if the facility meets the receiving water limitation for salinity* in chapter III.M.3.

ii. At a facility that has received a conditional Water Code section 13142.5(b) determination and is over 80 percent constructed by [the effective date of this plan]. If the ~~An~~owner or operator of the facility proposes ~~proposing~~ to use flow augmentation* as an alternative brine* discharge technology, the facility must: ~~U~~use low turbulence intakes (e.g., screw centrifugal pumps or axial flow pumps) and conveyance pipes~~.~~; c~~C~~onvey and mix dilution water in a manner that limits thermal stress, osmotic stress, turbulent shear stress, and other factors that could cause intake and mortality of all forms of marine life*; ~~Facilities proposing to using flow augmentation* must~~ comply with chapter III.~~L~~M.2.d.(1); ~~Facilities proposing to using flow augmentation* through surface intakes are prohibited from~~ and not discharge~~ing~~ through multiport diffusers.*

~~iii. Within three years of beginning operation, submit to the regional water board an empirical study that evaluates intake and mortality of all forms of marine life* associated with flow augmentation*. The study must evaluate impacts caused by augmented intake volume, intake and pump technology, water conveyance, waste brine* mixing, and effluent discharge. Unless demonstrated otherwise, organisms entrained by flow augmentation* are assumed to have a mortality rate of 100 percent. The study period shall be at least 12 consecutive months.~~

~~iv. If the empirical study shows that flow augmentation* is less protective of all forms of marine life* than a facility using wastewater dilution or multiport diffusers,* then the facility must either (1) cease using flow augmentation* technology and install and use wastewater dilution or multiport diffusers* to discharge brine* waste, or (2) re-design the flow augmentation* system to minimize intake and mortality of all forms of marine life* to a level that is comparable with wastewater dilution if wastewater is available, or multiport diffusers if wastewater is unavailable,* subject to regional water board approval.~~

~~v. Facilities proposing to using flow augmentation* must comply with chapter III.L.2.d.(1).~~

~~vi. Facilities proposing to using flow augmentation* through surface intakes are prohibited from discharging through multiport diffusers.*~~

~~(c) Facilities that use subsurface intakes* to supply augmented flow water for dilution are exempt from the requirements of chapter III.L.2.d.(2) if the facility meets the receiving water limitation for salinity in chapter III.L.3.~~

e. Mitigation for the purposes of this section is the replacement of all forms of marine life* or habitat that is lost due to the construction and operation of a desalination facility* after minimizing intake and mortality of all forms of marine life* through best available site, design, and technology. The regional water board shall ensure an owner or operator fully mitigates for the operational lifetime of the facility and uses the best available mitigation measures feasible* to minimize intake and mortality of all forms of marine life.* The owner or operator may choose whether to satisfy a facility's mitigation measures pursuant to chapter III.~~L~~M.2.e.(3) or, if available, ~~L~~M.2.e.(4), or a combination of the two.

(1) *Marine Life Mortality Report.* The owner or operator of a facility shall submit a report to the regional water board estimating the marine life mortality resulting from construction and operation of the facility after

implementation of the facility's required site, design, and technology measures.

(a) For operational mortality related to intakes, the report shall include a detailed entrainment study. The entrainment study period shall be at least 12 consecutive months and sampling shall be designed to account for variation in oceanographic or hydrologic conditions and larval abundance and diversity such that abundance estimates are reasonably accurate. At their discretion, the regional water boards may permit the use of existing entrainment data from the facility to meet this requirement. Samples must be collected using a mesh size no larger than 335 microns and individuals collected shall be identified to the lowest taxonomical level practicable. The ETM/APF analysis* shall be representative of the entrained species collected using the 335 micron net. The APF* shall be calculated using a one-sided, upper 95 percent confidence bound for the 95th percentile of the APF distribution.

[** ***NOTE: This language is optional additional language for the board members to consider at the May 6, 2015 board meeting***: *An owner or operator may use an alternative mitigation assessment method if the method assesses intake and mortality of all forms of marine life* and can be used to determine the number of mitigation acres needed to fully mitigate for the impacts. The method must be peer reviewed by a neutral third party expert review panel and then approved by the regional water board in consultation with the State Water Board staff.*]

An owner or operator with subsurface intakes* is not required to do an ETM/APF analysis* for their intakes and is not required to mitigate for intake-related operational mortality. The regional water board may apply a one percent reduction to the APF* acreage calculated in the Marine Life Mortality Report to account for the reduction in entrainment~~ reduction~~ of all forms of marine life* when using a 1.0 mm slot size screen.

(b) For operational mortality related to discharges, the report shall estimate the area in which salinity* exceeds 2.0 parts per thousand above natural background salinity* or a facility-specific alternative receiving water limitation (see ~~§L~~chapter III.M.3). The area in excess of the receiving water limitation for salinity* shall be determined by modeling and confirmed with monitoring. The report shall use any acceptable approach approved by the regional water board for evaluating mortality that occurs due to shearing stress resulting from the facility's discharge, including any incremental increase in mortality resulting from a commingled discharge.

(c) For construction-related mortality, the report shall use any acceptable approach approved by the regional water board for evaluating the mortality that occurs within the area disturbed by the facility's construction. The regional water board may determine that the construction-related disturbance does not require mitigation because the disturbance is temporary and the habitat is naturally restored.

(d) Upon approval of the report by the regional water board in consultation with State Water Board staff, the calculated marine life mortality shall form the basis for the mitigation provided pursuant to this section.

(2) The owner or operator shall mitigate for the mortality of all forms of marine life* determined in the report above by choosing to either complete a mitigation project as described in chapter III.~~L~~M.2.e.(3) or, if an appropriate fee-based mitigation program is available, provide funding for the program as described in chapter III.~~L~~M.2.e.(4). The mitigation project or the use of a fee-based mitigation program and the amount of the fee that the owner or operator must pay is subject to regional water board approval.

(3) *Mitigation Option 1: Complete a Mitigation Project.* The mitigation project must satisfy the following provisions:

(a) The owner or operator shall submit a Mitigation Plan. Mitigation Plans shall include: project objectives, site selection, site protection instrument (the legal arrangement or instrument that will be used to ensure the long-term protection of the compensatory mitigation project site), baseline site conditions, a mitigation work plan, a maintenance plan, a long-term management plan, an adaptive management plan, performance standards and success criteria, monitoring requirements, and financial assurances.

(b) The mitigation project must meet the following requirements:

i. Mitigation shall be accomplished through expansion, restoration or creation of one or more of the following: kelp beds,* estuaries,* coastal wetlands, natural reefs, MPAs, or other projects approved by the regional water board that will mitigate for intake and mortality of all forms of marine life* associated with the facility.

ii. The owner or operator shall demonstrate that the project fully mitigates for intake-related marine life mortality by including expansion, restoration, or creation of habitat based on the APF* acreage calculated in the Marine Life Mortality Report above. The owner or operator using surface water intakes shall do modeling to evaluate the areal extent of the mitigation project's production area to confirm that it overlaps the facility's source water body.* Impacts on the mitigation project due to entrainment by the facility must be offset by adding compensatory acreage to the mitigation project.

iii. The owner or operator shall demonstrate that the project also fully mitigates for the discharge-related marine life mortality projected in the Marine Life Mortality Report above.

iv. The owner or operator shall demonstrate that the project also fully mitigates for the construction-related marine life mortality identified in the Marine Life Mortality Report above.

v. The regional water board may permit out-of-kind mitigation* for mitigation of open water or soft-bottom species. In-kind mitigation* shall be done for all other species whenever feasible.*

vi. For out-of-kind mitigation,* an owner or operator shall evaluate the biological productivity of the impacted open water or soft-bottom habitat calculated in the Marine Life Mortality Report and the proposed mitigation habitat. If the mitigation habitat is a more biologically productive habitat (e.g. wetlands, estuaries,* rocky reefs, kelp beds,* eelgrass beds,* surfgrass beds*), the regional water boards may apply a mitigation ratio based on the relative biological productivity of the impacted open water or soft-bottom habitat and the mitigation habitat. The mitigation ratio shall not be less than one acre of mitigation habitat for every ten acres of impacted open water or soft-bottom habitat.

vii. For in-kind mitigation,* the mitigation ratio shall not be less than one acre of mitigation habitat for every one acre of impacted habitat.

viii. For both in-kind* and out-of-kind mitigation,* the regional water boards may increase the required mitigation ratio for any species and impacted natural habitat calculated in the Marine Life Mortality Report when appropriate to account for imprecisions associated with mitigation, including but not limited to, the likelihood of success, temporal delays in productivity, and the difficulty of restoring or establishing the desired productivity functions.

ix. The rationale for the mitigation ratios must be documented in the administrative record for the permit action.

(c) The Mitigation Plan is subject to approval by the regional water board in consultation with State Water Board staff and with other agencies having authority to condition approval of the project and require mitigation.

(4) *Mitigation Option 2: Fee-based Mitigation Program*. If the regional water board determines that an appropriate fee-based mitigation program has been established by a public agency, and that payment of a fee to the mitigation program will result in the creation and ongoing implementation of a mitigation project that meets the requirements of ~~section~~ chapter ~~L~~ M.2.e.(3), the owner or operator may pay a fee to the mitigation program in lieu of completing a mitigation project.

(a) The agency that manages the fee-based mitigation program must have legal and budgetary authority to accept and spend mitigation funds, a history of successful mitigation projects documented by having set and met performance standards for past projects, and stable financial backing in order to manage mitigation sites for the operational life of the facility.

(b) The amount of the fee shall be based on the cost of the mitigation project, or if the project is designed to mitigate cumulative impacts from multiple desalination facilities or other development projects, the amount of the fee shall be based on the desalination facility's* fair share of the cost of the mitigation project.

(c) The manager of the fee-based mitigation program must consult with the California Department of Fish and Wildlife, Ocean Protection Council, Coastal Commission, State Lands Commission, and State and regional water boards to develop mitigation projects that will best compensate for intake and mortality of all forms of marine life* caused by the desalination facility.* Mitigation projects that increase or enhance the viability and sustainability of all forms of marine life* in Marine Protected Areas are preferred, if feasible.*

(5) California Department of Fish and Wildlife, the regional water board, and State Water Board may perform audits or site inspections of any mitigation project.

(6) An owner or operator, or a manager of a fee-based mitigation program, must submit a mitigation project performance report to the regional water board 180 days prior to the expiration date of their NPDES permit.

(7) For conditionally permitted facilities or expanded facilities, the regional water boards may:

(a) Account for previously-approved mitigation projects associated with a facility when making a new Water Code section 13142.5(b) determination.

(b) Require additional mitigation when making a new Water Code section 13142.5(b) determination for any additional mortality of all forms of marine life resulting from the occurrence of the conditional event or the expansion of the facility. The additional mitigation must be to compensate for any additional construction, discharge, or other increases in intake or impacts or an increase in intake and mortality of all forms of marine life.*

3. Receiving Water Limitation for Salinity*

a. Chapter III.~~L~~M.3 is applicable to all desalination facilities discharging brine* into ocean waters,* including facilities that commingle brine* and wastewater.

b. The receiving water limitation for salinity* shall be established as described below:

(1) Discharges shall not exceed a daily maximum of 2.0 parts per thousand (ppt) above natural background salinity* measured no further than 100 meters (328 ft) horizontally from ~~the~~ each discharge point. There is no vertical limit to this zone.

(2) In determining an effluent limit necessary to meet this receiving water limitation, permit writers shall use the formula in chapter III.C.4 that has been modified for brine* discharges as follows:

Equation 1: $Ce= Co + Dm(2.0 \text{ ppt})$
$Ce= (2.0 \text{ ppt} + Cs) + Dm(2.0 \text{ ppt})$

Where:

Ce= the effluent concentration limit, ppt
Co= the salinity* concentration to be met at the completion of initial* dilution= 2.0 ppt + Cs
Cs= the natural background salinity,* ppt
Dm= minimum probable initial dilution* expressed as parts seawater* per part brine* discharge

(a) The fixed distance referenced in the initial dilution* definition shall be no more than 100 meters (328 feet).

(b) In addition, the owner or operator shall develop a dilution factor (Dm) based on the distance of 100 meters (328 feet) or initial dilution,* whichever is smaller. The dilution factor (Dm) shall be developed within the brine mixing zone* using applicable water quality models that have been approved by the regional water boards in consultation with State Water Board staff.

(c) The value 2.0 ppt in Equation 1 is the maximum incremental increase above ~~ambient~~ natural background salinity* (Cs) allowed at the edge of the brine mixing zone.* A regional water board may substitute an alternative numeric value for 2.0 ppt in Equation 1 based upon the results of a facility-specific alternative salinity* receiving water limitation study, as described in chapter III.~~L~~M.3.c below.

c. An owner or operator may submit a proposal to the regional water board for approval of an alternative (other than 2 ppt) salinity* receiving water limitation to be met no further than 100 meters horizontally from the discharge. There is no vertical limit to this zone.

(1) To determine whether a proposed facility-specific alternative receiving water limitation is adequately protective of beneficial uses, an owner or operator shall:

(a) Establish baseline biological conditions at the discharge location and at reference locations over a 12-month period prior to commencing brine* discharge. The biologic surveys must characterize the ecologic composition of habitat and marine life using measures established by the regional water board. At their discretion, the regional water boards may permit the use of existing data to meet this requirement.

(b) Conduct at least the following chronic toxicity* Whole Effluent Toxicity (WET) tests: germination and growth for giant kelp (*Macrocystis pyrifera)*; development for red abalone (*Haliotis refescens)*; development and fertilization for purple urchin (*Strongleocentrotus purpuratus)*; development and fertilization for sand dollar (*Dendraster excentricus)*; larval growth rate for topsmelt (*Atherniops affinis)*. WET tests shall be performed by an Environmental Laboratory Accreditation Program (ELAP) certified laboratory.

(c) The regional water board in consultation with State Water Board staff may require an owner or operator to do additional toxicity studies if needed.

(2) The regional water board in consultation with the State Water Board staff may require an owner or operator to provide additional studies or information in order to approve a facility-specific alternative receiving water limitation for salinity.*

(3) The facility-specific alternative receiving water limitation shall be based on the lowest observed effect concentration (LOEC)* for the most sensitive species and toxicity endpoint as determined in the chronic toxicity* studies. The regional water board in consultation with State Water Board staff has discretion to approve the proposed facility-specific alternative receiving water limitation for salinity.*

~~(4)~~ The regional water board shall review a facility's monitoring data, the studies as required in chapter III.~~L~~M.4 below, or any other information that the regional water board deems to be relevant to periodically assess whether the facility-specific alternative receiving water limitation for salinity* is adequately protective of beneficial uses. The regional water board may eliminate or revise a facility-specific alternative receiving water limitation for salinity* based on its assessment of the data.

d. The owner or operator of a facility that has received a conditional Water Code section 13142.5(b) determination and is over 80 percent constructed by [the effective date of this plan] that proposes flow augmentation* using a surface water intake may submit a proposal to the regional water board in consultation with the State Water Board staff for approval of an alternative brine mixing zone* not to exceed 200 meters laterally from the discharge point and throughout the water column. The owner or operator of such a facility must demonstrate, in accordance with chapter III.M.2.d.(2)(c), that the combination of the alternative brine mixing zone* and flow augmentation* using a surface water intake provide a comparable level of intake and mortality of all forms of marine life* as the combination of the standard brine mixing zone* and wastewater dilution if wastewater is available, or multiport diffusers* if wastewater is unavailable. In addition to the analysis of the effects required by chapter III.M.2.d.(2)(c), the owner or operator must also evaluate the individual and cumulative effects of the alternative brine mixing zone* on the intake and mortality of all forms of marine life.* In no case may the discharge result in hypoxic conditions outside of the alternative brine mixing zone.* If an alternative brine mixing zone* is approved, the alternative distance and the areal extent of the alternative brine mixing zone* shall be used in lieu of the standard brine mixing zone* for all purposes, including establishing an effluent limitation and a receiving water limitation for salinity, in chapter III.M.

e. Existing facilities that do not meet the receiving water limitation at the edge of the brine mixing zone* and throughout the water column by [the effective date of this plan] must either: 1) establish a facility-specific alternative receiving water limitation for salinity* as described in chapter III.~~L~~M.3.c; or, 2) upgrade the facility's brine* discharge method in order to meet the receiving water limitation in chapter III.~~L~~M.3.b in accordance with the State Water Board's Compliance Schedule Policy, as set forth in (e) below. An owner or operator that chooses to upgrade the facility's method of brine* discharge ~~disposal~~:

(1) Must demonstrate to the regional water board that the brine* discharge does not negatively impact sensitive habitats,* sensitive species, MPAs, or SWQPAs.*

(2) Is subject to the Considerations for Brine* Discharge Technology described in chapter III.~~L~~M.2.d.(2).

f. The regional water board may grant compliance schedules for the requirements for brine* waste discharges for desalination facilities.* All compliance schedules shall be in accordance with the State Water Board's Compliance Schedule Policy, except that the salinity* receiving water limitation set forth in chapters III.~~L~~M.3.b and III.~~L~~M.3.c. shall be considered to be a "new water quality objective" as used in the Compliance Schedule Policy.

g. The regional water board in consultation with the State Water Board staff may require an owner or operator to provide additional studies or information if needed. All studies and models are subject to the approval of the regional water board in consultation with State Water Board staff. The regional water board may require an owner or operator to hire a neutral third party entity to review studies and models and make recommendations to the regional water board.

4. Monitoring and Reporting Programs

a. The owner or operator of a desalination facility* must submit a Monitoring and Reporting Plan to the regional water board for approval. The Monitoring and Reporting Plan shall include monitoring of effluent and receiving water characteristics and impacts to all forms of marine life.* The Monitoring and Reporting Plan shall, at a minimum, include monitoring for benthic community health, aquatic life toxicity, hypoxia, and receiving water characteristics consistent with Appendix III of this Plan and for compliance with the receiving water limitation in chapter III.~~L~~M.3. Receiving water monitoring for salinity* shall be conducted at times when the monitoring locations are most likely affected by the discharge. For new or expanded facilities the following additional requirements apply:

(1) An owner or operator must perform facility-specific monitoring to demonstrate compliance with the receiving water limitation for salinity,* and evaluate the potential effects of the discharge within the water column, bottom sediments, and the benthic communities. Facility-specific monitoring is required until the regional water board determines that a regional monitoring program is adequate to ensure compliance with the receiving water limitation. The monitoring and reporting plan shall be reviewed, and revised if necessary, upon NPDES permit renewal.

(2) Baseline biological conditions shall be established at the discharge location and at a reference location prior to commencement of construction. The owner or operator is required to conduct biological surveys (e.g., Before-After Control-Impact study), that will evaluate the differences between biological communities at a reference site and at the discharge location before and after the discharge commences. The regional water board will use the data and results from the surveys and any other applicable data for evaluating and renewing the requirements set forth in a facility's NPDES permit.

Add the following new definitions to, and amend existing definitions in, Appendix I of the Ocean Plan.

ALL FORMS OF MARINE LIFE includes all life stages of all marine species.

AREA PRODUCTION FOREGONE (APF), also known as habitat production foregone, is an estimate of the area that is required to produce (replace) the same amount of larvae or propagules* that are removed via entrainment at a desalination facility's* intakes. APF is calculated by multiplying the proportional mortality* by the source water body,* which are both determined using an empirical transport model.*

BRINE is the byproduct of desalinated* water having a salinity* concentration greater than a desalination facility's* intake source water.

BRINE MIXING ZONE is the area where salinity* may exceed~~s~~ 2.0 parts per thousand above natural background salinity,* or the concentration of salinity* approved as part of an alternative receiving water limitation. The standard brine mixing zone shall not exceed 100 meters (328 feet) laterally from the points of discharge and throughout the water column. An alternative brine mixing zone, if approved as described in chapter III.M.3.d, shall not exceed 200 meters (656 feet) laterally from the points of discharge and throughout the water column. The brine mixing zone is an allocated impact zone where there may be toxic effects on marine life due to elevated salinity.

DESALINATION FACILITY is an industrial facility that processes water to remove salts and other components from the source water to produce water that is less saline than the source water.

EELGRASS BEDS are aggregations of the aquatic plant species of the genus *Zostera*.

EMPIRICAL TRANSPORT MODEL (ETM) is a methodology for determining the spatial area known as the source water body* that contains the source water population, which are the organisms that are at risk of entrainment as determined by factors that may include but are not limited to biological, hydrodynamic, and oceanographic data. ETM can also be used to estimate proportional mortality,* P_m.

ETM/APF APPROACH or ANALYSIS. For guidance on how to perform an ETM/APF analysis please see Appendix E of the Staff Report for Amendment to the Water Quality Control Plan for Ocean Waters of California Addressing Desalination Facility Intakes, Brine* Discharges, and the Incorporation of Other Non-substantive Changes.

FEASIBLE, for the purposes of chapter III.~~L~~M, shall mean capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors.

FLOW AUGMENTATION is a type of in-plant dilution and occurs when a desalination facility* withdraws additional source water for the specific purpose of diluting brine* prior to discharge.

IN-KIND MITIGATION is when the habitat or species lost is the same as what is replaced through mitigation.

KELP BEDS are aggregations of marine algae of the order Laminariales, including species in the genera *Macrocystis, Nereocystis, and Pelagophycus*. Kelp beds include the total foliage canopy throughout the water column.

LOEC is the lowest observed effect concentration or the lowest concentration of effluent that causes observable adverse effects in exposed test organisms.

MARKET SQUID NURSERIES are comprised of numerous egg capsules, each containing approximately 200 developing embryos, attached in clusters or mops to sandy substrate with moderate water flow. Market squid (*Doryteuthis opalescens*) nurseries occur at a wide range of depths; however, mop densities are greatest in shallow, nearshore waters between ten and 100 meters (328 feet) deep.

MULTIPORT DIFFUSERS are linear structures consisting of spaced ports or nozzles that are installed on submerged marine outfalls. For the purposes of chapter III.~~L~~M, multiport diffusers discharge brine* waste into an ambient receiving water body and enable rapid mixing, dispersal, and dilution of brine* within a relatively small area.

NATURAL BACKGROUND SALINITY is the salinity* at a location that results from naturally occurring processes and is without apparent human influence. For purposes of determining natural background salinity, the regional water board may approve the use of:

(1) the mean monthly natural background salinity ~~shall be used~~. Mean monthly natural background salinity shall be determined by averaging 20 years of historical salinity* data in the proximity of the proposed discharge location and at the depth of the proposed discharge, when feasible.* For historical data not recorded in parts per thousand, the regional water boards may accept converted data at their discretion.

When historical data are not available, natural background salinity shall be determined by measuring salinity* at depth of proposed discharge for three years, on a weekly basis prior to a desalination facility* discharging brine,* and the mean monthly natural salinity* shall be used to determine natural background salinity~~.~~; or

(2) the actual salinity at ~~Facilities shall establish~~ a reference location, or reference locations, that is representative of ~~with similar~~ natural background salinity at the discharge location ~~to be used for comparison in ongoing monitoring of brine*discharges~~. The reference locations shall be without apparent human influence, including wastewater outfalls and brine discharges.

Either method to establish natural background salinity may be used for the purpose of determining compliance with the receiving water limitation or an effluent limitation for salinity. If a reference location(s) is used for compliance monitoring, the permit should specify that historical data shall be used if reference location data becomes unavailable. An owner or operator shall submit to the regional water board all necessary information to establish natural background salinity.

OUT-OF-KIND MITIGATION is when the habitat or species lost is different than what is replaced through mitigation.

PROPAGULES are structures that are capable of propagating an organism to the next stage in its life cycle via dispersal. Dispersal is the movement of individuals from their birth site to their reproductive grounds.

PROPORTIONAL MORTALITY, P_m, is percentage of larval organisms or propagules* in the source water body* that is expected to be entrained at a desalination facility's* intake. It is assumed that all entrained larvae or propagules* die as a result of entrainment.

SALINITY is a measure of the dissolved salts in a volume of water. For the purposes of this Plan, salinity shall be measured using a standard method approved by the regional water board (e.g. Standard Method 2520 B, EPA Method 120.1, EPA Method 160.1) and reported in parts per thousand (ppt). For historical salinity data not recorded in parts per thousand, the regional water boards may accept converted data at their discretion.

SEAWATER is salt water that is in or from the ocean. For the purposes of chapter III.~~L~~M, seawater includes tidally influenced waters in coastal estuaries and lagoons and underground salt water beneath the seafloor, beach, or other contiguous land with hydrologic connectivity to the ocean.

SENSITIVE HABITATS, for the purposes of this Plan, are kelp beds,* rocky substrate, surfgrass beds,* eelgrass beds,* oyster beds, spawning grounds for state or federally managed species, market squid nurseries,* or other habitats in need of special protection as determined by the Water Boards.

SOURCE WATER BODY is the spatial area that contains the organisms that are at risk of entrainment at a desalination facility* as determined by factors that may include but are not limited to biological, hydrodynamic, and oceanographic data.

SUBSURFACE INTAKE, for the purposes of chapter III.~~L~~M, is an intake withdrawing seawater* from the area beneath the ocean floor or beneath the surface of the earth inland from the ocean.

SURFGRASS BEDS are aggregations of marine flowering plants of the genus *Phyllospadix*.

APPENDIX B
Subsurface Seawater Intake Technology Overview

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SUBSURFACE SEAWATER INTAKE TECHNOLOGY OVERVIEW

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Project Number: LA0324

11 December 2015

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LIST OF ACRONYMS AND ABBREVIATIONS

AOC	Assimilable Organic Carbon
BIG	Beach Infiltration Gallery
CCC	California Coastal Commission
CEQA	California Environmental Quality Act
CPT	Core Penetration Test
CSLC	California State Lands Commission
DDW	Division of Drinking Water
DIG	Deep Infiltration Gallery
DOC	Dissolved Organic Carbon
DWSP	Domestic Water Supply Permit
HDD	Horizontal Directionally Drilled
LCP	Local Coastal Program
MCTSSA	Marine Corps Tactical Systems Support Activity
MGD	Million Gallon per Day
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
RO	Reverse Osmosis
RWQCB	Regional Water Quality Control Board
SDI	Silt Density Index
SIG	Seabed Infiltration Gallery
SMR	Santa Margarita River
SRTTP	Southern Region Tertiary Treatment Plant
SSI	Subsurface Intake
SWRO	Seawater Reverse Osmosis
TDC	Total Dissolved Carbon

1. BACKGROUND AND INTRODUCTION

West Basin Municipal Water District (West Basin) provides imported drinking water and recycled water to nearly one million people in the coastal Los Angeles area. To reduce dependency on imported water, West Basin is evaluating the feasibility of developing ocean water desalination (desal) as component of its water supply portfolio. A desal facility would also reduce the vulnerability of water supply to drought and other external factors.

During the last several years West Basin began a step-wise investigation of desalination, which began with pilot testing from 2002 to 2009 of desalination at the NRG Power Station in El Segundo, California, and was followed by demonstration scale testing (2011-2014) in Redondo Beach, California.

The feedwater intake is a critical component of ocean water desal operations. There are two general types of feedwater intakes for desal facilities: screened open ocean intakes and subsurface seawater intakes (SSIs). Screened open ocean intakes collect seawater directly from the ocean typically via offshore inlet structures. Open ocean intakes have been used by power plants and sewer facilities for over 100 years, but have the potential to cause impingement and entrainment impacts on marine life. These impacts can be reduced by using SSIs that collect water from beneath the sea floor and coastal margin.

On May 6 2015, the California State Water Board approved its updated Ocean Plan which includes regulations for desal facilities. The current Ocean Plan states that (1) the owner or operator must evaluate whether SSIs are feasible and (2) that regional water board in consultation with the State Water Board shall require SSIs unless they are determined to be infeasible. If SSIs are not feasible, the regional water board may approve surface water intakes using best available technology to minimize entrainment and impingement (State Water Board, 2015).

West Basin has initiated an “Ocean Water Desalination Subsurface Intake Study” to investigate SSI technologies and their potential viability for a full-scale desal facility. This report was prepared as part of this study, in order to provide 1) an overview of SSI technologies, 2) a summary of case studies of existing and proposed SSIs, and 3) a review of current applicable regulations in California.

2. SUBSURFACE INTAKE TECHNOLOGIES

A variety of different SSI technologies have been proposed and implemented as discussed in the following sections.

2.1 Vertical Wells

Vertical wells are identical to conventional groundwater production wells, and therefore are a well-established technology that are easily implemented. Typically, a series of vertical wells are drilled along a beach location (Figure 1), with the number of wells being a function of the hydraulic conductivity of sediments or aquifer transmissivity (depending on the location of the screened interval) and the desired capacity of the desal unit.

“Shallow” vertical wells are screened in beach deposits and therefore typically are not hydraulically connected to regional aquifers. Shallow wells produce water from induced vertical leakage from the ocean through the seafloor and have relatively limited per unit yield. “Deep” vertical wells are screened beneath beach deposits in the regional aquifer system. Deep wells induce some vertical leakage from the ocean, but primarily draw water from the aquifer adjacent to the well including water from the inland aquifers through induced horizontal flow. Deep vertical wells can therefore complicate seawater intrusion management efforts and can have undesirable impacts on coastal wetlands.

Because vertical wells go straight down, they must be located close to the ocean (e.g., on the beach front) in order to achieve a good hydraulic connection to the ocean. The close proximity to the ocean can be undesirable due to potentially interfering with recreational beach activities and increasing exposure of the infrastructure to coastal erosion and sea level rise. Additionally, each well requires its own completion which may increase both land acquisition and construction costs.

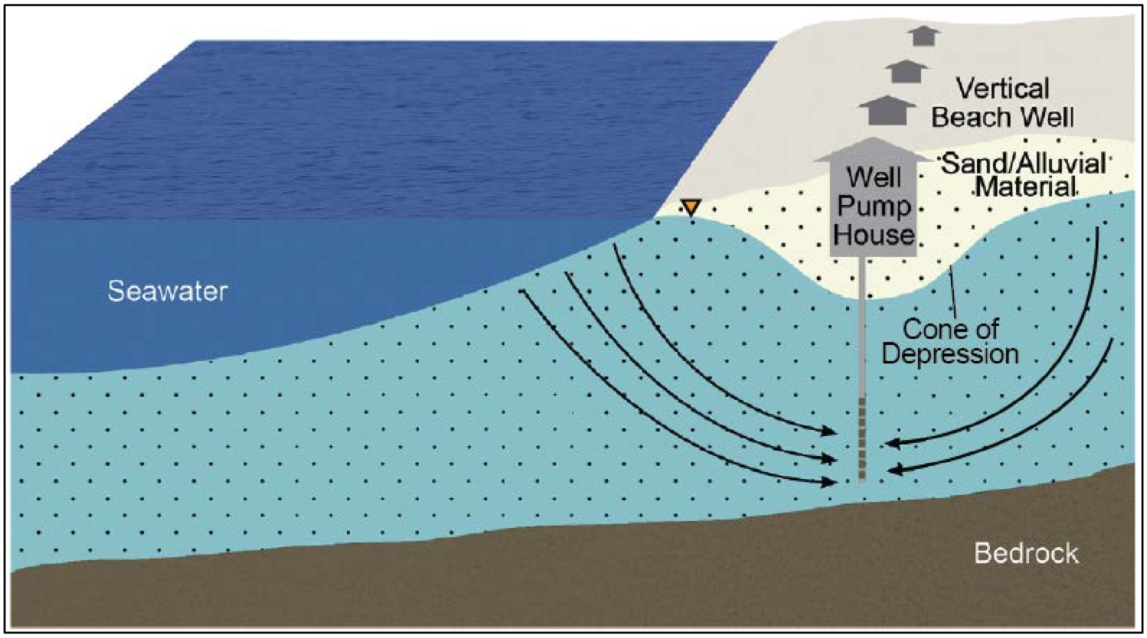

Figure 1 - Schematic Representation of a Series of Vertical Wells Along a Beach. (Adapted from Missimer et al., 2013)

2.1.1 Testing, Analysis and Design Criteria

The production capacity from vertical beach well intakes is dependent on the local geological conditions. Testing and analysis should be performed for characterization of subsurface hydraulic properties in order to estimate the production capacity from a vertical well and the number of wells necessary to achieve the proposed feedwater flow rate for the desalination facility. This information can be obtained through soil borings and laboratory grain-size and permeability analyses, Cone penetration testing (CPT), pore pressure dissipation testing, specific capacity tests, aquifer pumping tests, and geophysical surveys. Results of testing and analysis are used for preliminary design criteria for vertical wells such as location, depth, and spacing. Lower hydraulic conductivity of the screened interval results in a need for larger numbers of beach wells to provide the proposed feedwater flowrate to a desalination facility (e.g., Kennedy/Jenks, 2011).

The proximity to the shoreline, the depth of the screened interval, the vertical hydraulic conductivity of the seafloor and material between the seafloor and screened interval of the wells all influence the relative proportion of seawater and inland groundwater that would be produced from vertical well SSIs along the beach. Groundwater modeling may be necessary to more fully understand these proportions. Information gained from groundwater modeling efforts can provide guidance for regional aquifer management and assist in predicting anticipated feedwater quality.

2.1.2 Construction Cost

Because vertical wells are the same as common conventional groundwater production wells, the cost per unit for drilling and construction of vertical wells is generally lower than other SSI alternatives that require more specialized equipment. Costs can however be prohibitive if the geologic conditions necessitate large numbers of wells to achieve the desired capacity. For example, the design for the Carlsbad Desalination Project proposed 253 wells to achieve an intake capacity of 304 MGD, costing a total of $650 million for the wells. This is significantly higher than for the slant wells (76 wells and $418 million estimated cost) and radial collector wells (76 wells and $438 million estimated cost) considered for the same project (Poseidon Resources Corporation, 2008).

Cost estimates are site specific and may vary substantially due to differing hydrogeologic conditions (primarily hydraulic conductivity and transmissivity), economic conditions (i.e., local material and labor costs and competitiveness of local market), and scale (i.e., small versus large capacity).

2.1.3 Raw Water Quality

Due to the filtration provided by sand all SSIs completed in sand can be expected to have significantly lower concentrations of particulate matter, algae, bacteria, and organic compounds that promote membrane biofouling compared to water drawn through a screened open ocean intake. Since seawater typically has a longer flow path for vertical wells compared to other SSIs, more filtration is provided resulting in improved water quality. Additionally, water quality of deep vertical wells is influenced by the percentage of water that is drawn from inland aquifers which will tend to have better water quality than seawater. However, inland aquifers may contain iron and manganese. Vertical wells may also draw and mobilize inland contaminated groundwater.

2.1.4 Long Term Performance (Reliability and Cost)

All wells must be maintained to avoid bacterial growth and fouling within the wellbore and periodic disinfection of the wells may be necessary. Periodic maintenance to remove any buildup of calcium carbonate scale or a biofilm on the well casings or well screens (e.g. Missimer et al., 2013) typically is required on all seawater wells.

Mixing of oxygenated seawater with anoxic seawater within wells can lead to the precipitation of elemental sulfur, ferric hydroxide or manganese dioxide, which would require removal before the membrane treatment process (Missimer et al., 2013). This can also be a problem for other well-based SSIs.

Depending on their location and depth, vertical wells along the beach can be vulnerable to storm events (coastal erosion) and rising sea level (e.g., Kennedy/Jenks, 2011).

In addition to the well itself, the service life of the pumps can be a significant maintenance consideration.

2.1.5 Potential Environmental Impacts

Drawdown of the water table caused by pumping from shallow vertical wells along the beach may potentially impact wetlands or other surface water features, including sensitive habitats. Additionally contamination within groundwater may be drawn and mobilized by vertical wells. Pumping from deep vertical wells can change groundwater flow patterns in coastal margin aquifers and potentially accelerate seawater intrusion of coastal margin aquifers (e.g., ISTAP, 2014). Depending on the setting, a series of beach wells and the associated infrastructure could impact aesthetic appearance and limit land use options (Missimer et al., 2013).

2.1.6 Operational Data for Existing Systems

Existing desalination facilities with vertical well intakes reported by Missimer et al. (2013, Table 3) include the Morro Bay Desalination Facility in Morro Bay, California, which includes five vertical wells with a total capacity of approximately 800 gallons per minute (GPM) (1.1 MGD). The plant was constructed in 1992, operated for several months following completion of construction and was shut down due to excessive operating costs. The plant remained unused until 1995 when the City of Morro Bay again operated the plant as a reliable water source during a drought. Operation of the facility ceased after increasing iron concentrations in the raw water caused rapid fouling of the pretreatment system. Between 1995 and 2002, the desalination plant was not operated. In 2002, a filter was installed to improve plant performance. The plant was operated for approximately one month during fall 2002, but the iron pretreatment system did not provide adequate flocculation for the specific type of iron in the raw water supply (CH2M Hill, 2011). The construction cost for the desal plant (including the vertical wells and treatment system) was $34 million (in 1992 dollars) (MIT, 2012).

A 0.3 million gallons per day (MGD) desal facility in Sand City, Monterey County, California, has operated continuously since 2009. The facility uses four vertical wells approximately 60 feet deep along the beach for the feedwater (ISTAP, 2014).

The highest reported capacities for systems of vertical well intakes for desal facilities range from 22,000 to 29,000 GPM (31 to 42 MGD) using 10 to 30 wells (Missimer et al., 2013).

Characteristics of existing vertical well installations are summarized and compared with other SSIs in Table 1

.

Table 1: General Space Requirements and Costs for SSIs

Intake Technology	Facility Name, Location	Number of Wells	Depth of Wells (ft)	Screen Interval	Length of Wells (ft)	Area (acre)	Angle Drilled	Distance from Shoreline (ft)	Intake Capacity	Cost	Years of Operation	Other Information	References
Vertical Wells	Morro Bay Desalination Facility; Morro Bay, California	5					N/A		1.1 MGD	$34 million (including desal plant)	Few months in 1992-1993 and in 2009-2010	High operating costs issues with iron fouling of the pretreament system	Missimer et al. 2013 CH2M Hill, 2011 MIT, 2012
	Sand City, Monterey, California	4	60				N/A		0.3 MGD		2009 - present		ISTAP, 2014
Slant Wells	Doheny State Beach, Dana Point, California	1	130		350		23	325	0.04 - 0.06 MGD (1,600 -2,100 GPM)	$6,147,000 for pumping and pilot testing	Operated for testing in 2006 and 2012	Well efficiency 78%-81% in 2006; reduced to 52% in 2012	Geoscience, 2009; ISTAP, 2014
	Coast of Monterey Bay, California	1	200	600 ft long	750		19		0.02 - 0.06 MGD (1,000 - 2,500 GPM)		Operated for testing	Installed in 2015	ESA, 2015; Geoscience, 2015; SWCA, 2014
HDD Wells	San Pedro del Pinatar I, Spain	19			1,600 - 2,200				44 MGD (31,000 GPM)		2003 - present	Lower capacity than anticipated and water quality issues	Missimer et al., 2013; ISTAP, 2014 Voutchkov, 2013
Radial Collector Wells	PEMEX Salina Cruz Refinery, Mexico	3					N/A		4 MGD each 12 MGD total		2002 - present	Feedwater contains high levels of iron and manganese, pretreatment is required	Missimer et al., 2013 Voutchkov, 2013
Beach Infiltration Gallery	Long Beach, California								0.01 (400 GPM)		Operated for testing in 2008	9.5 - 19 ft/day infiltration rate	Missimer et al., 2013; Allen et al., 2011
Seabed Infiltration Gallery	Fukuoka Gallery, Japan					5.3	N/A	2100	27.2 MGD		2005 - present	10 feet deep; infiltration rate of 16.7 ft/day; retention time is 7 hours	Kennedy/Jenks, 2011
Deep Infiltration Gallery	Tunnel Intake to Alicante II SRWO, Spain	104	45				N/A		34.3 MGD		Operating	3,280 feet long tunnel parallel to shoreline apparently in limestone rock, 10 feet diameter	ISTAP, 2014

2.2 Slant Wells

Slant wells are wells drilled at an angle from the shore toward the sea (Figure 2). The angled installation allows the well screen to be beneath the sea floor and have an increased screen length in the targeted hydrostratigraphic zone, which can result in slant wells having greater yields than vertical wells (Missimer et al., 2013; RBF Consulting, 2014). The slant also allows the surface completion to be set back from the shore and potentially off the beach.

Typical angles for slant wells are between 15˚ and 45˚ from horizontal (Missimer et al., 2013; RBF Consulting, 2014). The maximum length of slant wells is dependent on the geological conditions and the diameter of the well (e.g. Missimer et al., 2013), and is estimated to be up to 1,000 feet. The longest slant well collector installed to date is a test slant well completed in 2015 beneath the coastline of Monterey Bay that is 724 feet long and drilled at an angle of 19˚ below horizontal (Geoscience, 2015a).

Compared to vertical wells, slant wells may be less likely to pull from inland aquifers and have higher per unit yields. Furthermore, several wells (typically two to four) can be drilled from a single location to create clusters, thus reducing total footprint of the project.

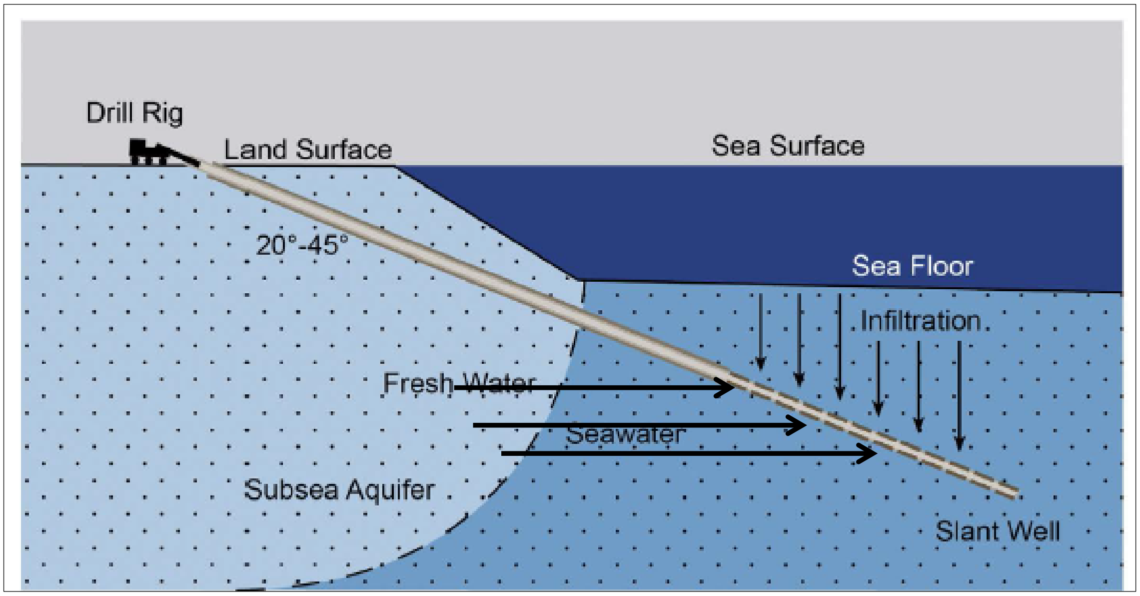

Figure 2 - Schematic Representation of a Slant Well (Adapted from Missimer et al., 2013).

2.2.1 Testing, Analysis, and Design Criteria

The testing and analysis for slant wells is similar to that for vertical wells. However, because drilling in the surf zone typically is not feasible, near shore geologic characteristics must be inferred from results of tests done onshore. Additionally, offshore testing (such as borings and/or shallow seafloor sampling) may be done to better determine the near shore geologic characteristics. Whether these additional tests are required may depend on how far off shore the slant wells will extend.

2.2.2 Construction Cost

In consolidated sediments, slant well construction is similar to vertical well construction, and therefore costs are comparable. However, within unconsolidated sediments, gravity can cause slant wells to collapse, and therefore dual-rotary drilling equipment may be required. This process requires the use of specialized equipment and skilled operators, so cost is higher than for vertical wells. However, due to typically higher per unit yields as compared to vertical wells, the overall costs for project utilizing slant wells potentially may be lower. For example, the slant well option considered for the Carlsbad Desalination Plant required only 76 wells to achieve the desired 304 MGD capacity, compared with 253 vertical wells. Subsequently the estimated costs were lower for the slant wells ($418 million) versus for the vertical wells ($650 million) (Poseidon Resources Corporation, 2008).

It should be noted that costs are very site-specific and these examples may not apply in other cases.

2.2.3 Raw Water Quality

Raw water quality issues for slant wells is similar to that of vertical wells, although slant wells have potential for better hydraulic connection to the ocean and therefore can draw less groundwater from inland aquifers than vertical wells. Additionally, the flow path of the seawater to the well is somewhat shorter to slant wells than for vertical wells and therefore less seawater filtration may occur with slant well intakes.

2.2.4 Long Term Performance (Reliability and Cost)

Long term performance issues for slant wells are similar to those of vertical wells. However, full-scale desal facilities with slant wells have not been constructed or operated, thus long-term operational data are not available.

Because slant wells can be designed to avoid locating exposed infrastructure directly on the beach, they are less likely to be vulnerable to sea level rise and storms than vertical wells. However, if design constraints cause the infrastructure to be located on the beach, these issues remain a concern.

2.2.5 Potential Environmental Impacts

Like vertical wells, slant wells may draw in fresh groundwater from coastal aquifers and potentially influence groundwater flow patterns in adjacent inland aquifers. However, inland impact of slant wells may be less than vertical wells due to the potentially greater portion of sea water pumped by slant wells (e.g., Missimer et al., 2013).

If slant wells are completed on the beach, they could impact aesthetic appearance and limit land use options.

2.2.6 Operational Data for Existing Systems

A slant well with a length of 350 feet and a depth of 130 feet was constructed in 2006 in California at Dana Point (Geoscience, 2009a). The slant well was drilled at an angle of 23 degrees below horizontal and reaches approximately 325 feet from the shoreline. (Municipal Water District of Orange County (MWDOC), 2014a). When initially tested in 2006 the well was pumped at 1,660 GPM and 2,000 GPM, and displayed a well efficiency of 81% and 78%, respectively. Recent longer term testing in 2012 documented a reduction in well efficiency to 52% (ISTAP, 2014). Possible reasons for this observed decrease in well efficiency were identified as clogging of the well screen by fine-grained material due to insufficient well development in 2006, clogging of the well screen by iron and/or manganese precipitates, or blockage of well screen due to fill at the bottom of the well (GeoScience, 2012).

Pumping of a test slant well installed at the coastline of Monterey Bay began in April 2015 at a rate of approximately 2000 gpm (Geoscience, 2015a).

There are currently no full-scale operational desal facilities that utilize slant well SSIs in California or elsewhere (Kennedy/Jenks, 2011).

Characteristics of existing slant well installations are summarized and compared with other SSIs in Table 1. Case studies for slant well installations in California are provided in Sections 3.1 and 3.3.

A recent survey of information on slant wells (MWH, 2015) summarizes information regarding construction, operation and maintenance history of eight slant wells used for water production in the United States.

2.3 Horizontal Directionally Drilled Wells

Similar to slant wells, Horizontal Directional Drilling (HDD) technologies can be used to install wells beneath the seafloor from the coastal margin (Figure 3). However, unlike slant wells, the angle of the well can be adjusted gradually over the length of the well, allowing it to remain in the desired stratum and close to the sea floor. As a result, wells constructed with HDD technologies (referred to subsequently as HDD wells) typically do not draw water from inland aquifers and have higher per unit yields (compared to both vertical and slant wells) due to a better hydraulic connection to the ocean.

Installation of HDD wells beneath the sea traditionally would require an “exit pit” on the seafloor to pull the casing and well screen into each pilot boring from offshore. These pits can also be completed as permanent access ports on the seafloor to facilitate construction and maintenance. This increases the amount of ocean floor disturbance as compared to other well types and can complicate environmental permitting. Newer technologies allow smaller diameter wells to be installed without an “exit pit” thereby simplifying construction and permitting processes. One type of HDD well technology utilizes a porous polyethylene casing (e.g., Neodren®) that acts as both a well screen and filter pack, hence no additional external packing media is required for long-term operation.

Similar to slant wells, groups of HDD wells can fan out from a common location inland of the beach (Figure 3), therefore reducing the land area required and potentially eliminating the need for infrastructure to be located on the beach (Missimer et al., 2013).

HDD technologies have been used in the oil and gas industry and for installation of utility pipelines beneath roads and rivers for years. However, there is limited available information on HDD wells in a coastal marine unconsolidated alluvial setting for production of sea water.

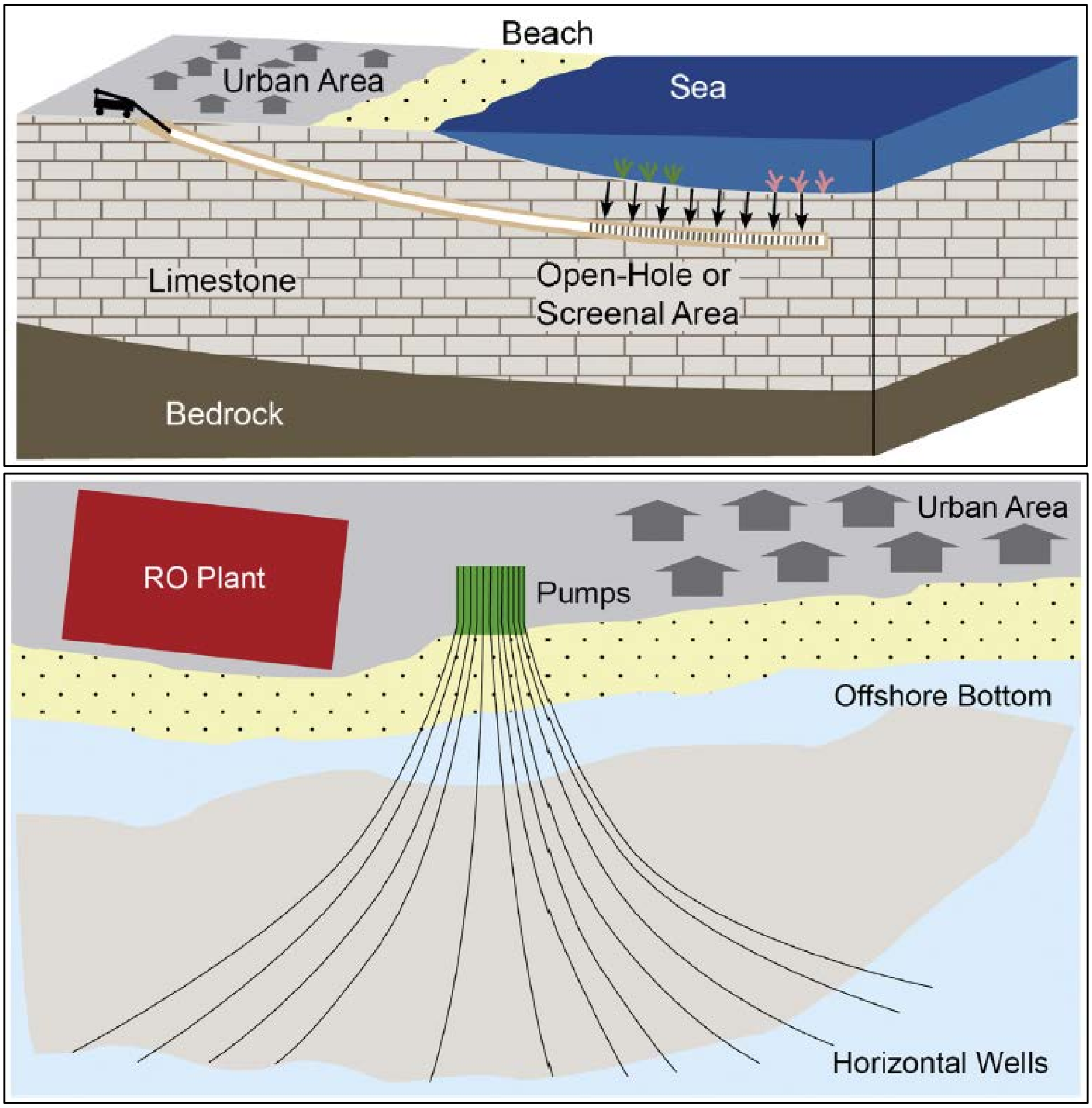

Figure 3 - Schematic Representation of a HDD Well Installation (Cross-Section) and a Cluster of HDD Wells (adapted from Missimer et al., 2013)

2.3.1 Testing, Analysis, and Design Criteria

The production capacity from HDD well intakes is dependent on the well construction and permeability of the overlying sediments between the HDD and the ocean. Testing and analysis should be performed for characterization of the seafloor, including geometry, hydraulic properties, depth of sediments, and sedimentation rate. Potential tests include offshore geophysical testing, vibracores or other offshore borings, and shallow seafloor sediment sampling.

2.3.2 Construction Cost

HDD wells typically involve processes and products that are proprietary (e.g., Neodren®) and as such cost estimates of completed projects are difficult to obtain. Typically offshore construction and divers would be required to introduce the casing and well screen into each pilot boring from offshore through “exit pit”. However, newer techniques may not require the “exit pit” and may be easier to permit. Additionally, an array of HDD wells can be drilled from a small construction footprint, which allows savings for land acquisition and a single building can house the pumps and associated electrical equipment (Missimer et al., 2013).

2.3.3 Raw Water Quality

HDD wells completed close to the seafloor are expected to result in minimal filtration of the seawater and raw water quality would be similar to that of the seawater. Deeper HDD well intakes beneath a sandy seafloor would result in more filtration similar to slant or vertical wells. However, the long screen length of HDDs beneath the seafloor can result in the HDD wells intersecting areas with varying water quality including anoxic zones which could result in mixing of waters with incompatible geochemical properties. As a result additional pre-treatment may be needed for intake water provided by HDD wells (e.g., Missimer et al., 2013).

2.3.4 Long Term Performance (Reliability and Cost)

In general, cleaning or re-development of HDD wells is problematic. Therefore HDDs well technologies are considered less reliable and more risky than other well technologies for SSIs.

For HDD wells that use porous HDPE rather than screens and gravel pack, potential clogging within the pores of the pipe may be irreversible and could result in significant decreases in yields over time.

A high sedimentation rate of finer-grained material on the seafloor can result in a gradual reduction of the hydraulic conductivity of seafloor, which could decrease well yield and affect long term performance (e.g., Missimer et al. 2013).

2.3.5 Potential Environmental Impacts

The "exit pit" that is often used in the installation of HDD wells creates a disturbance on the ocean floor that may impact marine organisms (ARCADIS, 2013). Therefore, permitting of HDD wells using the "exit pit" may present challenges, but new techniques may facilitate installation of these wells without the need for the "exit pit".

If HDD wells are completed on the beach, they could impact aesthetic appearance and limit land use options.

2.3.6 Operational Data for Existing Systems

HDD well intakes have been installed in several facilities in Spain with the highest total capacity reported at 31,000 GPM (44 MGD) at San Pedro del Pinatar desal plant (Missimer et al. 2013). The feedwater for the plant is provided by 19 HDD drains (Bartak et al., 2012). The individual intake wells are between 1,600 and 2,000 feet long and have a diameter of 14 inches. Each well produces between 2.3 and 3.1 MGD (Voutchkov, 2013). San Pedro del Pinatar desal plant has been operating continuously since its construction in 2003. A recent study compared water quality of HDD, water tunnel and vertical wells at Alicante, Spain and concluded that HDD wells were less efficient at removing algae and bacteria than vertical wells and water tunnel, and provided feedwater with higher SDI (Rachman et al., 2014).

Characteristics of an HDD installation are summarized and compared with other SSIs in Table 1.

2.4 Radial Collectors Wells

Radial collector wells (e.g., Ranney Wells^{TM}) include a central caisson, typically having a diameter of 10 to 20 feet (ISTAP, 2014) that extends down into the sand to a depth typically in the range of 30 to 150 feet. Horizontal lateral wells with diameter ranging from 6 to 12 inches fan out from the caisson to distances of 200 to 300 feet. Radial collector wells are commonly used for large-scale water production beneath rivers (e.g., Missimer et al., 2013).

They are functionally similar to shallow vertical wells in that they draw from shallow beach deposits. However, like slant wells the laterals allow them to extend closer to the ocean (Figure 4), giving them a higher yield per unit than shallow vertical wells and minimizing water drawn from inland aquifers.

This technology is constrained by the fact that construction techniques limit the maximum length of the laterals to approximately 300 feet (Kennedy/Jenks, 2011). As a result, they typically must be located directly on the beach (Missimer et al., 2013). As with many of the well technologies, several wells can be extended from a single caisson, reducing total project footprint.

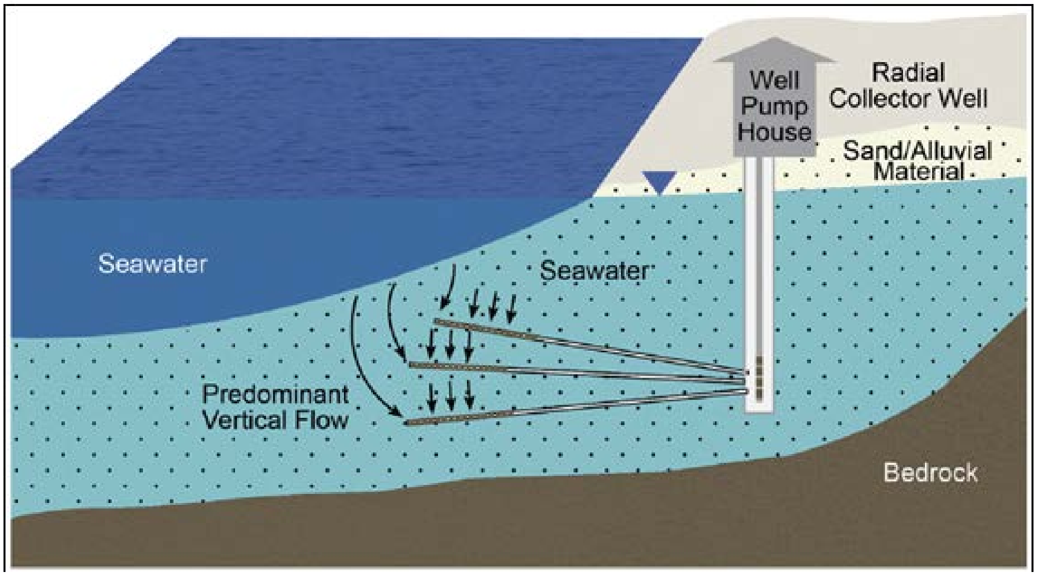

Figure 4 - Schematic Representation of Radial Collector Wells (Adapted from Missimer et al., 2013)

2.4.1 Testing, Analysis, and Design Criteria

Testing and analysis required to characterize the site and design radial collector wells is similar to that of shallow vertical wells and slant wells.

2.4.2 Construction Cost

Radial wells are more complicated and expensive per unit than vertical wells, but similar to slant wells they may provide higher yields with a greater portion of seawater. They have comparable yields and cost approximately the same as the slant wells. For example, the radial collector well option considered for the Carlsbad Desalination Plant required only 76 wells to achieve the desired 304 MGD capacity, the same number as for slant wells and compared with 253 vertical wells. Subsequently the estimated costs for the radial collector wells ($438 million) are similar to for the slant wells ($418 million) and much lower than for the vertical wells ($650 million) (Poseidon Resources Corporation, 2008).

It should be noted that costs are very site-specific and these examples may not apply in other cases.

2.4.3 Raw Water Quality

Because radial collector wells draw from the same source as shallow vertical wells (nearshore beach deposits), the feed water quality for radial collector wells would be similar to that for vertical wells. However, the proportion of the feedwater made up of inland aquifers would be expected to be less than for vertical wells.

2.4.4 Long Term Performance (Reliability and Cost)

No long-term operating data are available on radial collector wells used for desal intakes, but they have a long performance history of successful performance as freshwater intakes beneath rivers. The large diameter of the central caisson facilitates standard maintenance associated with all well technologies.

As with other technologies that have infrastructure located on the beach, radial collector wells may be subject to beach erosion and damage by storms and also are sensitive to sea level rise.

2.4.5 Potential Environmental Impacts

As with vertical wells, slant wells, and deep HDDs the potential to draw from inland aquifers can lead to mobilizing groundwater contamination and/or negative impacts on coastal wetlands. However, in settings where the laterals can reach beneath the seafloor, the influence on inland aquifers can be minimized.

As with other technologies that have infrastructure located on the beach, the physical and aesthetic impact of the infrastructure could limit land use options.

2.4.6 Operational Data for Existing Systems

Radial collector wells are commonly used for large-capacity water production along rivers in the United States and Europe. Operational radial collector well capacities range from 0.1 to 13 MGD. The only known operating radial collector well system used for a desal facility is located at the PEMEX Salina Cruz refinery in Mexico, which has three wells each with a capacity of 4 MGD (Missimer et al., 2013) and has been operating continuously since construction in 2002. The feedwater from these wells contains high levels of iron and manganese, and has to be treated in greensand filters prior to RO separation (Voutchkov, 2012).

Characteristics of an existing radial collector well installation are summarized and compared with other SSIs in Table 1.

2.5 Beach Infiltration Gallery

Beach infiltration galleries (BIGs) draw water from beneath the beach over a large surface area. They typically consist of a network of perforated pipes placed beneath series of sand layers that increase in grain size with depth (Figure 5). The top layer is native sand and the lowest layer is gravel. Seawater percolates through the sand into the pipes which feed a single pumped collector pipe (ISTAP, 2014). This construction, similar to that of a slow sand filter, provides pretreatment of the feed water. Because they are constructed in shallow beach deposits, they do not interfere with inland aquifers. Unlike wells, infiltration galleries require a large footprint to achieve desired capacities. This footprint results in significant construction costs due to the quantity of materials required for the gallery, as well as the complexity associated with construction on the beach and ocean floor.

BIG intake systems are constructed beneath the intertidal zone of the beach (Figure 5). A potential advantage of BIGs is that the mechanical energy of breaking waves may continuously clean the overlying sand layer (Missimer et al., 2013) and prevent clogging.

An important consideration for BIGs is the stability of the beach. If the shore line is unstable and migrates over time, the performance of a BIG may not be sustainable. The wave energy at the construction site is also an important consideration when assessing construction complexity and sustainability.

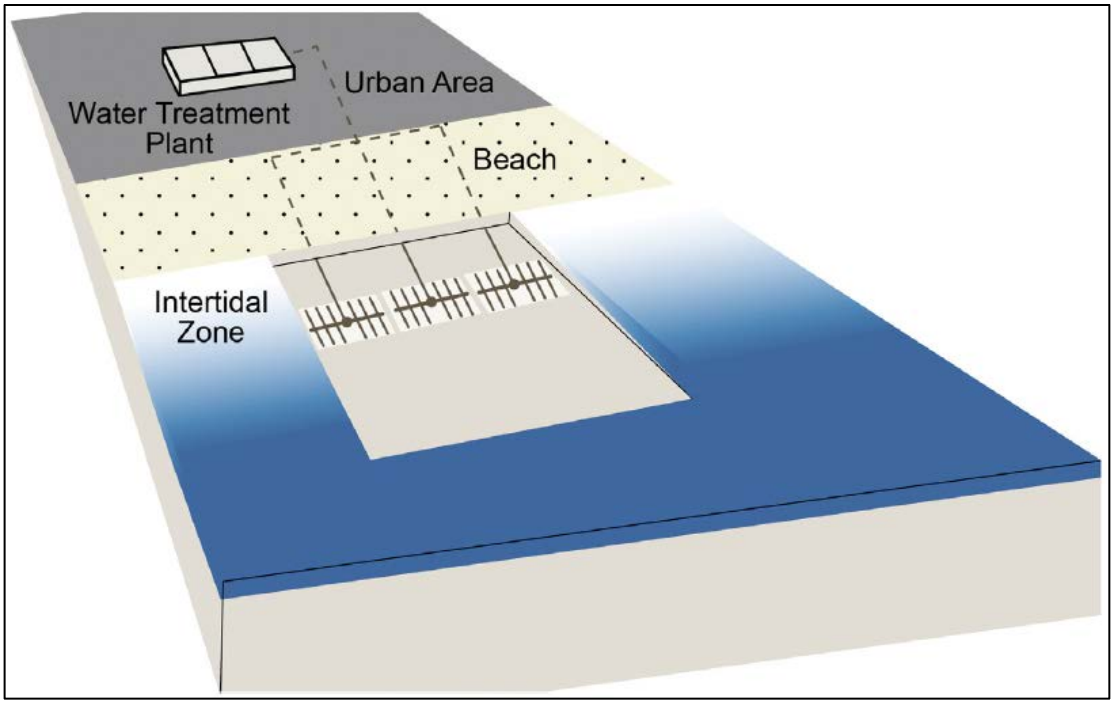

Figure 5 - Schematic Representation of a Beach Infiltration Gallery (Adapted from Missimer et al., 2013)

2.5.1 Testing, Analysis, and Design Criteria

Testing and feasibility analysis for BIGs should be performed to determine the sedimentation rate, stability of the beach, and potential for scouring of the seabed in the intertidal zone. Potential evaluation methods include drilling borings and characterization of seafloor sediment, review of historical records, and modeling coastal evolution to assess beach stability.

2.5.2 Construction Cost

Generally the construction of infiltration galleries is expected to be more costly relative to well-based SSIs. But the construction cost of a BIG would typically be lower than seabed infiltration gallery (SIG) due to the closer proximity to shore (Missimer et al., 2013). However, additional complexities and cost may arise from construction near and within the surf zone, particularly in high-energy ocean environments.

2.5.3 Raw Water Quality

Slow sand filtration improves water quality with filtering and biological activity that can bind or break down many different organic compounds that commonly occur in seawater (Missimer et al., 2013). The uppermost natural sand layer is the primary treatment zone and commonly will remove algae, a high percentage of bacteria and naturally occurring organic compounds (e.g. ISTAP, 2014). Particulate materials are typically are trapped and bound in the upper part of the filter in a layer termed the “schmutzdecke”, which is a biologically active layer containing bacteria, bound particulates, and organic carbon compounds (Missimer et al., 2013).

2.5.4 Long Term Performance (Reliability and Cost)

Because BIG systems underlie the surf zone of the beach, the active infiltration face of the filter is continuously cleaned by the mechanical energy of the breaking waves and is therefore self-cleaning. However, as mentioned previously, beach stability is a key factor in long term performance. Beach deposition (accumulation of sediment) can reduce hydraulic conductivity and reduce capacity over time (Missimer et al., 2013). Alternatively, storm waves can remove the engineered coarse-grain sand and replace it with lower permeability sediment, which would also reduce the gallery intake capacity. There are no large-scale BIG intakes constructed to date, and the long-term operational issues associated with this technology are not well understood (Missimer et al., 2013).

2.5.5 Potential Environmental Impacts

Construction of a BIG requires significant disturbance to the beach and surf zone during construction. However, after completion a BIG is beneath the beach surface and thus do not result in limitations to land use.

2.5.6 Operational Data of Existing Systems

While no-large scale BIG intakes have been constructed to date, several are in design or have been proposed. A large-capacity system has been designed and recommended for construction at the Tia Maria seawater RO plant in southern Peru (Missimer et al., 2013).

A case study for a BIG installation in Long Beach, California is provided in Section 3.2, but it is noted that this is a demonstration project. It was operated with infiltration rates ranging from 9.5 to 19 feet per day and a capacity of 400 GPM. This testing revealed substantial reduction in turbidity, SDI_{15}, total dissolved carbon (TDC), and heterotrophic total plate counts (mHPCs) with some reduction in concentrations of dissolved organic carbon (DOC) and assimilable organic carbon (AOC). However the SDI was greater than 4 (Missimer et al., 2013), and was approaching values that would result in clogging of RO membranes[1]. Moreover, the Long Beach test BIG was constructed in protected harbor, not in an active surf zone, so functionally it is more like a SIG than a BIG.

2.6 Seabed Infiltration Gallery

A seabed infiltration gallery (SIG) is similar to a BIG in that it includes a network of perforated pipes or screens covered by engineered fill, but it is located further offshore at a more stable location (Figure 6). While construction issues related to wave energy are reduced as compared to BIGs, being further offshore results in additional depth of overlying ocean, introducing additional construction complexity and cost.

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[1] http://www.lenntech.com/sdi.htm

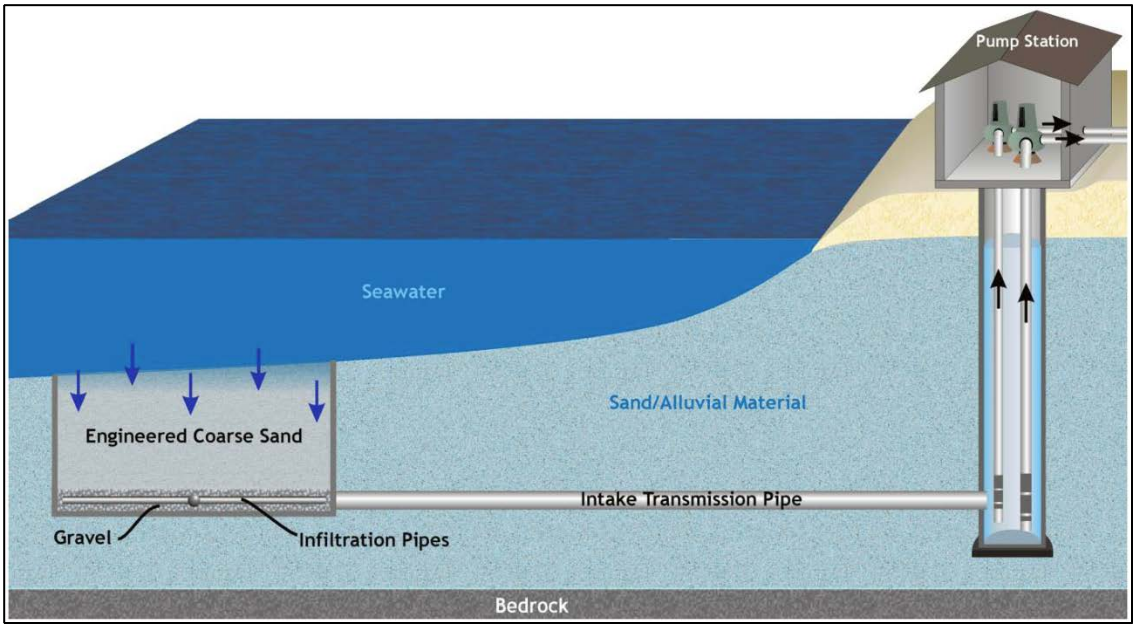

Figure 6 - Schematic representation of a seabed infiltration gallery (Adapted from Missimer et al., 2013)

2.6.1 Testing, Analysis, and Design Criteria

A marine survey should be conducted to determine the presence of potentially sensitive environmental conditions on the bottom (e.g., marine grass beds or coral reefs), which could impact construction schedule or prohibit certain locations due to permitting issues.

Sedimentation and scour rates should be assessed. Deposition of muddy sediments can clog a SIG, but currents and bioturbation can be favorable for maintaining the production capacity. The presence of some benthic fauna, such as polychaete worms and mollusks, are also favorable because they can ingest deposits on the top of the gallery and thus prevent the buildup of a clogging layer at the sediment–water interface (Missimer et al., 2013).

2.6.2 Construction Cost

Large-scale SIGs can be technically complex and expensive to construct (Missimer et al., 2013), but can be comparable to well technologies in some circumstances where a large number of wells would be required. For example, the SIG option considered for the Carlsbad Desalination Plant (304 MGD capacity) was estimated to cost $647 million which is comparable to the vertical wells ($650 million), but considerably more than the slant and radial collector wells ($418 million and $438 million, respectively) (Poseidon Resources Corporation, 2008).

It should be noted that costs are very site-specific and these examples may not apply in other cases.

2.6.3 Raw Water Quality

Due to the similarity of the designs the water quality of SIGs generally is expected to be similar to that of BIGs.

2.6.4 Long Term Performance (Reliability and Cost)

Maintenance requirements of a SIG depends on the strength of currents, which can keep fine-grained sediments in suspension and decrease frequency of cleaning or replacement of the engineered fill above the perforated pipes. However, storm waves may remove the engineered coarse grain sand and fine-grained low permeability sediment may subsequently be deposited on the gallery and reduce the gallery capacity. As such, assessment of the sedimentation and scour rates is critical to ensuring long term performance.

2.6.5 Potential Environmental Impacts

Excavation of a large area of the ocean floor is needed to install a SIG system of adequate size to supply the full-scale desalination facility. This excavation would result in the complete removal of the entire benthic ecosystem, which would result in a significant impact to benthic marine organisms. The material removed would require disposal elsewhere, thus creating additional environmental impacts. The dredging of the sea floor and construction of a SIG could disrupt normal public use of the beach and offshore coastal margin during construction.

2.6.6 Operational Data of Existing Systems

The Fukuoka gallery in Japan is approximate 1,100 feet long, 210 feet wide, 10 feet deep, and operates at a capacity of 27.2 MGD and an infiltration rate of 16.7 feet per day with a corresponding retention time of 7 hours (Kennedy/Jenks, 2011). It is located

2,100 feet from the shore in a low energy setting. It has been operating successfully since 2005 without the need to clean the offshore gallery and with minimal cleaning of the membranes. Monitoring of the feedwater pumped from the gallery since 2011 shows a significant improvement in water quality with the SDI being reduced from background levels exceeding 10 to below 2.0, which helps prevent clogging of the RO membranes.

Characteristics of existing SIG installations are summarized and compared with other SSIs in Table 1.

2.7 Deep Infiltration Gallery (Water Tunnel)

A deep infiltration gallery (DIG) or water tunnel is a large pipe or tunnel beneath the sea floor that connects a series of vertical or radial collector wells to an onshore pump station. Figure 7 below shows a DIG that consists of two concentric pipelines with the inner pipeline serving for brine discharge.

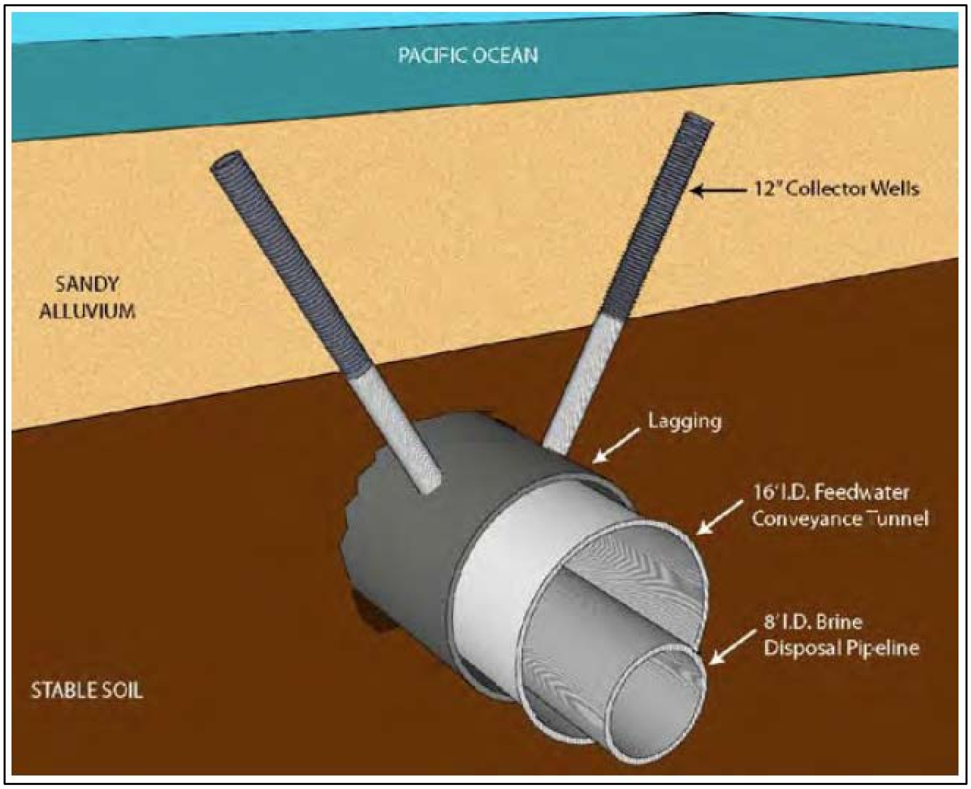

Figure 7 - Schematic Representation of a Deep Infiltration Gallery (Adapted from ISTAP, 2014)

Figure 8 below shows an alternative DIG design in which a single tunnel connects a series of vertical wells completed both above and beneath the tunnel. In the example below the access to the wells is provided by ports in seafloor.

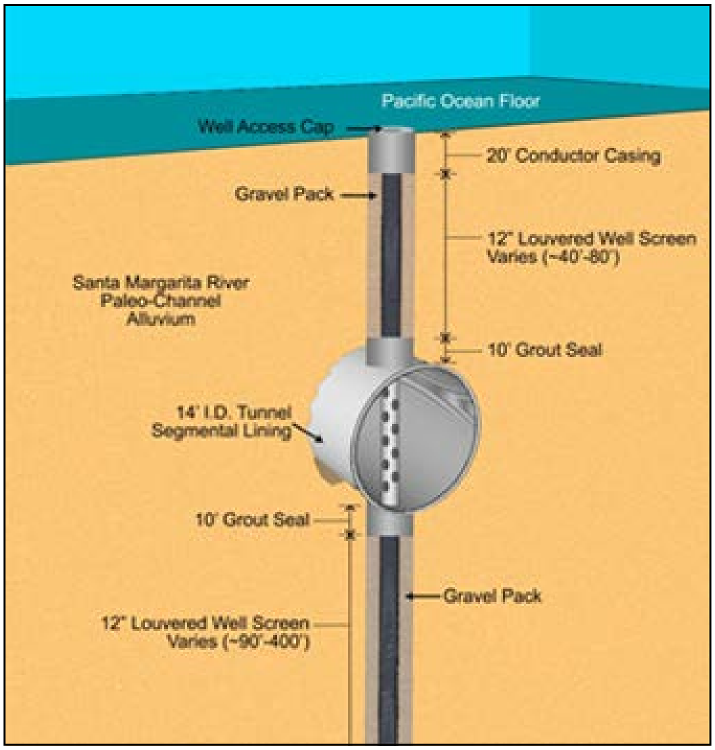

Figure 8 – Schematic Representation of an Alternative Concept of a Deep Infiltration Gallery[2]

2.7.1 Testing, Analysis, and Design Criteria

Testing and analysis should be performed to characterize the site-specific ecology, subsurface geometry, and hydraulic properties. The aquifer should be profiled and characterized before the design of the system to assess the aquifer depth, thickness, and water quality (RBF Consulting, 2009). Potential tests include offshore geophysical testing, vibracores, and other borings.

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[2] http://www.desalination.com/wdr/48/42/sub-seabed-intake-being-considered

2.7.2 Construction Cost

Construction of offshore DIGs is highly complex and very expensive. For example, ground freezing or other advanced technologies may be required to stabilize the sea floor during construction of the tunnel. Construction challenges will require high costs and pilot testing is impracticable (ISTAP, 2014).

2.7.3 Raw Water Quality

A DIG would potentially produce high water quality stability due to sand filtration (ISTAP, 2014). Feedwater from a deep infiltration gallery could be slightly less saline and have less suspended particulates than seawater, which would increase overall reverse osmosis (RO) efficiency (RBF Consulting, 2009).

2.7.4 Potential Environmental Impacts

A DIG system lies fully beneath the seafloor and is expected to have no significant environmental impact during operations, however some conceptual DIG designs include access portals in the seafloor to collector wells. The induced vertical flow of seawater into a DIG generally would not induce impacts to inland aquifers (ISTAP, 2014).

2.7.5 Long Term Performance (Reliability and Cost)

There are insufficient data available to make conclusions with respect to long term reliability and operational costs of DIGs.

2.7.6 Operational Data of Existing Systems

A DIG intake was constructed to provide some or all of the 34.3 MGD of feedwater required to operate the Alicante II Seawater Reverse Osmosis (SWRO) plant in Spain. This system contains a tunnel underlying the beach area, apparently constructed in limestone rock parallel to the shoreline. The tunnel has a length of 3,280 feet, a diameter of 10 feet and lies 45 feet bgs. The tunnel contains a series of 104 lateral collectors, drilled into the aquifer (Rachman et al., 2014; Missimer et al., 2015). The laterals contain screens that are open to the aquifer and yield water to the tunnel as it is pumped (ISTAP, 2014). A comparison of water quality at the HDD, water tunnel and vertical wells at Alicante, Spain concluded that water tunnel laterals were less efficient at removing bacteria than the vertical wells, and provided feedwater with higher SDI than vertical wells but lower than HDD wells (Rachman et al., 2014). However, these findings are site-specific.

Characteristics of an existing DIG installation are summarized and compared with other SSIs in Table 1.

3. CASE STUDIES OF EXISTING AND PROPOSED SUBSURFACE SEAWATER INTAKES

This section includes an overview of several existing and proposed subsurface seawater intakes for existing and proposed desal facilities in California.

3.1 Doheny Ocean Desalination Slant Test Well Project

A test slant well with a 12-inch internal diameter was installed in 2006 at Doheny State Beach in Dana Point, California. The well was drilled at an angle of 23 degrees below horizontal and is approximately 350 feet long (Figure 9). The well reaches a depth of approximately 130 feet below land surface and is 325 feet from the shoreline (see Figure 9). It was pumped at 2,100 GPM (3 MGD) from June 2010 to April 2012, with system shutdown from July to October 2011. Modelling indicated that a full scale slant wellfield, with three clusters of three wells, for a total of nine wells, could produce about 30 MGD at acceptable drawdowns to wells in the local vicinity. The total cost of the pumping and pilot testing project was $6,147,000 (MWDOC, 2014a).

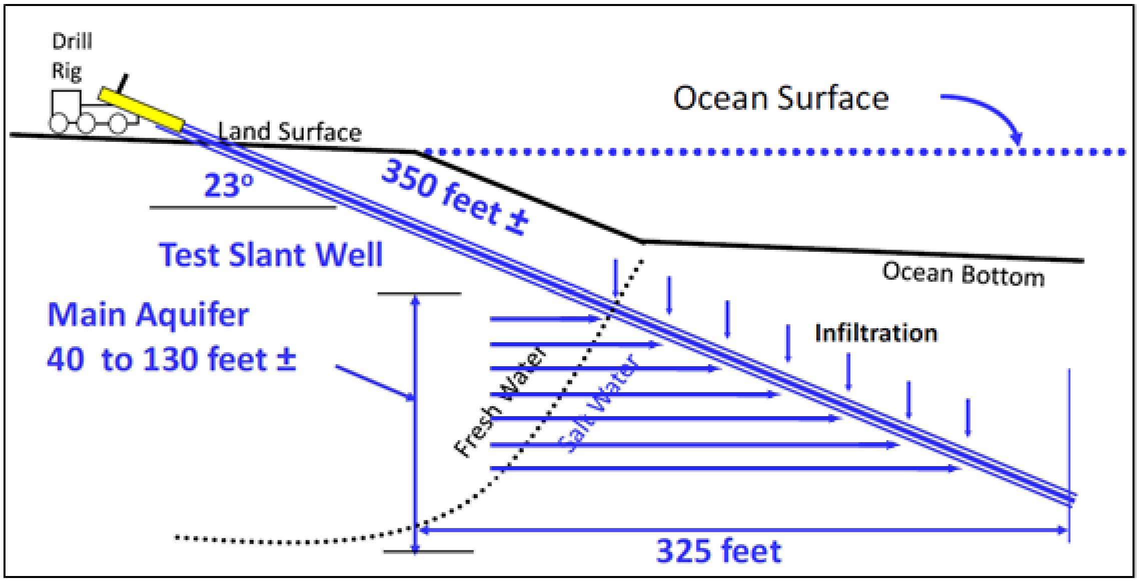

Figure 9 - Schematic of Test Slant Well (Adapted from MWDOC, 2014a)

The choice of slant wells for the Dana Point Project was based on early discussions with the California Coastal Commission staff, and the infeasibility of other technologies. Infiltration galleries had high costs, ocean floor impacts, risk of clogging and decreasing yields and maintenance challenges. Radial collector wells had higher costs, a long construction period prohibited by State Parks, limitations on the ability to gravel pack the laterals, and the limitation to extend the laterals to significance distance out under the ocean (MWDOC, 2014a).

The analysis conducted at Dana Point prior to the installation of the pilot test well consisted of exploratory borings, geophysical logs, soil and water quality samples and laboratory testing. In 2004-05, four exploratory boreholes were drilled along the beach to a depth of 188 feet below ground surface. The boreholes encountered highly permeable alluvium through their depth. Laboratory testing consisted of hydraulic conductivity estimation with grain size analysis and permeameters (Geoscience, 2005).

The full scale project for production of 30 MGD is currently being investigated. The well field would consist of nine slant wells constructed in clusters of up to three wells. The wells would be constructed at a 20-degree angle below horizontal, with a linear length of 500 feet and to a depth of 170 feet bgs. The slant wells would be screened below the seafloor, between 200 and 500 feet linear, corresponding to between 40 and 165 feet bgs. (Geoscience, 2009b).

A regional surface watershed and groundwater model was developed to evaluate drawdown and groundwater take impacts on the basin. The drawdown of the full operation estimated to be 90 feet below mean sea level while pumping at 30 MGD from seven wells with the remaining two wells idle to allow for rotation during maintenance. The aquifer thickness of about 200 feet along the coastline, was determined to be sufficient to accommodate the expected drawdown and required well yields. Groundwater modeling indicated that about 5% of the pumped water would be derived from the landward portion of the aquifer, while the remaining draw would come from the ocean (MWDOC, 2014a).

An unexpected finding was a high level of dissolved iron and manganese contained in old marine groundwater that lies under the ocean. This water was anoxic and slightly acidic, and was found to be about 7,500 years old. It is expected that under full production capacity, the old marine groundwater would be mostly pumped out and replaced by ocean water within about a year, so pretreatment to remove iron and manganese may not be necessary. However, after of more than a year of test pumping, the salinity of the water produced by the slant well was less than 60 percent that of seawater (MWDOC, 2014a).

Additional work is being conducted and the results could set the stage for the implementation phase. The estimated capital cost for the full scale project is $153 million (in 2012 dollars) and the estimated unit cost for water is $1,611 per Acre Foot (MWDOC, 2014b).

3.2 Long Beach Infiltration Gallery Demonstration Project

A pilot test infiltration gallery was constructed in Long Beach, California. The ocean floor topography of the site is fairly flat and smooth. Permeable sand extends to depths of 20 feet at a distance of 200 feet offshore. Beach sand deposits become increasingly dense with depth and are underlain by layers of silt and clay. The seafloor is capped by up to 1 foot of very fine silty sand deposits which locally affects hydraulic conductivity (Black and Veatch, 2010).

Testing consisted of geotechnical and hydrological investigations, including seafloor bathymetry survey, offshore geotechnical borings, hollow-stem flight auger borings and aquifer testing. The testing was performed to determine beach sand thickness, characterize the beach sand deposits, provide a seabed profile, evaluate variability of hydraulic conductivity, and model intake/discharge capacity (Black and Veatch, 2010).

Based on the results of the field investigations, a fatal flaw analysis and flow modeling analysis were performed to select an intake option. The selected intake option was an infiltration gallery that was 400 feet in length. Flow modeling was used to assess the capacity of an infiltration gallery at this location and results of this analysis showed capacities ranging from 600 GPM to 720 GPM (0.86 to 1.04 MGD). Radial collector wells and vertical wells were also considered; however, modeling showed insufficient intake capacities of 140 GPM and 40 GPM (0.2 and 0.06 MGD), respectively (Black and Veatch, 2010).

Pilot testing was conducted in 2008 at a near-shore demonstration facility, with two 5-feet deep pits - an intake gallery measuring 60 feet by 50 feet, and discharge gallery measuring 50 feet by 40 feet. The test facility operated for 6 months at an infiltration rate of 0.15 GPM/ft^2 (a total capacity of 450 GPM, or 0.65 MGD) without any clogging, and data collected from test operation in 2008 showed that infiltration rate and production are not impacted by tidal fluctuations. However the SDI was greater than 4

(Allen et al., 2011), which approached levels that can result in clogging of RO membranes[3].

Currently, seawater desalination is not considered a cost-effective option for water supply reliability in Long Beach, primarily due to the high energy cost for operations and environmental impacts. However, as the costs of imported water increase over time and the costs of desalination, and its environmental impacts decrease with technological advances, seawater desalination might be reassessed at Long Beach Water Department (Long Beach Water Department, 2015).

3.3 Monterey Peninsula Test Slant Well

An approximately 10 MGD desal facility[4] is proposed in the City of Marina in northwest Monterey County at an existing CEMEX sand mining plant within an area of active mining activity to avoid disturbing adjacent dune areas. A test well (Figure 10) was completed in April 2015 to extract water from the Dune Sand and 180-ft Aquifers (SWCA, 2014; ESA, 2015).

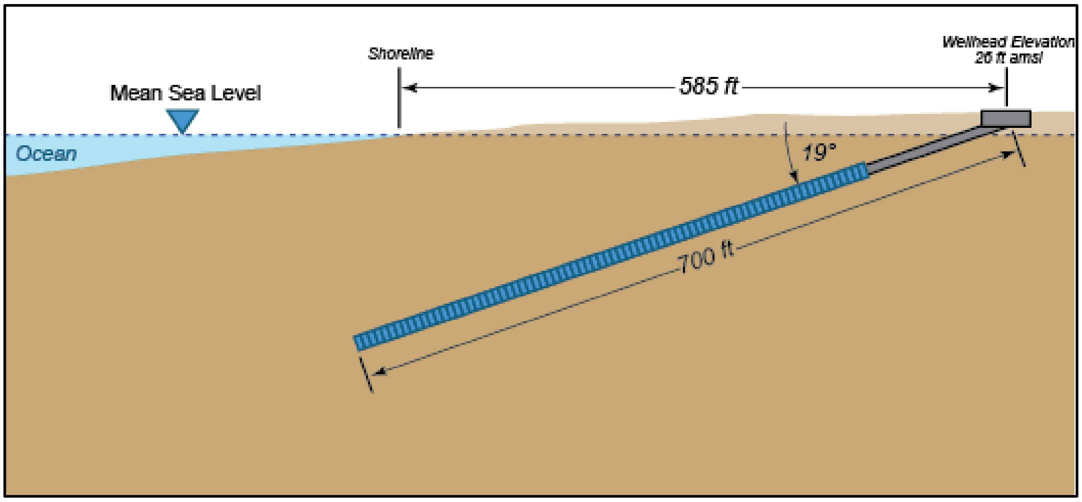

Figure 10 - Schematic Illustration of the Slant Test Well (Adapted from ESA, 2015)

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[3] http://www.lenntech.com/sdi.htm

[4] http://www.watersupplyproject.org/

Thirteen exploratory boreholes were drilled to depths between 200 feet bgs and 350 feet bgs in order to investigate the hydrogeological conditions of the area. Multiple estimates of hydraulic conductivity were made using mechanical grading analysis properties and vertical and horizontal conductivity/permeability values from laboratory analyses of relatively undisturbed soil samples. An aquifer test and water quality tests were conducted. The data were used to refine the existing North Marina Ground Water Model and construct a new model focused on the CEMEX area, which will be used to evaluate proposed project operation and impacts (Geoscience, 2014).

The test well is approximately 750 feet long and was constructed at an angle of 19 degrees below horizontal at the CEMEX site. The well extends to a depth of approximately 200 feet below mean sea level (msl) (ESA, 2015). The test well screened interval is approximately 600 feet long and includes both the Dune Sand Aquifer and the underlying 180-foot equivalent (FTE) Aquifer (ESA, 2015). The well was designed to pump between 1,000 GPM and 2,500 GPM (1.4 and 3.6 MGD) over a maximum 18-month test operational period (SWCA, 2014). The construction phase was completed in April 2015 with a five-day pumping test at 2,000 GPM. A second phase of the Test Slant Well Investigation is in progress including a long-term pumping test and characterization of baseline water quality (Geoscience, 2015b; http://www.watersupplyproject.org/).

Following completion of the test phase in 2016, the construction of nine additional slant wells is proposed in 2017 (Cal Am, 2015). The test slant well would be converted into a permanent seawater intake well and utilized as part of the proposed project’s seawater intake system. The wells would be constructed using a dual-wall, reverse-circulation drilling rig and completed using 30-inch diameter casings. The nine additional wells would have similar specification as the test slant well, with linear lengths of 700 to 800 feet long, a minimum angle of approximately 14 degrees below horizontal, and extend offshore to a depth of 200 to 220 feet below msl. Each well would be screened for 400 to 500 linear feet at depths corresponding to both the Dune Sand Aquifer and the underlying 180-FTE Aquifer. On average, Cal Am would operate eight wells at a time at approximately 2,100 GPM, and maintain the other two wells on standby. The total feedwater supply would be 24.1 MGD (ESA, 2015).

The desalination plant with a capacity of 9.6 MGD (ESA, 2015) is scheduled to be completed in 2019. The capital cost for the subsurface intake system (slant wells) and supply return facilities is estimated to be $51,000,000 (Cal Am, 2015).

The slant wells are expected to require maintenance every 5 years. Mechanical brushes would be lowered into the wells to mechanically clean the screens. The total duration of maintenance activities was estimated to be between 9 and 18 weeks, and would be conducted between October and February (ESA, 2015)

3.4 San Diego County Water Authority Deep Infiltration Gallery

A feasibility study was conducted for a DIG in the vicinity of Camp Pendleton near the Santa Margarita River (SMR) Estuary. The study area is generally underlain by fill, topsoil, alluvium, older paralic deposits, and materials of the San Mateo and San Onofre formations. Offshore geology has been mapped as mostly unconsolidated and poorly consolidated Pleistocene sand, silt, and clay deposits that mantle the modern seafloor including sandstone, siltstone, conglomerate, and breccia. Alluvial deposits of the Santa Margarita River are anticipated to be present on the continental shelf.

Two sites were considered: (1) an area northwest of the Southern Region Tertiary Treatment Plant (SRTTP) and (2) an area east of the Marine Corps Tactical Systems Support Activity (MCTSSA) Center. The SRTTP Site is located east of I-5, south of the SMR, approximately 1.0-mile east of the Pacific Ocean. The site is approximately 25 acres in size and is bisected by an abandoned rail line. The MCTSSA Site is located north of SMR, adjacent to and west of I-5. The site is currently leased agricultural tomato fields (RBF Consulting, 2009).

Three intake technologies were studied – seabed infiltration gallery (SIG), deep infiltration gallery (DIG or water tunnel), and slant wells. For a SIG, the design intake water feed rate of 100 to 300 MGD required an estimated SIG area of 18 to 55 acres. The conceptual design for a deep infiltration gallery showed a water tunnel intake connecting 30 to 90 collector wells over a distance of 3,500 ft, with each well drilled at an angle of approximately 45 degrees from the tunnel. Each well would have a capacity of 2,400 GPM (3.5 MGD) with a screen diameter of 12 inches and an average length of 80 feet. For slant wells, an optimum configuration of 30 supply wells was modeled, each well having a diameter of 12 inches, screen length of 400 to 500 feet, and total length of 600 to 750 feet.

The DIG intake system was recommended for the SRTTP site due to the assumed permeable hydrogeology offshore and the alluvial soil near the mouth of the river that has high hydraulic conductivity for greater infiltration rates. An open-ocean intake system was selected for the MCTSSA site due to the assumed unfavorable hydrogeologic conditions directly offshore of the site. However, based on further investigation of offshore conditions, a subsurface intake was suggested to be feasible (RBF Consulting, 2009).

Depending on the source of power supply, the capital cost of constructing a 150 MGD capacity plant with a deep infiltration gallery intake was estimated to be \$2.3 billion to \$2.5 billion (2009 dollars), and the total annual operation and maintenance costs between \$104 million and \$130 million (2009 dollars) (RBF Consulting, 2009).

3.5 Proposed Poseidon Water Huntington Beach Desalination Facility

Feasibility studies of SSIs have been conducted and are in progress for a desal facility proposed by Poseidon Water in Huntington Beach, California. The near shore area is underlain by a sequence of Holocene and Pleistocene sediments to a depth of approximately 200 feet. The majority of the San Pedro Shelf is characterized as muddy, and several faults are present parallel to the shoreline near the proposed site (Wong et al., 2012; Geosyntec 2013; ISTAP, 2014).

Vertical wells, radial collector wells, slant wells, HDD wells, BIGs, SIGs, and DIGs were considered. An evaluation matrix was used to consider the technical feasibility of these technologies with a seawater extraction goal between 100 and 127 MGD. Seven of the nine technologies were eliminated because of fatal flaws due to the regional hydrogeologic and oceanographic conditions, such as unacceptable drawdown levels of the shoreline, complications with seawater intrusion, inappropriate geologic conditions, geochemical impacts, and maintenance of well performance. Only a BIG and SIG were considered technically feasible in the Phase 1 analyses (ISTAP, 2014).

Subsequent Phase 2 analyses re-evaluated the feasibility of the BIG and determined it to be infeasible due to the migrating surf zone between periodic beach re-nourishments and a construction time of many years due to access constraints on a highly used public beach (ISTAP, 2015). Additionally, a full life-cycle economic analyses determined that the SIG option is not economically viable at the Huntington Beach location within a reasonable time frame, due to high capital costs and only modest reduction in annual operating costs (ISTAP, 2015).

4. CALIFORNIA SUBSURFACE INTAKE REGULATORY SETTING

The California and federal regulations that apply to installation and operation of SSI in California are summarized in Table 2 below.

Table 2: Summary of California and Federal Regulations

Regulatory/Permitting Activity	Time Frame	Responsible Federal/State Agencies	Description/Applicability
Environmental Impact Assessment / Environmental Impact Report	Part of California Environmental Quality Act (CEQA)/National Environmental Policy Act (NEPA) certification	California Coastal Commission (CCC), Local Coastal Program (LCP), California State Lands Commission (CSLC) California Public Utility Commission (PUC)	Describe the impact of site preparation, construction, and operation on navigation, fish and wildlife resources, water quality, water supply, and aesthetics. Describe mitigation measures. These are typically submitted as one document.
Coastal Development Permit	After CEQA/NEPA certification	CCC	Applies to development in and on the California Coastal Zone. Must also be in compliance with LCP.

Regulatory/Permitting Activity	Time Frame	Responsible Federal/State Agencies	Description/Applicability
Incidental Take Permit and Statement (Endangered Species Act Consultation, Marine habitat Consultation)	Prior to CEQA/NEPA certification	US Fish and Wildlife Service	Assess habitat for the presence of endangered and/or threatened species.
	Prior to CEQA/NEPA certification	National Oceanic and atmospheric Administration	Issue permits for “taking species incidental to (not the purpose of) an otherwise lawful activity (ESA Section 10(a)(1)(B)).” A Habitat Conservation Plan must accompany it.
	Prior to CEQA/NEPA certification	National Marine Fisheries Services	Enforce federal marine resources and habitats laws (e.g., ESA, Marine Mammal Protection Act).
	After CEQA/NEPA certification	California Department of Fish and Wildlife	The state agency that manages terrestrial, marine, estuarine, and freshwater habitats and associated endangered, threatened, and exotic species.
Section 401/404 of the Clean Water Act	Prior to construction	U.S. Army Corps of Engineers, Regional Water Quality Control Board (RWQCB)	Needed for the discharge of dredge or fill materials into navigable waters.
Revised National Pollutant Discharge Elimination System (NPDES) permit	Prior to construction	RWQCB	A provision of the Clean Water Act that prohibits discharge of pollutants into waters of the United States unless a special permit is issued. The NPDES permit for an existing ocean intake/outfall must be revised and approved if it is to be used as an intake for a desalination facility.

Regulatory/Permitting Activity	Time Frame	Responsible Federal/State Agencies	Description/Applicability
Lease for coastal and offshore land/Right-of-way Permit	After CEQA/NEPA certification and obtaining 401 permit	CSLC	Permit evaluation includes the biological review of entrainment, impingement, and discharge effects of intake and discharge facilities operating on the state-leased lands
Section 10 of the Rivers and Harbors Act permit	After CEQA/NEPA certification and obtaining 401 Permit	U.S. Army Corps of Engineers	Applies to construction of any structure in or over any “navigable water” of the United States, the excavation/dredging or deposition of material in these waters or any obstruction or alteration in a “navigable water.”
Permit to Construct/Operate	Prior to Construction	e.g. South Coast Air Quality Management District	To comply with the federal and state requirements of the Clean Air Act, all equipment (such as pumps and back-up generators) of a facility are subject to “no net emissions increase” and source-specific, prohibitory and toxic roles.
Domestic Water Supply Permit (DWSP) Amendment	Prior to Operation	State Water Resources Control Board Division of Drinking Water (DDW)	A water system that intends to serve potable drinking water to the public may not operate without having secured a DWSP from DDW. The field operations branch staff perform field inspections, issue operating permits, review plans and specifications for new facilities, and review water quality monitoring results.
Encroachment Permits	Prior to Construction	City, County, potentially California Department of Transportation	An encroachment permit must be obtained for any proposed activities related to the placement of encroachments such as pipe, pipeline, fencing, or structures within, under, or over the a public right-of-way or State highway right-of-way.

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APPENDIX C
NWRI Panel Reports

APPENDIX C-1

NWRI Panel Report of the February 26, 2015 Meeting (Meeting #1)

NATIONAL WATER RESEARCH INSTITUTE

Draft Final Report

of the February 26, 2015, Meeting (Meeting #1) of the

Independent Advisory Panel

for

West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Study – Guidance Manual Review

(Bureau of Reclamation Project No. R14AP00173)

Prepared for:

West Basin Municipal Water District
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Under Contract to:

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March 20, 2015

DISCLAIMER

This report was prepared by a National Water Research Institute (NWRI) Independent Advisory Panel, which is administered by the NWRI. Any opinions, findings, conclusions, or recommendations expressed in this report were prepared by the Panel. This report was published for informational purposes.

ABOUT NWRI

A 501c3 nonprofit organization, the NWRI was founded in 1991 by a group of California water agencies in partnership with the Joan Irvine Smith and Athalie R. Clarke Foundation to promote the protection, maintenance, and restoration of water supplies and to protect public health and improve the environment. NWRI's member agencies include Inland Empire Utilities Agency, Irvine Ranch Water District, Los Angeles Department of Water and Power, Orange County Sanitation District, Orange County Water District, and West Basin Municipal Water District.

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ACRONYMS

CEQA	California Environmental Quality Act
MF	Microfiltration
MGD	Million gallons per day
NTU	Nephelometric turbidity unit
NWRI	National Water Research Institute
SDI	Silt density index
SSI	Subsurface Seawater Intake
TWL	Total water level
UF	Ultrafiltration
USBR	United States Department of Interior, Bureau of Reclamation
WBMWD	West Basin Municipal Water District

CONTENTS

1. PURPOSE AND HISTORY OF THE PANEL

In 2015, NWRI formed an Independent Advisory Panel on behalf of the West Basin Municipal Water District (WBMWD) to provide expert peer review of the technical and scientific aspects of a proposed Subsurface Seawater Intake (SSI) Feasibility Guidance Manual, which is being developed by Geosyntec Consultants, under subcontract to WBMWD, with grant funding from the United States Department of Interior, Bureau of Reclamation (USBR) under USBR Project No. R14AP00173. The Guidance Manual is also a part of a larger WBMWD study, the "Ocean Water Desalination Subsurface Intake Study."

The Panel will review the Guidance Manual, which consists of a desktop tool for conducting feasibility analyses of SSIs based on site-specific observations or measurements, available data from public or private sources, or assumptions based on engineering judgment or professional experience.

1.1 Project Description

WBMWD has initiated the "Ocean Water Desalination Subsurface Intake Study" to investigate full-scale SSI technologies used to collect seawater through the ocean bottom and coastal aquifer sediments. The purpose of the study, which is under contract to Geosyntec Consultants, is to develop a comprehensive, systematic procedure to evaluate the technical feasibility of SSI technologies at a given project site.

This project will help the industry by providing a subsurface intake guidance manual for ocean-water desalination projects (particularly in California) to follow, as well as aiding regulatory agencies and non-governmental organizations by compiling the body of research on subsurface intakes that could be utilized to evaluate other projects.

The project involves the development of a Guidance Manual that can be used by project proponents when evaluating SSI technologies during the preliminary planning phase of an ocean water desalination plant. Once the Guidance Manual is completed, WBMWD's full-scale ocean water desalination planned facility will be used as a test case for the application of the Guidance Manual.

A "Subsurface Seawater Intake (SSI) Feasibility Matrix" has been prepared as part of the Guidance Manual. The Matrix provides a screening-level methodology to assess the technical feasibility[1] of seven different SSIs to provide feedwater to meet a desired desalination production capacity at a particular location. The seven SSIs include vertical wells, slant wells, horizontal

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[1] "Feasibility" is defined as meeting the feasibility criteria established by the California Coastal Commission (Seawater Desalination and the California Coastal Act, 2004), which is consistent with the California Environmental Quality Act (CEQA) definition of "feasibility." However, while the CEQA definition considers technical, environmental, economic, and social feasibility, the scope of the Matrix is limited to technical feasibility. Additional analysis would have to be conducted by project proponents to determine environmental, economic, and social feasibility.

wells, radial collector wells (Ranney wells), beach infiltration galleries, seafloor infiltration galleries, and water tunnels with radial collectors.

The Matrix consists of two steps: the evaluation of potential fatal flaws (step 1) and the evaluation of potential challenges (step 2). If an SSI is not initially eliminated by a fatal flaw (step 1), the Matrix will then use a weighted scoring system to qualify the technical and site assessment features of each SSI (step 2). The score generated through the Matrix would rank the technical feasibility of each SSI by quantifying in terms of construction, operation, potential impacts, and risk/uncertainty for project implementation the degree of challenges of each SSI.

1.2 Panel Charge and Members

To review the development of the Guidance Manual, the Panel was charged with the following:

- Validating each of the proposed fatal flaws as they relate to the technical feasibility for each type of SSI.
- The comprehensive list of technical fatal flaws is complete and all assumptions are accurate.
- Proposed fatal flaw thresholds and significant challenge thresholds for each SSI are complete and accurate.
- Scoring for the significant challenges and all assumptions are accurate.
- Weighting allocations for challenges as applied to the scoring of different SSIs are accurate and appropriate.
- Recommended tests and analysis to be performed after use of the Guidance Manual to continue determining the feasibility for SSIs.

To undertake this review, the four-member Panel consists of individuals with expertise in the fields of intake and well design, hydrogeology, coastal processes, evaluation of structures and vessels in the marine and coastal environment, development and implementation of alternate water supply projects (such as seawater desalination) at public agencies, and other areas relevant to the study.

Specifically, Panel members included:

- Chair: Thomas M. Missimer, Ph.D., Florida Gulf Coast University (Fort Myers, FL)
- Claudio Fassardi, CH2M HILL (Long Beach, CA)
- Heidi R. Luckenbach, P.E., City of Santa Cruz Water Department (Santa Cruz, CA)
- Robert G. Maliva, Ph.D, P.G., Schlumberger Water Services (Fort Myers, FL)

Background information about the NWRI Panel process can be found in Appendix A, and brief biographies of the Panel members can be found in Appendix B.

2. PANEL MEETING #1

A 1-day meeting of the Panel was held on February 26, 2015, at WBMWD's Edward C. Little Water Recycling Facility in El Segundo, California. This meeting represents the first time the Panel has met to review the framework of the proposed SSI Feasibility Guidance Manual. A portion of this meeting was open to the public for input.

2.1 Background Materials

Background materials were provided to the Panel and the public in advance of the meeting. These materials include:

- "Screening Flowchart" – This document was used as a pictorial representation of how to use the Guidance Manual and how computer logic will be set up once the Matrix is finalized.

- "Screening Narrative" – This document provided an explanation of details found in the Matrix.

- "Screening Framework" or the "Subsurface Seawater Intake (SSI) Feasibility Matrix" – This Matrix served as the basis for the Guidance Manual. The details of this Matrix were reviewed, including:

    - Inputs.
    - Fatal Flaws.
    - Criteria for Scoring.
    - Weighted Scoring System.
    - Next Level Testing Recommendations.

For clarity, the components of this effort are as follows:

- *The "Ocean Water Desalination Subsurface Intake Study."* The Study refers to the entire effort, which includes the development of the SSI Feasibility Guidance Manual Guidance Manual and the beta test of the Guidance Manual.

- *Subsurface Seawater Intake (SSI) Feasibility Guidance Manual or "Guidance Manual."* The Guidance Manual will be the desktop tool for conducting feasibility analyses of SSIs based on site-specific observations or measurements, available data from public or private sources, or assumptions based on engineering judgment or professional experience.

- *"Screening Framework" or the "Subsurface Seawater Intake (SSI) Feasibility Matrix."* The Matrix is a component of the Guidance Manual and provides the screening-level methodology to assess the technical feasibility of seven different SSIs to provide feedwater to meet a desired desalination production capacity at a particular location.

2.2 Meeting Agenda

The Panel meeting was divided into two sessions: the first session (from 9:00 am to 12:30 pm) was open to the public, and the second session (from 12:30 pm to 4:00 pm) was a closed working session for Panel members. NWRI staff, WBMWD staff, and Geosyntec project team members collaborated on the development of the two agendas for Panel meeting, which are included in Appendix C.

For the public portion of the meeting, the agenda was based on meeting the following objectives:

- Clarify the Panel's charge and Panel review process.
- Describe the goal and objectives of the Ocean Water Desalination Subsurface Intake Study Guidance Manual.
- Receive public input on this effort and clarify how to provide public comments.

The majority of this session was devoted to presentations made by WBMWD staff members and the Geosyntec project team. Presentations included:

- Introduction to WBMWD's Ocean Water Desalination Program.
- Introduction to the Ocean Water Desalination Subsurface Intake Study.
- Introduction of the SSI Feasibility Matrix.

Time was provided at the meeting for the Panel to ask questions and engage in discussions with WBMWD staff and members of the Geosyntec project team. In addition, time was allotted for members of the public to provide written and oral comments about the Panel process and proposed framework for the SSI Feasibility Guidance Manual.

During the closed portion of the meeting, the Panel discussed specifics of the Matrix with WBMWD staff and members the Geosyntec project team. The Panel then met in a closed (Panel-only) session to prepare a report outline and draft preliminary findings and recommendations on the proposed framework for the SSI Guidance Manual, which are expanded upon in this report.

2.3 Meeting Attendees

All Panel members attended this meeting in-person with the exception of Dr. Thomas Missimer, who participated via Skype. Other meeting attendees included NWRI staff, WBMWD staff, Geosyntec project team members, and others. A complete list of Panel meeting attendees is included in Appendix D.

3. FINDINGS AND RECOMMENDATIONS

The principal findings and recommendations provided below are focused on the framework for the SSI Feasibility Guidance Manual, particularly the SSI Feasibility Matrix, and are derived from the material presented and discussed during the meeting. The findings and recommendations are organized under the following categories:

- General Comments
- Weighting Scoring System
- List of Inputs
- Level 1 Fatal Flaws
- Level 1 Challenges
- Scoring Matrix
- Levels 2 and 3
- Public Comments

3.1 General Comments

These comments pertain to the overall Panel review of the proposed framework for the SSI Feasibility Guidance Manual.

- The Panel recognizes WBMWD and Geosyntec for their effort in preparing for the meeting. The Panel appreciates the level of organization and information provided for the Panel to conducts its review.

- The meeting presentations were informative and helpful in conducting this Panel review (with public input) of the Guidance Manual framework.

- WBMWD needs to be clear as to the purpose and users of the Guidance Manual (as well as be clear in the documentation as they develop this manual).

    - Although the Guidance Manual is geared towards California, will it be general enough to use in other regions?
    - A statement is needed as to how it should be used, who should use it (i.e., the technical backgrounds of users), and what level of effort is required.
    - Be clear that the Guidance Manual framework is a cursory feasibility analysis performed with a desktop tool with limited information. It is a tool to provide guidance as to which options may be most appropriate for a given site. It is not a final determination.
    - Use of the Guidance Manual will standardize SSI evaluations in terms of consistency in SSIs evaluated and the evaluation criteria used.
    - The Guidance Manual is a tool to demonstrate that all SSI technologies have been considered and those eliminated had justification for being eliminated.

- The Panel suggests that including practical issues (e.g., beach stability) in the Guidance Manual is important. In addition, input parameters should be data that could be obtained through a literature and database review and site inspection.

- The intake type is linked to economics (i.e., to the cost of the project and the cost of water to consumers).

    - Describe in the Guidance Manual that proponents should recognize that economic, environmental, social, and regulatory issues should also be factored into the decision-making process, perhaps not at Level 1, but at subsequent levels.

    - Proponents should consider conducting an initial feasibility analysis (i.e., this Guidance Manual) followed by an economic and regulatory and environmental impact analysis to assess the full feasibility of each SSI and whether or not a given option might face insurmountable regulatory challenges.

    - Please refer to the modified flowchart in Appendix E.

- The issue of risk of pursuing SSI options with limited experience is important. There is a need for pilot projects of different SSIs to reduce this risk and increase knowledge and confidence.

- The Panel suggests that the Guidance Manual could be beta tested on one or more existing facilities as a validation of the Guidance Manual. The tool could show that the technology used for an existing facility selected is ranked high, but not necessarily the highest.

- If the Guidance Manual is beta tested with existing facilities, the results could be used to validate the "weightings" addressed in Section 3.2.

- The definition for "feasibility" is derived from the feasibility criteria established by the California Coastal Commission (Seawater Desalination and the California Coastal Act, 2004). Is this definition consistent with the use of the tool for other regions outside of California?

- The Panel has the following recommendations on terminology:

    - The title of the project of the study is mentioned as: "Ocean Water Desalination Subsurface Intake Study Guidance." Consider the title: "Seawater Subsurface Intake (SSI) Feasibility Guidance Manual."

    - WBMWD and the project team need to be consistent in using a consistent phrase such as "subsurface seawater intake" and not other variations.

  - The Panel suggests that description “Subsurface Seawater Intake (SSI) Feasibility Matrix” may be a better phrase than “Screening Framework” when describing the Matrix.

3.2 Weighting Scoring System

These comments pertain to the weighting scoring system used for the SSI Guidance Manual.

- An explanation is needed of the weights that are included in the final version of the Guidance Manual, including a description of the methodology and justification of the individual weights.

- A weighting based on Southern California or California needs may not be as applicable to users in other regions. If it is to be a more general tool, then the basis for weighting needs to be general (e.g., eliminate California Environmental Quality Act [CEQA] definitions).

- Weights should be fixed by the Guidance Manual and should not allow the user to manipulate the numbers. Validating the weights based on a review of existing facilities would be a benefit if they are fixed. However, there could be an option to override the default weights if the user has more specific information. Users of the Guidance Manual may not understand, agree with, or actually disagree with the weights; therefore, the value of the tool may be diminished. WBMWD should consider this as a potential devaluing of the overall exercise and consider either a robust explanation of weights (as described above), or the ability of the user to change the weights after using the tool with “recommended weighting based on professional experience.”

- The Panel suggests qualifying the user input by adjusting weights on the basis of the input source. A risk factor would be assigned to the inputs, which in turn would be used to adjust the corresponding weights. For example, if the input is derived from a site-specific measurement or an observation, the input would be considered as high quality, if derived from regional estimates, literature review, and so on. The input would be considered of medium quality, and if the input is based on assumptions, anecdotal evidence, or any unsupported source, then the input would be considered of low quality. Also, uncertainly in the available data contributes to risk/uncertainty.

  The weightings could be adjusted based on the following assessment:

    - High quality input = low risk.
    - Medium quality input = medium risk.
    - Low quality input = high risk.

  The user would need to specify the source of the input, and the tool would perform the background calculation.

It would be useful at the end, when the scores are displayed, to show the level of uncertainty that was factored in the scores of the SSIs. This element could provide guidance into what investigations need to be performed to remove uncertainty.

3.3 List of Inputs

These findings and recommendations pertain to the List of Inputs (25 total) provided for the Draft SSI Feasibility Framework.

- Instead of providing a list of parameters, it may be possible to describe these items with a list of questions as questions can provide the context for better understanding the input required and limit misinterpretation. For example:

    - "What is the required capacity of the desalination plant?"
    - "What is the typical significant wave height at the depth of closure?"
    - "What is the top elevation of the beach relative to…?"

- The Panel would like more clarification as to what some of the inputs encompass. For instance, how were the "Number of Units" calculated? Terminology or descriptive details should be provided in the Matrix to assist users when addressing these inputs.

- Regarding "Number of Units":

    - It is recommended that the Number of Units be removed as an input. The Panel feels that the Number of Units should be calculated by the Guidance Manual (based on the input provided) rather than by the user. For example, using the available beach front (user input), the toolbox would calculate the number of conventional vertical wells and production that could be achieved on the basis of an estimate of well productivity (default provided by the toolbox, but adjustable by the user), well spacing (default provided by the toolbox, but adjustable by the user), redundancy (default provided by the toolbox, but adjustable by the user), etc. If the resultant production is less than required to match or exceed the design capacity of the desalination plant, then the technology would be flagged as unfeasible. The toolbox should perform similar calculations and provide guidance for input parameters for all the other SSIs.

    - To evaluate number of units and land take per unit (beach front and area), one would need to know the capacity per each type of unit and land take per unit for each intake option. Using vertical wells as an example, given a required capacity (+/- a safety factor) and well capacity (gallons per minute/well), the number of wells could be calculated and given a well spacing and well pad area, the total land take could be calculated. This information would be needed for each SSI option. There might be a default value and option to enter a site-specific estimated value.

- Guidance for the input on "Land per Unit (Linear Beach Front)" is needed, or this could be calculated (see above bullet).

- For the required input "Significant Wave Height," include additional sub-input like "Wave Period" and "Wave Direction." This information would be used to assess the individual SSIs. However:

    - The initial thought was to input several wave parameters to help assess beach dynamics, but this could be simplified if the user replies to the few questions (see next sub-bullet), which should help in determining the dynamics of the beach.

    - This could be simplified by entering the typical significant wave height and peak wave period at the depth of closure. The depth of closure is the depth beyond which sediment transport or bottom changes are negligible. Because a seabed infiltration gallery or the seaward end of a water tunnel would be constructed in this area, the wave height could make construction a challenge.

- The Panel recommends using turbidity (nephelometric turbidity units [NTU]) rather than silt density index (SDI) as an input.

    - Turbidity will tell you how much silt is in the water and if it will cause plugging of a seabed infiltration system.

    - Use the *Slow Sand Filter Manual* as reference to develop a threshold for turbidity (i.e., 50 NTU is the maximum value available for a slow sand filter).

    - SDI is not a measure of what will cause the fatal flaw because it cannot be related to the operation of the intake, but the surface water reverse osmosis process. As discussed below with reference to Criteria 15, all SSI types are capable of producing low SDI water and there is no one preferred option in this respected. A more important issue is the sensitivity of the intake to turbidity, which would be greatest for gallery type systems.

- The Panel recommends adding the following as inputs (for use with challenges):

    - The beach needs to be characterized; therefore, the Panel suggests questions like:
        - Is the beach artificial?
        - If the beach is artificial, how often is it nourished?
        - What is the beach width at mean higher high water (MHHW)?
        - What is the beach top elevation (relative to some common datum used throughout)?
        - What is the beach slope?
        - What is the depth of closure (depth beyond which there is no significant sediment transport or bottom changes)?

  - "Depth to bedrock" (challenge: project proponents will not be drilling into bedrock to put in a structure like a beach gallery).

  - "Erosion rate and/or return time for nourishment" (challenge: beach stability is important as it impacts the intake structure most).

    "Erosion rate" (e.g., in feet per year) may be difficult to determine. In any case, using the erosion rate with the beach width an estimate of the "life" of the beach could be computed (e.g., how many years until no beach or nourishment is required).

    This set of questions/answers should allow a determination as to how active or dynamic the beach is and factor that in in the scoring later, without trying to figure this out through wave conditions.

    The "rate of change of beach width over 30 years" should be removed, and replaced by the "erosion rate," which should be determined from measurements or literature. No estimate of "rate of change of beach width over 30 years" can be made from aerial photos alone (i.e., photos may not be available for 30 years, the beach may have been nourished, structures are installed, and the beach width depends on the tide, a photo may be taken at high tide showing a narrow beach and vice versa). While the analysis of photos to determine erosion rates is valid, it requires a level of analysis that is beyond what the typical user of the toolbox could do. Therefore, the Panel suggests the user input estimates made by others and published in the literature or reports by agencies. This refers to Challenge 13 (protection from erosion or scour), too.

  - Water levels relative to a common datum (e.g., NAVD88) used throughout should be included. For example:

    - What is the 100-year total water level (TWL)?
    - What is the MHHW?
    - What is the mean lower low water (MLLW)?
    - What is the 100-year TWL by mid-century (to account for the life of the facility [e.g., 30 to 40 years] and sea level rise due to climate change)?

    These water levels should be used to assess the challenge, feasibility, and other aspects of beach-based SSIs. At the same time, the elevation of the land where facilities could be installed should be defined, such as:

    - What is the elevation of the land beyond the beach where components of SSIs could be constructed?

- Requirements for the seven SSI options are needed. That is, the tool can make background calculations based on user inputs and values provided within the tool, like productivity, spacing, required area, and redundancy. Reasonable default values (or a range of values) are needed to help provide guidance on which well will work and how many wells are needed. There should be an override option in case the user has more specific information available.

3.4 Level 1 Fatal Flaws

These findings and recommendations pertain to the Level 1 Fatal Flaws provided as part of the Draft SSI Feasibility Framework.

- There is a large variety of coastal features to consider for Fatal Flaw #1 (land type makes construction of SSI infeasible). For example: Beach, Estuary, Bay, Wetland, Cliff, Bluff, Inlet, Lagoon, Reef, Flood Plain, Dune, Spit, etc. These could combine to define a specific coast type that may or may not be suitable for a particular SSI. For example, a beach could be in a bay and thought to be protected, but if the bay is like Santa Monica Bay, the location on the bay would be important in determining if the SSI would be exposed to large waves. A beach could be backed by a cliff or bluff, or be on a spit, and the beach may be fronted by a reef. All these scenarios would need to be defined if a flaw to a particular SSI is to be determined.

- The Panel feels that reference to CEQA in Fatal Flaw #4 is too California-specific and may be speculative at this stage of the review. The Panel recommends that WBMWD use a more general description (such as “state environmental review” or “regulatory review”). CEQA could then be referenced as an example. In addition, regulatory approval varies by intake type. A type-by-type evaluation of intakes will be needed based on state requirements.

- The Panel recommends including a fatal flaw that relates to sea level and/or elevation of the land. This effort may include defining what land elevation is not acceptable and where. Also, factor in flooding events and sea level rise, such as the 100-year flood and SLR due to climate change by mid-century or hurricane surge analysis for parts of the United States.

- Regarding Fatal Flaw #2 (insufficient beach front available to construct SSI): How is this computed and who computes it? Background calculations per user input and toolbox defaults could be used to compute this to determine if this is a fatal flaw or not.

- Similar for Fatal Flaw #3 (insufficient land available to construct SSI) and the proposed Fatal Flaw related to water level. If the top elevation of the beach is below the 100-year TWL, then beach-based SSIs like vertical well beach structures may not be a good idea.

3.5 Level 1 Challenges

These findings and recommendations pertain to the Level 1 Significant Challenges identified as part of the Draft SSI Feasibility Framework. They encompass construction, operation (intake and treatment), potential environmental impacts, and risk (uncertainty) challenges.

- Challenge #5 (limited area for drilling equipment). This challenge only deals with the staging area for drilling, but what about other staging areas for other land use considerations? A beach gallery will take up more space than a well. An offshore gallery may require the construction of a trestle that could impact the beach for months or years.

- Challenge #8 (wave limit for construction). Use two options instead of three. The two options include: less than 3 feet (zero points, feasible) and greater than 3 feet (2 points, unfeasible, too expensive, significant construction downtime). For Beach Infiltration Gallery, note that waves break as a function of depth with a ratio of height at breaking = 0.78 x depth, so the depth at the seaward end of the beach infiltration gallery will control the wave height at that location. Furthermore, a cofferdam may be built to protect/isolate the construction area from the waves (in which case waves would not be relevant).

- Challenge #9 (depth to seabed). The Panel recommends adding the phrase "at planned construction site." Note that greater than 35 feet is not feasible; the Matrix cites 50 feet for slant wells.

- The Panel noticed an inconsistency in the scoring with Challenge #10 (land type). For example, for radial collectors, a rocky coastline is considered a fatal flaw, while it is rated a (1) in Challenge 10. Cliffs are also listed as (2) and a fatal flaw.

- Challenge #12 (protection against sea level rise). Specify 30 years from what date (likely from the initiation of construction, which could reach to 40 years or greater from the time of project initiation). The SLR projection should account for the planning/design period, the construction period, and the lifetime of the facility. Refer to SLR projections by the National Research Council for California, Oregon, and Washington.

- Challenge #13 (protection from erosion or scour). Looking at historical aerial photos is reasonable, but it is also important to consider beach nourishment. Maybe this challenge should be redesigned to consider whether it is a stable or unstable beach. An important criteria would be if the beach needs nourishment (if it does, it is an eroding beach and would score a 2). Conversely, if the beach is receiving too much nourishment, the site will end up stranded. Also, see the discussion in Section 3.3 (List of Inputs) on "Erosion rate and/or return time for nourishment."

- Challenge #14 (clogging). This challenge is unlikely to be useful for screening due to a lack of information. Because more information is needed, it might be moved to Level 2. Alternatively, this challenge could be called "geochemical stability," with SSI rates based on the likelihood of mixing of waters with different chemistries (particularly redox conditions). Gallery types systems would rank (0), whereas vertical wells would receive a (2) and perhaps other types a (1).

- Challenge #15 (fouling). Replace this challenge with source water turbidity sensitivity. As previously noted, all SSI types can potentially provide very low SDI water. Thresholds will be needed for seabed and beach infiltration galleries.

- Challenge #16 (poor feedwater requiring additional permits). How will this challenge be practically applied in the absence of test well data? The SSIs would not differ from one another based on these criteria, and data will be hard to obtain. Can this be removed from the Guidance Manual, or does it belong in Level 2?

- Challenges #17-20. Why are these environmental challenges being considered when the guidance is focused on technical feasibility and not environmental feasibility? Also, these types of inputs need to be "well-type specific" and not generic inputs. However, it was noted that these only flag negative conditions (only scores of 2) and might still be worth considering in the Guidance Manual. In addition, remove references to CEQA.

- Challenge #20 (contaminant plumes). Horizontal wells under the seabed will not be affected by landward contamination. It should be "not applicable."

- Challenges #21 and #22. It was pointed out that precedents as far as capacity and units may not be of great value as SSIs tend to have a modular design and are readily scalable. As a hypothetical example, the largest beach gallery capacity to date is, say, 5 million gallons per day (MGD), which is not really a negative when considering a 10-MGD system, as there is no reason why the former could not have been made larger. Perhaps a more useful criterion is the number of (successful) operational systems with a capacity of 1 or 5 MGD or greater.

- In either the Risk section or Operations section, WBMWD should add challenge criteria "Maintainability." The input would be system-type specific, focusing on whether the user can readily and cost-effectively maintain these systems.

- Add "Practical Ability to Pilot Test" as a challenge in the Risk Section to consider economics. For example, it is relatively inexpensive to pilot test a vertical well (Score = 0), versus an off-shore gallery, water tunnel, or radial collector system (Score = 2), which can be impractical (i.e., too expensive) to pilot test. Other SSI types would be intermediate.

3.6 Scoring Matrix

These findings and recommendations pertain to the tables provided in "Scoring Matrix," which covered "SSI Significant Challenge Raw Score Calculation Matrix" and "Summary of Max Scores for Each SSI."

- The Panel would like to note that higher scores, traditionally, represent the better option. Perhaps WBMWD should consider reversing the scoring system so that zero is "highly challenging" and 2 is "not challenging/slightly challenging."

- A single weight should be provided for each Challenge in the Scoring Matrix. Currently, weights are listed for each SSI. That is, Challenge "Area available for drilling" should be weighted "1" for each SSI. This change would simplify the table/spreadsheet. After the "Challenge" column, add another column on "weight" and then include scores.

- Is the "Summary of Max Scores for Each SSI" showing the weighted scores? It needs to be clear.

- Thresholds can be dealt with qualitatively. However, there is a need to include an interpretation of the normalized score.

- In the flow chart, the purple box with "Refine Site Characteristics" should automatically move to "Apply Feasibility Matrix Challenges." See the modified flow chart in Appendix E for the Panel's edits.

3.7 Level 2 and 3 Matrix

These findings and recommendations pertain to the tables provided under "Level 2 and 3 Analyses," which covered fatal flaws and challenges.

- If a SSI has a fatal flaw, then it would logically no longer be considered. Hence, there is no need for additional Level 2 and 3 testing.

- The Panel notes that the Guidance focuses only on technical feasibility. Before the Level 2 and 3 analyses, the Guidance Manual should point users towards evaluating for environmental and economic challenges to assess whether the options should be further considered. It is strongly suggested that it be recommended that an initial economic and regulatory analysis be performed before proceeding to field testing (i.e., if it is clear that an option would be too expensive or could never be permitted, than it makes no sense to do any testing).

- The Panel would like a better description of the value added by Level 2 and 3.

- The Panel recommends separating the Level 2 and Level 3 information into different tables in the Matrix, including separating them in the flow chart (see Appendix E). Once they are separated, be more specific and individualize the information provided.

- Level 3 would include constructing and operating a pilot test well as a challenge.

3.8 Public Comments

The following comments were provided by members of the public who attended the Panel meeting. The Panel has addressed each comment below.

- Warren Teitz of Metropolitan Water District of Southern California congratulated WBMWD for taking a leadership role in developing a new water supply for the State of California. WBMWD took a leadership role with recycling, and now they are doing so with desalination. The work that this Panel is doing is very important and will help agencies in California wrestle with the issue of subsurface intakes.

Panel Response: Noted.

- Dana Murray of Heal The Bay works with marine and coastal environmental issues in California. She provided the following questions for consideration:
    - Will this guidance be undertaken for open ocean intakes as well? Can you integrate open ocean intakes into the SSI Guidance Manual effort to determine the best options for different sites?
    - How will you allow for adjustments when looking at the challenges? What feedback and/or input will you consider?
    - Will you look at the impact on coastal and marine spatial planning in California?
    - Who will undertake quality assurance/quality control to verify the accuracy of inputs?

  Panel Response: These questions should be addressed by WBMWD as they are not a part of the Panel review of the proposed framework of the SSI Guidance Manual.

- Richard Bell of the Municipal Water District of Orange County (MWDOC) thanked WBMWD for the leadership and great work they have been doing for years. This is a neat process and great tool. He noted that MWDOC constructed a slant well several years ago, and wanted to ask if mitigation or design protective measures were considered as part of the SSI Guidance Manual. For example, putting in a well head on a beach may involve dealing with liquefaction, so protective measures may be needed against earthquakes. Another issue that can come up long after a project is built is the listing of endangered species in your site area. He asked how we can work with Fish and Game to mitigate these issues. He also noted issues pertaining to the draw of water and water rights, and cautioned to not just look at required capacity but rather what the resource can produce.

  Panel Response: Mr. Bell is encouraged to submit written comments with additional detail.

- Jeff Barry of GSI Water Solutions has been involved in large projects like this, including evaluating feasibility. He suggested that WBMWD consider creating “off ramps” for people going through the feasibility process (that is, places to go where you can identify fatal flaws early). He suggested setting up the process in tiers, which can help users eliminate options earlier in the process.

  Panel Response: Noted.

- John Loveland of Poseidon congratulated WBMWD for undertaking this process. He noted that Poseidon has been engaged in a similar collaborative process with the California Coastal Commission and has vetted most of the issues spoken about today.

They have worked on their own process for 18 months and have published a feasibility study. He also noted that members of the Panel and technical project team have been drawn from Poseidon's own expert panel. Keep this transparent, he stated, because WBMWD may receive a lot of questions on their process, as Poseidon did. In response, Jeff Mosher of NWRI acknowledged that Poseidon's effort had a specific project site, but that WBMWD's effort is more of a general project to develop a screening tool that has wide use throughout the United States. Mosher also acknowledged that some of the same experts were drawn from Poseidon's project and are using their knowledge to inform WBMWD's project.

Panel Response: Noted.

- Tom Seacord of Carollo Engineers noted that the State Water Resources Control Board is finalizing amendments to the California Ocean Plan. He wondered if the manual would be flexible enough to insert future inputs based on new information from the State Board's amendment plan. Diane Gatza of WBMWD responded that they are following the State Board process closely and if new criteria come out before the Guidance Manual is finalized, then it can be included in this effort. Seacord then asked if there is a way to include additional inputs or fatal flaws once the Guidance Manual is finalized. Gatza replied that it is a great comment that requires further consideration.

  Panel Response: Noted.

- Tom Luster of the California Coastal Commission submitted the following comments:

  Thank you for the opportunity to comment on the draft documents you provided earlier this week. You received comments earlier today from myself, Poseidon, and Concur, Inc. regarding our concerns about how your Panel process may affect our separate Independent Science and Technical Advisory Panel process for the Poseidon Huntington Beach proposal. I'm providing just a few brief initial comments below on the substance of the draft documents, based on my preliminary review, but would appreciate the opportunity to provide more detailed review and comments later.

  Overall, the proposed tools don't appear to recognize or incorporate the main regulatory reasons for finding suitable designs and locations for subsurface intakes (i.e., both the State Water Code and the Coastal Act require that entrainment be minimized to the extent feasible). In fact, the tools overall emphasize the difficulties, rather than the need for, and benefits of, subsurface intakes. We recommend the tools identify these regulatory requirements and that the tools emphasize the importance of identifying site characteristics best suited for subsurface sites rather than focus solely on the challenges.

  Even with that change, however, the tools will likely have limited usefulness in regulatory review. While some of the proposed components may provide a useful framework for evaluating sites and designs (e.g., the "Required Inputs"), the proposed tools overall do not adequately recognize the site-specific nature of the regulatory review required for desalination facilities and their intakes. The proposed "Fatal Flaws," "Challenge Ranking," "Scoring Ranking," and other screening criteria are overall not consistent with regulatory review and, in some cases, are arbitrary or incorrect (see examples below).

Re: "Required Capacity" – The Screening Flowchart uses the phrase "required capacity" and includes it with the "fatal flaw" criteria. We recommend the phrase be changed to "proposed capacity" and that "proposed capacity" be recognized as a contributing factor to project design and regulatory review, but not as a component of "fatal flaw" criteria. We also recommend the tools recognize that a project's "proposed capacity" may be a result of site-specific conditions rather than something used to "screen out" a particular site.

Re: Preliminary Overview and User's Guide: SSI Feasibility Guidance Manual – As noted above, several of the proposed criteria are not consistent with those used in regulatory review. For example, this document's "Potential Feasibility" section describes four criteria that would be used to "trigger an infeasibility ranking." However, at least one of the "fatal flaws" (i.e., CEQA approvability) is incorrect or misstated, as a preliminary screening tool cannot be used to determine whether a subsurface intake can be "approved" or not through CEQA. Other components of the proposed "fatal flaws" are incorrect or appear arbitrary (e.g., >80 percent of beachfront, presence of cliffs, etc.). These types of characteristics are evaluated on a site-by-site basis and the screening tool errs in automatically rejecting certain designs or sites without considering the detailed location-specific information needed to evaluate various sites and designs.

In closing, and as noted above, I would appreciate the opportunity to provide a more detailed review and additional comments later in your process.

Panel Response: The Panel agrees that qualifying the use of the tool when it is used by a project proponent in their planning process would be a benefit for users and those reviewing the results. A significant amount of work will be put into completing Level 1 of the tool to understand the location and production capability of each SSI. As a result, it would be beneficial for the results to be useful for regulatory agencies. However, the tool results should be considered in the context that the tool is an initial screening/guidance tool. One suggestion is that project proponents should review the Level 1 results with regulatory agencies to get comments prior to eliminating any SSIs from considerations and before embarking on to Level 2.

The Panel recognizes the benefits of SSIs and it is assumed that a tool user would also understand the benefits. As a result, the tool would not need to highlight these benefits versus a conventional open ocean intake.

Some of these concerns can be addressed in the description/narrative for the tool.

The Panel agrees that the use of CEQA be removed from the Matrix as described in the Panel's responses. In addition, the Panel made specific comments on components of the

Matrix, including "Fatal Flaws," "Challenge Ranking," and "Scoring Ranking," so that the tool reflects current experience and can provide reasonable results.

- Mark Williams, Ph.D., P.E., of GEOSCIENCE Support Services, Inc., submitted the following comments:

  FATAL FLAWS:

  1. The inputs and fatal flaws are too simplistic and cannot be generally applied to all SSI and all sites. For example, to reject a site because it lies on a cliff is not sufficient as the site may be engineered to be acceptable (e.g., Marina Coast). Many of the proposed fatal flaw determinations listed cannot be practically evaluated to any reliable extent at this early stage and may be more appropriately evaluated during later (Level 2 or 3) evaluations.

  Panel Response: *The tool is intended as an initial screening tool. In addition, the site-specific nature of each alternative would need to be reflected in the use of the tool. As such, the Panel agrees that potential engineering solutions to allow for specific SSIs to be viable should be a part of the process. In addition, if the tool is made too complex by covering many details it could become problematic to implement.*

  2. There is no theoretical upper limit of the yield and sustainability of slant wells or some of the other SSI types used as a source of feed water supply to ocean desalination plants. Research and field testing over the past 9 years suggest that slant wells extracting water from subsea alluvial aquifers can provide a high yielding and long-lasting sustainable water supply when designed, constructed, and maintained properly. Furthermore, the total yield is a function of scale, and the reliability is guaranteed by the ocean source.

  Panel Response: *WBMWD and the Project Team should consider this comment.*

  SIGNIFICANT CHALLENGES: CONSTRUCTION

  1. Many of the Significant Challenges for Construction are not relevant at all or are not relevant at this preliminary screening stage. For example, in Monterey and Dana Point projects, drilling footprints were all well under 10,000 square feet with staging nearby the site. Access and construction were all challenging, but certainly did not prevent successful construction of the two projects. This will be the case, to some extent, for most coastal sites.

  Panel Response: The tool is intended to evaluate the feasibly of SSI options for the proposed full-scale project.

  2. It does not make sense to have such general statements in this section. It appears that the authors have selected a handful of topics and tried to apply to all SSI types and all site conditions. Potential subsurface intakes are quite site-specific and subject to a number of factors. These projects usually have high visibility with a good deal of public attention.

As such, siting considerations need to consider a number of factors other than just feed water production and proximity to the desalination plant. For example, along the coast of California, these factors include the normal permitting land acquisition and access factors, but are also dependent upon a number of environmental and operational factors, which if not complied with, could prohibit the project altogether. For example, many of these projects are tied to a maximum percentage of feed water derived from inland water supplies, which if not met, may require expensive mitigation or provision of supplemental supplies, all of which add to the cost of supplied desalination product water.

Panel Response: *WBMWD and the Project Team should consider this comment.*

3. Ranney-type collector wells have lateral lengths typically limited to approximately 46 meters or less. They also may draw a high percentage of recharge from inland supplies and require construction of a large diameter caisson, which is visually offensive in a beach environment. Horizontal directionally drilled wells could potentially be used for subsurface supply; however, the main disadvantage is the inability to place an engineered artificial filter pack around the well screen, which may result in clogging and limited well production in fine-grained alluvial formations.

Panel Response: WBMWD and the Project Team should consider this comment.

SIGNIFICANT CHALLENGES: OPERATIONAL

1. You cannot just select a range of aquifer parameters as a criteria for discrediting a subsurface intake. Groundwater modeling of site-specific areas and for site-specific feedwater supplies needs to be part of the selection. To say that the transmissivity has to be a certain value is pointless unless you consider other factors, specifically benthic zone leakance values.

Panel Response: *WBMWD and the Project Team should consider this comment.*

2. To maintain feed water production, planned rehabilitation should be performed with all subsurface intake types based on efficiency and yield decline. All wells (vertical and angled) need redevelopment from time to time to maintain performance. This periodic redevelopment typically consists of mechanical and/or chemical redevelopment using the same “tried and true” methods developed in the water well industry for vertical wells over the past 70 years. As access to the wellhead area is required, provision must be made during siting to minimize disturbance during routine maintenance.

Panel Response: WBMWD and the Project Team should consider this comment.

3. As a general rule, with all wells, when well efficiencies decline to 50 percent of the maximum value (at the design production rate), it is a good idea to take the well out of service and perform a video inspection and rehabilitation plan. Based on limited data from the Dana Point Test Slant Well, it is expected that in wells properly designed,

developed, and consisting of corrosion resistant steels, the frequency between well rehabilitation would be on the order of 3 to 5 years. However, depending on other constituents in the groundwater (e.g., iron and manganese), rehabilitation frequency may vary.

Panel Response: *WBMWD and the Project Team should consider this comment.*

APPENDIX A: PANEL BACKGROUND

About NWRI

For over 20 years, NWRI – a science-based 501c3 nonprofit located in Fountain Valley, California – has sponsored projects and programs to improve water quality, protect public health and the environment, and create safe, new sources of water. NWRI specializes in working with researchers across the country, such as laboratories at universities and water agencies, and are guided by a Research Advisory Board (representing national expertise in water, wastewater, and water reuse) and a six-member Board of Directors (representing water and wastewater agencies in Southern California).

Through NWRI's research program, NWRI supports multi-disciplinary research projects with partners and collaborators that pertain to treatment and monitoring, water quality assessment, knowledge management, and exploratory research. Altogether, NWRI's research program has produced over 300 publications and conference presentations.

NWRI also promotes better science and technology through extensive outreach and educational activities, which includes facilitating workshops and conferences and publishing White Papers, guidance manuals, and other informational material.

More information on NWRI can be found online at www.nwri-usa.org.

About NWRI Panels

NWRI also specializes in facilitating Independent Advisory Panels on behalf of water and wastewater utilities, as well as local, county, and state government agencies, to provide credible, objective review of scientific studies and projects in the water industry. NWRI Panels consist of academics, industry professionals, government representatives, and independent consultants who are experts in their fields.

The NWRI Panel process provides numerous benefits, including:

- Third-party review and evaluation.
- Scientific and technical advice by leading experts.
- Assistance with challenging scientific questions and regulatory requirements.
- Validation of proposed project objectives.
- Increased credibility with stakeholders and the public.
- Support of sound public-policy decisions.

NWRI has extensive experience in developing, coordinating, facilitating, and managing expert Panels. Efforts include:

- Selecting individuals with the appropriate expertise, background, credibility, and level of commitment to serve as Panel members.

- Facilitating hands-on Panel meetings held at the project's site or location.
- Providing written report(s) prepared by the Panel that focus on findings and recommendations of various technical, scientific, and public health aspects of the project or study.

Over the past 5 years, NWRI has coordinated the efforts of over 20 Panels for water and wastewater utilities, city and state agencies, and consulting firms. Many of these Panels have dealt with projects or policies involving groundwater replenishment and potable (indirect and direct) reuse. Specifically, these Panels have provided peer review of a wide range of scientific and technical areas related water quality and monitoring, constituents of emerging concern, treatment technologies and operations, public health, hydrogeology, water reuse criteria and regulatory requirements, and outreach, among others.

Examples of recent NWRI Panels include:

- **Development of Water Recycling Criteria for Indirect Potable Reuse through Surface Water Augmentation and the Feasibility of Developing Criteria for Direct Potable Reuse** for the State Water Resources control Board Division of Drinking Water (CA)
- **Evaluating Water Quality Testing at the Silicon Valley Advanced Water Purification Center for Future Potable Reuse Applications** for the Santa Clara Valley Water District (CA)
- **Developing Proposed Direct Potable Reuse Operational Procedures and Guidelines for New Mexico** for the New Mexico Environment Department (NM)
- **Monterey Peninsula Groundwater Replenishment Project** for the Monterey Regional Water Pollution Control Agency (CA)
- **Groundwater Recharge Scientific Study** for the LOTT Clean Water Alliance (WA)
- **Groundwater Replenishment System Program Review** for the Orange County Water District (CA)
- **Examining the Criteria for Direct Potable Reuse** for Trussell Technologies (CA) and WateReuse Research Foundation (VA)
- **Evaluating Potable Reuse** for the Santa Clara Valley Water District (CA)
- **Indirect Potable Reuse/Reservoir Augmentation Project Review** for the City of San Diego (CA)
- **BDOC as a Surrogate for Organics Removal in Groundwater Recharge** for the California Department of Public Health (CA)
- **Recycled Water Master Plan** for Tucson Water (AZ)
- **Groundwater Replenishment Project Review** for the Los Angeles Department of Water and Power (CA)

More information about the NWRI Independent Advisory Panel Program can be found on the NWRI website at http://nwri-usa.org/Panels.htm.

APPENDIX B: PANEL BIOGRAPHIES

PANEL CHAIR: Thomas Missimer, Ph.D., P.G.
President, Missimer Hydrological Services, Inc., and
Visiting Professor, Florida Gulf Coast University (Fort Myers, FL)

Thomas Missimer has 40 years of experience in the field of hydrogeology and is a recognized expert in artificial recharge and aquifer storage and recovery. He has managed more than 250 technical projects and is the author of eight books, 80 peer-reviewed articles, and 300 technical consulting reports. He currently serves as Executive Editor of *Groundwater*, a technical journal for groundwater hydrogeologists. Missimer co-founded the consulting firm Missimer & Associates, Inc., and helped grow the company's revenues to exceed $25 million per year. Before that, he was Vice President and national practice leader in artificial recharge/aquifer storage and recovery technology for CDM Missimer. He currently holds a courtesy faculty appointment at Florida Gulf Coast University. Missimer's education includes degrees in Geology from Franklin and Marshall College (BA), Florida State University (MS), and University of Miami (PhD). He is a registered Professional Geologist in the states of Florida, Georgia, and Virginia, and holds certifications from the American Institute of Professional Geologists and the National Groundwater Association.

Claudio Fassardi
Senior Principal Engineer
CH2M HILL (Long Beach, CA)

Claudio Fassardi has nearly 30 years of experience in the management and execution of coastal engineering projects. He specializes in planning, field work, analysis and design to support the development of waterfront facilities, analysis of coastal processes, and climate change impact assessment and adaptation. Additionally, Fassardi has expertise in analyzing and developing solutions to natural and anthropogenic impacts to the coastal environment. As the coastal engineering lead, Fassardi was part of a multidisciplinary team that performed a site characterization and feasibility assessment for the planned West Basin Municipal Water District (WBMWD) Desalination Plant in Santa Monica Bay. Fassardi was responsible for evaluating marine conditions and site characterization, and he assisted with evaluating existing intake/discharge infrastructure, reviewing the existing intake and discharge technologies, and selecting the preferred alternatives. He managed a multidisciplinary team of geotechnical and civil engineers, assisted in the development of the intake and discharge conceptual designs, and performed preliminary analysis of brine dispersion.

Heidi Luckenbach, P.E.
Deputy Director/Engineering Manager
City of Santa Cruz Water Department

Heidi Luckenbach is a civil engineer with more than 20 years of experience in water supply planning, drinking water treatment, and distribution. She has worked for the City of Santa Cruz Water Department for 17 years. As Deputy Director, she is responsible for managing engineering services for maintenance, operation, and improvement of the water utility, including long-range water supply planning. Luckenbach previously served as Desalination Program Coordinator for seven years, during which she developed and implemented the work plan for the ***scwd^2 Regional Seawater Desalination Project***. Program elements included a seawater desalination pilot study, evaluation of intake alternatives, analysis of brine dilution, comparison of water supply alternatives, and engagement with regulatory agencies. The 2.5-million gallon per day supplemental water supply would serve several communities in North Santa Cruz County. Luckenbach received her BS in Civil Engineering from California State University, Northridge, and an MS in Environmental Engineering from University of California, Los Angeles. She is a Registered Civil Engineer in California, serves as Vice Chair of the Desalination Committee for the California Nevada Section of American Water Works Association (AWWA), and was recently a board member for the American Membrane Technology Association (AMTA).

Robert Maliva, Ph.D., P.G.
Principal Hydrogeologist
Schlumberger Water Services (Fort Myers, FL)

Robert Maliva has more than 24 years of international research and consulting experience in groundwater resources management, subsurface geology, and fluid flow investigations. Prior to joining Schlumberger Water Services, Maliva was a Principal and Senior Hydrogeologist at CDM, and he held research positions at Harvard University, University of Cambridge, and University of Miami. He specializes in the development of alternative water supplies for municipal and industrial clients and has varied expertise in hydrogeology, including: design and permitting of injection wells; aquifer storage and recovery; managed aquifer recharge systems; stratigraphy and sedimentology; and aqueous geochemical modeling. Maliva has authored or co-authored more than 70 peer-reviewed journal articles and book chapters, and he is the senior author on two books on water management. His education includes degrees in Geology from The State University of New York at Binghamton (BS), Indiana University at Bloomington (MS), and Harvard University (Ph.D.). He is a registered Professional Geologist in the states of Florida and Texas.

APPENDIX C: MEETING #1 AGENDAS

NATIONAL WATER RESEARCH INSTITUTE

Independent Advisory Panel:

West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Study – Guidance Manual Review

(Bureau of Reclamation Project No. R14AP00173)

PUBLIC MEETING – Final Agenda

Thursday, February 26, 2015

Location	**Contacts:**
Edward C. Little Water Recycling Facility	**Jeff Mosher (Cell)**
1935 S. Hughes Way	714-705-3722
El Segundo, CA	**Brandi Caskey (NWRI Office)**
(310) 414-0183	(714) 378-3278

Meeting Objectives:

- Clarify the Panel's charge and Panel review process.
- Describe the goal and objectives of the Ocean Water Desalination Subsurface Intake Study Guidance Manual.
- Receive public input on this effort and clarify how to provide public comments.

Thursday, February 26, 2015

9:00 am	Agenda Item #1: Welcome and Introductions • Introductions • Review Agenda • Provide Panel Framework o Charge and Review Process	Jeff Mosher, NWRI Thomas Missimer, Panel Chair
9:30 am	Agenda Item #2: Welcome by West Basin's General Manager	Rich Nagel, West Basin
9:45 am	Agenda Item #3: Introduction to West Basin's Desalination Program	Shivaji Deshmukh and Diane Gatza, West Basin
10:15 am	Agenda Item #4: Introduction to Subsurface Intake Study	Diane Gatza, West Basin

10:30 am	Agenda Item #5: Introduction of the Feasibility Matrix	Gordon Thrupp, Geosyntec Consultants
11:00 am	Agenda Item #6 Public Comment Period	Facilitated by Jeff Mosher, NWRI
12:00 pm	Agenda Item #7: Panel Comment Period	Facilitated by Jeff Mosher, NWRI
12:15 pm	Agenda Item #8: Closing Remarks • How to Provide Comments • Next Steps in Panel Review Process	Jeff Mosher, NWRI
12:30 pm	**ADJOURN**	
12:30 pm – 1:30 pm	Guided Tour of Edward C. Little Water Recycling Facility	Open to Interested Parties
12:30 pm – 4:00 pm	Panel Deliberations	Panel Members

NATIONAL WATER RESEARCH INSTITUTE

Independent Advisory Panel:

West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Study – Guidance Manual Review

(Bureau of Reclamation Project No. R14AP00173)

PANEL MEETING #1 – Final Agenda

Thursday, February 26, 2015

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El Segundo, CA	**Brandi Caskey (NWRI Office)**
(310) 414-0183	(714) 378-3278

Meeting Objectives:

- Provide finding and recommendations on efforts to-date to develop the Ocean Water Desalination Subsurface Intake Study Guidance Manual.
- Provide recommendations on future work and activities.

Thursday, February 26, 2015

12:30 pm	**WORKING LUNCH**	Panel Members, West Basin, Geosyntec, and Regulators
1:30 pm	CLOSED SESSION: • Panel Discussion • Develop Framework for Panel Report • Assignments	Panel
2:30 pm	**BREAK**	
2:45 pm	Continue with Closed Session	Panel
4:00 pm	**ADJOURN**	

APPENDIX D: MEETING #1 ATTENDEES

Panel Members:

- Chair: Thomas M. Missimer, Ph.D., Florida Gulf Coast University (Fort Myers, FL) (on Skype)
- Claudio Fassardi, CH2M HILL (Long Beach, CA)
- Heidi R. Luckenbach, P.E., City of Santa Cruz Water Department (Santa Cruz, CA)
- Robert G. Maliva, Ph.D, P.G., Schlumberger Water Services (Fort Myers, FL)

National Water Research Institute:

- Jeff Mosher, Executive Director
- Gina Vartanian, Communications Manager

West Basin Municipal Water District:

- Shivaji Deshmukh, Assistant General Manager
- Diane Gatza
- Richard Nagel, General Manager
- Oliver Perez, Information Technology Officer
- Justin Pickard
- Ron Wildermuth, Communications Manager

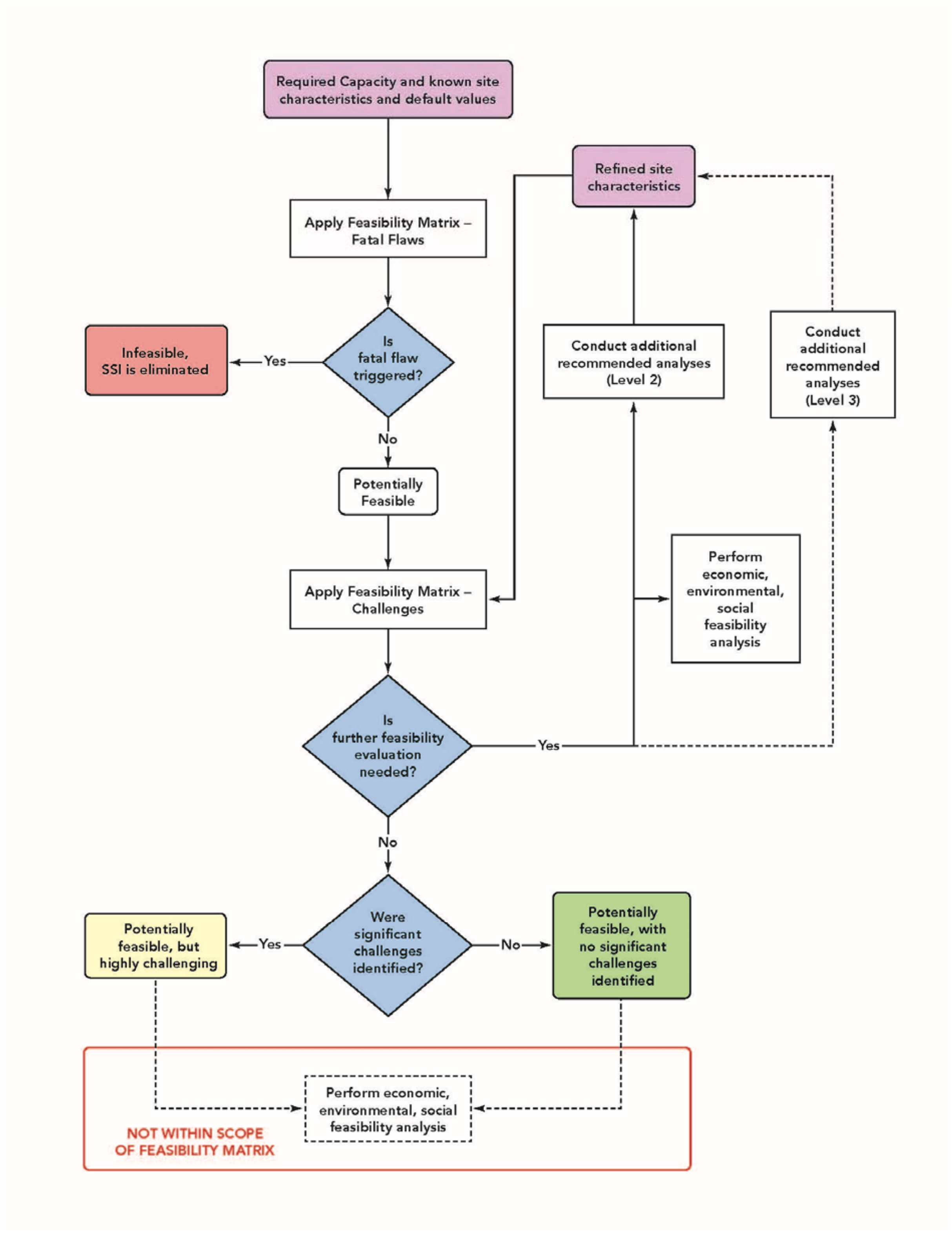
Geosyntec Consultants:

- Rebecca Batchelder
- Julie Chamber
- Mark Hanna
- Gordon Thrupp, Ph.D., P.G., CH.G.

Others:

- Jeff Barry, GSI Water Solutions
- Richard Bell, Municipal Water District of Orange County
- Bryan Bundy, Calleguas Municipal Water District
- Jeremy Crutchfield, San Diego County Water Authority
- Gerry Filteau, SPI Engineering
- Kris Helm, KH Consulting
- John Loveland, Poseidon
- Doug McPherson, United States Bureau of Reclamation
- Dana Murray, Heal the Bay
- Tom Seacord, P.E., Carollo Engineers
- Frances Spivy-Weber, California State Water Resources Control Board
- Linda Sumansky, P.E., City of Santa Barbara
- Warren Teitz, Metropolitan Water District of Southern California
- Kevin Thomas, RBF Consulting and Michael Baker International
- Mark Williams, GEOSCIENCE

APPENDIX E: MODIFIED FLOW CHART



APPENDIX C-2

NWRI Panel Report of the April 14, 2015 Meeting (Meeting #2)

NATIONAL WATER RESEARCH INSTITUTE

Draft Final Report

of the April 14, 2015, Meeting (Meeting #2) of the

Independent Advisory Panel

for

West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Study – Guidance Manual Review

(Bureau of Reclamation Project No. R14AP00173)

Prepared for:

West Basin Municipal Water District
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ABOUT NWRI

A 501c3 nonprofit organization, the NWRI was founded in 1991 by a group of California water agencies in partnership with the Joan Irvine Smith and Athalie R. Clarke Foundation to promote the protection, maintenance, and restoration of water supplies and to protect public health and improve the environment. NWRI's member agencies include Inland Empire Utilities Agency, Irvine Ranch Water District, Los Angeles Department of Water and Power, Orange County Sanitation District, Orange County Water District, and West Basin Municipal Water District.

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ACRONYMS

CEQA	California Environmental Quality Act
MF	Microfiltration
MGD	Million gallons per day
NTU	Nephelometric turbidity unit
NWRI	National Water Research Institute
SDI	Silt density index
SSI	Subsurface Seawater Intake
TWL	Total water level
UF	Ultrafiltration
USBR	United States Department of Interior, Bureau of Reclamation
WBMWD	West Basin Municipal Water District

1. PURPOSE AND HISTORY OF THE PANEL

In 2015, NWRI formed an Independent Advisory Panel on behalf of the West Basin Municipal Water District (WBMWD) to provide expert peer review of the technical and scientific aspects of a proposed Subsurface Seawater Intake (SSI) Feasibility Guidance Manual, which is being developed by Geosyntec Consultants, under subcontract to WBMWD, with grant funding from the United States Department of Interior, Bureau of Reclamation (USBR) under USBR Project No. R14AP00173. The Guidance Manual is also a part of a larger WBMWD study, the "Ocean Water Desalination Subsurface Intake Study."

The Panel will review the initial framework (i.e., assumptions, criteria, etc.) for the Guidance Manual. The Guidance Manual, which will be based on the initial framework will consist of a desktop tool for conducting feasibility analyses of SSIs based on site-specific observations or measurements, available data from public or private sources, or assumptions based on engineering judgment or professional experience.

1.1 Project Description

1.1.1 Purpose

WBMWD has initiated the "Ocean Water Desalination Subsurface Intake Study" to investigate full-scale SSI technologies used to collect seawater through the ocean bottom and coastal aquifer sediments. The purpose of the study, which is under contract to Geosyntec Consultants, is to develop a comprehensive, systematic procedure to evaluate the technical feasibility of SSI technologies at a given project site.

This project will help the industry by providing an SSI Guidance Manual for ocean-water desalination projects (particularly in California) to follow, as well as aiding regulatory agencies and non-governmental organizations by compiling the body of research on SSIs that could be used to evaluate other projects.

1.1.2 Product

The proposed Guidance Manual can be used by project proponents when evaluating SSI technologies during the preliminary planning phase of an ocean water desalination plant. Once the Guidance Manual is completed, WBMWD's full-scale ocean water desalination planned facility will be used as a test case (beta test) for the application of the Guidance Manual.

A "Subsurface Seawater Intake (SSI) Feasibility Matrix" has been prepared as part of the Guidance Manual. The Matrix provides a screening-level methodology to assess the technical feasibility of seven different SSIs to provide feedwater to meet a desired desalination production capacity at a particular location. The seven SSIs include vertical wells, slant wells, horizontal wells, radial collector wells (Ranney wells), beach infiltration galleries, seafloor infiltration galleries, and water tunnels with radial collectors.

The Matrix consists of two steps: the evaluation of potential fatal flaws (step 1) and the evaluation of potential challenges (step 2). SSIs with fatal flaws will be eliminated (step 1); a weighted scoring system will then be used to qualify the technical and site challenges of the remaining SSIs (step 2). The score generated through the Matrix would rank the technical feasibility of each SSI by quantifying the degree of challenges in terms of construction, operation, potential impacts, and risk/uncertainty for project implementation.

1.1.3 Summary of Project Components

For clarity, the components of this the review of the initial framework are summarized as follows:

- *The "Ocean Water Desalination Subsurface Intake Study."* The Study refers to the entire effort, which includes the development of the SSI Feasibility Guidance Manual Guidance Manual and the beta test of the Guidance Manual.

- *Subsurface Seawater Intake (SSI) Feasibility Guidance Manual or "Guidance Manual."* The Guidance Manual will be the desktop tool for conducting feasibility analyses of SSIs based on site-specific observations or measurements, available data from public or private sources, or assumptions based on engineering judgment or professional experience.

- *"Screening Framework" or the "Subsurface Seawater Intake (SSI) Feasibility Matrix."* The Matrix is a component of the Guidance Manual and provides the screening-level methodology to assess the technical feasibility of seven different SSIs to provide feedwater to meet a desired desalination production capacity at a particular location. It includes the following elements:
  - Inputs.
  - Fatal Flaws.
  - Criteria for Scoring.
  - Weighted Scoring System.
  - Next Level Testing Recommendations.

1.2 Panel Charge and Members

In the review of the initial framework of the Guidance Manual, the Panel was charged with the following:

- Validating each of the proposed fatal flaws as they relate to the technical feasibility for each type of SSI.
- The comprehensive list of technical fatal flaws is complete and all assumptions are accurate.
- Proposed fatal flaw thresholds and significant challenge thresholds for each SSI are complete and accurate.
- Scoring for the significant challenges and all assumptions are accurate.

- Weighting allocations for challenges as applied to the scoring of different SSIs are accurate and appropriate.
- Recommended tests and analysis to be performed after use of the Guidance Manual to continue determining the feasibility for SSIs.

The Panel includes individuals with expertise in the fields of intake and well design, hydrogeology, coastal processes, evaluation of structures and vessels in the marine and coastal environments, development and implementation of alternate water supply projects (such as seawater desalination) at public agencies, and other areas relevant to the study.

Specifically, Panel members included:

- Chair: Thomas M. Missimer, Ph.D., Florida Gulf Coast University (Fort Myers, FL)
- Claudio Fassardi, CH2M HILL (Long Beach, CA)
- Heidi R. Luckenbach, P.E., City of Santa Cruz Water Department (Santa Cruz, CA)
- Robert G. Maliva, Ph.D, P.G., Schlumberger Water Services (Fort Myers, FL)

Background information about the NWRI Panel process can be found in Appendix A, and brief biographies of the Panel members can be found in Appendix B.

2. PANEL MEETING #2

The Panel met in person on April 14, 2015, at WBMWD's Edward C. Little Water Recycling Facility in El Segundo, California. It was the second meeting of the Panel. The goal of this meeting was to clarify the Panel's findings and recommendations from its initial review of the framework for the proposed SSI Feasibility Guidance Manual and to address follow-up questions by WBMWD and the Geosyntec project team. A portion of this meeting was open to the public for input.

2.1 Background Materials

Background materials were provided to the Panel in advance of the meeting. These materials included:

- *NWRI Draft Final Panel Report of the February 26, 2015, Meeting (Meeting #1) of the Independent Advisory Panel for West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Study – Guidance Manual Review (dated March 20, 2015).*

- Response to Comments from the *NWRI Draft Final Report of the February 26, 2015, Meeting (Meeting #1) of the Independent Advisory Panel for West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Study – Guidance Manual Review (dated March 20, 2015)* (8-page table drafted April 2015 by WBMWD and Geosyntec Consultants).

- Comments Requiring Additional Input: West Basin's Response to *NWRI Draft Final Panel Report of the February 26, 2015, Meeting (Meeting #1) of the Independent Advisory Panel for West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Study – Guidance Manual Review (dated March 20, 2015)* (3-page table drafted March 31, 2015, by WBMWD and Geosyntec Consultants).

2.2 Meeting Agenda

The Panel meeting was divided into two sessions: the first session (from 9:00 am to 11:30 am) was open to the public and was followed by a closed session with the Geosyntec project team; the second session (from 11:30 am to 4:00 pm) was a closed working session for Panel members only. NWRI staff, WBMWD staff, and Geosyntec project team members collaborated on the development of the two agendas for Panel meeting, which are included in Appendix C.

For the public portion of the meeting, the agenda was based on meeting the following objectives:

- Clarify the Panel's charge and Panel review process.
- Describe the goal and objectives of the Ocean Water Desalination Subsurface Intake Study Guidance Manual.
- Receive public input on this effort and clarify how to provide public comments.

The majority of this session was devoted to presentations made by the Geosyntec project team and Panel members regarding the Panel's finding and recommendations of their review of the proposed framework for the SSI Feasibility Guidance Manual. Presentations included:

- Feasibility Matrix Overview.
- Panel Findings and Recommendations from Meeting #1.
- West Basin's Response to the Panel's Findings and Recommendations from Meeting #1.

Time was provided at the meeting for the Panel to ask questions and engage in discussions with WBMWD staff and members of the Geosyntec project team. In addition, time was allotted for members of the public to provide written and oral comments about the Panel's findings and updates to the proposed framework for the Guidance Manual.

During the closed portion of the meeting, the Panel addressed specific questions posed by WBMWD staff and members the Geosyntec project team regarding the Panel's findings and recommendations. The Panel then met in a closed (Panel-only) session to prepare a report outline focused on the Panel's responses to these questions, which are expanded upon in this report.

2.3 Meeting Attendees

All Panel members attended this meeting in person. Other meeting attendees included NWRI staff, WBMWD staff, Geosyntec project team members, and others. A complete list of Panel meeting attendees is included in Appendix D.

3. FINDINGS AND RECOMMENDATIONS

The principal findings and recommendations provided below are focused on the framework for the SSI Feasibility Guidance Manual, particularly the SSI Feasibility Matrix, and are derived from the material presented and discussed during the meeting. The findings and recommendations are organized under the following categories:

- General Comments
- Panel Response to the Project Team's Questions
- Public Comments

3.1 General Comments

These comments pertain to the overall Panel review of the proposed framework for the SSI Feasibility Guidance Manual.

- The Panel understands it is reviewing the project team's responses to the Panel's report from the first meeting, and the project team will be responsible for incorporating the Panel's comments into the final product.

- The Panel acknowledges an updated matrix was not prepared for the second meeting.

- Emphasize in the Guidance Manual that it is a screening tool, and is not meant to be used for a final decision.

3.2 Panel Response to the Project Team's Questions

The Panel comments below are in direct response to the background material document titled, "Response to Comments from the *NWRI Draft Final Report of the February 26, 2015, Meeting (Meeting #1) of the Independent Advisory Panel for West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Study – Guidance Manual Review (dated March 20, 2015)* (8-page table drafted April 2015 by WBMWD and Geosyntec Consultants)." The item numbers correspond to the numbering in the table.

Item #3 on the Purpose and Users of the Guidance Manual

- The Panel recommends removing some of the California-specific material to make the Guidance Manual more beneficial to a broad range of locations.

Item #9 on the Definition of Feasibility

- The Panel recommends defining "feasibility" without referring to the California Environmental Quality Act (CEQA).
- Clarify that the user should conduct economic and environmental analyses outside of the technical feasibility assessment.

Item #14 on Adjusting Weights on the Basis on Input Sources

- Regarding transparency when adjusting the weights:
  - The Panel suggests stating in the Guidance Manual that users must provide justification (e.g., appropriate data) when changing the default weights.
  - The Panel recommends providing users with details on the rationale used to develop the weightings. Communities and/or stakeholders may want guidance on how the weighting works to ensure it is not being manipulated by the user.
- Regarding the quality of input:
  - The Panel agrees it is appropriate to use "low," "medium," and "high" to qualify the quality of data.
  - Clarify how the final ranking will be determined (i.e., weighed by the quality of the data; if data based on actual data or assumptions, this is where uncertainties can be accounted for) and how this will be made clear to the user (e.g., flags will be used to qualify the ranking of the SSIs based on input provided by the user).

Item #19 on Input for Significant Wave Height

- The Panel recommends characterizing the wave climate.
  - Use the average wave height at the depth of closure (defined as *the depth beyond which sediment transport or bottom changes are negligible*).
  - To score depth of closure:
    - All SSIs except the offshore gallery receive a score of 0.
    - Water depth of less than 10 feet, and less than 1,000 feet from the shore (receives a score of 0)
    - Water depth of 10-20 feet, and less than 2,000 feet from shore (receives a score of 1).
    - Water depth of greater than 20 feet, and greater than 2,000 feet from shore (receives a score of 2).

Items #21 and #23 on Beach Characterization, including Beach Stability

- When characterizing beach stability, the Panel recommends using the following:
  - Stable Beach (receives a score of 0):
    - Beaches that are not nourished and with no significant seasonal beach profile changes.
  - Unstable Beach:
    - Beaches that could exhibit peak annual mean sea level (MSL) shoreline changes greater than 15 feet/year, or have been re-nourished in the past 10 years (receives a score of 2).
    - Beaches that could exhibit peak annual mean sea level (MSL) shoreline changes of less than 15 feet/year, or has been re-nourished in the last 10 years (receives a score of 1).

Item #22 on Depth to Bedrock

- The Panel recommends scoring "depth to bedrock" as follows:
  - A depth of 0-10 feet receives a score of 2.
  - A depth of 10-20 feet receives a score of 1.
  - A depth of greater than 20 feet receives a score of 0.

Item #24 on Water Levels Relative to Common Datum

- Because it is a design issue, the Panel suggests eliminating it from the matrix. If it is not eliminated, then the scheme will need to be considered.

Issue related to Item #24 on Water Levels Relative to Common Datum

- Should "vulnerability to sea level changes" be included in the criteria?

Item #26 on Coastal Features to Consider for Fatal Flaw #1

- The Panel recommends using a limited number of categories (with a "yes/no" response), such as:
    - Shallow bedrock (less than 5 feet) (which is a fatal flaw for all the SSI options).
    - Narrow beach (less than 50 feet) backed by cliffs (which is a fatal flaw for all the SSI options except offshore galleries).
    - Rocky shoreline (which is a fatal flaw for all the SSI options except offshore galleries).
    - Inlet (which is a fatal flaw for all the SSI options except offshore galleries).
- In addition, for each SSI category, a decision will need to be made as to whether a "yes" response is a fatal flaw.

Item #35 on Sea Level Rise Projections (Challenge #12)

- The Panel agrees to using "40 years from project initiation" as the date to assess sea level rise. Forty years would include 8 years for planning and permitting, 2 years for construction, and 30 years for operation.

Item #48 on Interpretation of a Normalized Score

- The Panel agrees on eliminating the categories from normalization.
- Typically, the higher the score, the better the feasibility. But in this matrix, the higher score represents lower feasibility. Because of the potential for confusion and/or misinterpretation, the Panel recommends that the scoring be changed so that the higher score reflects higher feasibility/opportunity.
    - If changed, use a default of 2 for high-end and 0 for low-end.
- The Panel suggests the following parameters for normalization:
    - The score should be a measure of better feasibility/opportunity.
    - Adjust weighting so that the maximum score is 100.
    - View the weightings as a value judgment (i.e., on a scale of 1-5). Weightings must have meaning.
    - Weights should be uniform across the categories and technologies.
- The Panel is especially concerned that the scoring system results are very sensitive to the weights used, which can bias the results towards a few SSIs. In particular, the original scoring and weighting system tends to conclude that the water tunnel and beach galleries are the best choices because, for a given set of user inputs, it is least sensitive to near shore and beach conditions (e.g., the sum of their weights is less than for the other SSIs). This bias could be reduced once categories of maintainability and the ability to pilot test are added (and given an appropriate weight), which factors would favor vertical wells. The sensitivity of the scoring system to the effects of weighting must be further evaluated. Can the system score a vertical well, slant well, or radial collector as the best

choice knowing where these systems are likely to be suitable? Regardless of which weighting system is used, the mathematical component that can cause biasing and the weighting factor/scores cannot be in same range. If this is the case, the mathematical component will bias the results.

- The Panel recommends beta testing the matrix. The City of Santa Cruz could be used as a potential beta test case.

3.3 Public Comments

The following comments were provided by members of the public who attended the Panel meeting. The Panel has addressed each comment below.

- Joe Geever, environmental consultant, stated that the environmental community is interested in identifying the best combination of siting and technology to minimize the impact of desalination SSIs on the environment and fish mortality. He was pleased that WBMWD is addressing a concern of the environmental community. He also commented that many projects look at existing intake structures that have been or will be abandoned; conducting an economic feasibility on the use of an existing intake vs. constructing a new intake is not an "economic" analysis but rather a "financial" analysis. He also felt it is reasonable to look at the frequency and the need for maintenance. He used a gallery in Long Beach, California, as an example of maintenance issues leveling off.

  Panel Response: Noted.

- Craig Cadwallader of Surfrider South Bay questioned if the Guidance Manual will have "location specific" defaults (such as California-specific or regional-specific) as pre-loaded options. He would like credible, generally agreed-upon defaults that can be plugged in for the location and not come back flagged as outside the parameters. Can multiple defaults be set up so that they are reasonable, but location-specific?

  Panel Response: The parallel weighing for the quality of data should help address this issue.

- Peter Shellenbarger of Heal the Bay, commented that he is concerned about the limitations of the inputs. If "desired intake volume" is a constraint, and the project cannot be achieved by an SSI, then it can only be achieved by surface intakes. He feels that the ability to use SSIs should limit the size of the project. He noted that desalination facilities should be sited in areas where SSI is capable to prevent impacts on marine life. He also commented on changing the default settings of the weighting. He felt that regional default parameters are needed to represent current local conditions. But if the weights are changed by users, then the changes need to be reviewed to ensure they are appropriate.

  Panel Response: These two issues tie into the need to clarify who is the user of the Guidance Manual, why they are using it, and who is their audience.

- Peter Shellenbarger of Heal the Bay also provided written comments, which were submitted April 28, 2015, and included the following:

  Thank you for the opportunity to provide comments on the 2nd public meeting for the Ocean Water Desalination Subsurface Intake Study. We believe ocean desalination projects should only be pursued when all other options for increasing potable and non-potable supply have been exhausted – water conservation, recycled water use, stormwater capture, indirect potable reuse, etc. should be utilized to their fullest extent. In the event that ocean desalination is pursued, subsurface intakes (SSIs) should be the only intake technology implemented in order to minimize marine impacts, and feasibility of SSIs should be a guiding factor for selecting a site as well as overall facility design. Please see comments below as they relate to the meeting:

  I. User Inputs – the tool would allow users to control two inputs used to evaluate a site's feasibility for SSIs: (1) desired intake flow rate, (2) site-specific characteristics. Allowing users to manipulate the assessment tool can greatly influence its outputs and may allow users to always identify SSIs as infeasible. For example, users could strategically choose a desired intake volume that is not supported by site characteristics; this could be used as a technique to always deem SSIs as infeasible. This type of control over the tool is concerning. The assessment tool could be incorrectly used to justify co-locating ocean desalination facilities at power plants that use or in the past used ocean intakes for cooling. The Once-Through Cooling (OTC) Policy clearly identifies the marine impacts of OTC, reflected in the phasing out of OTC. Co-locating ocean desalination facilities at coastal power plants completely negates the spirit and intended outcome of the OTC policy.

  We believe a more appropriate method for the SSI assessment tool would be to only assess a site's feasibility based upon site-specific characteristics (i.e., not including desired intake volume in the tool). This would be the only way to identify if a site is capable of supporting SSIs. Including desired intake volume greatly clouds the tool's ability to identify areas capable of supporting SSIs. In addition, we believe that before ocean desalination is pursued, a general statewide study needs to be conducted identifying the areas along California's coast capable of supporting SSIs. The assessment tools being developed should then be applied to refine the statewide analysis and help determine if ocean desalination should be pursued at a specific site.

  Panel Response: This issue underscores the need to clarify who is the user of the Guidance Manual, why they are using it, and who is their audience.

  II. Site-specific conditions should always be incorporated into SSI intake volume design – When ocean desalination is pursued, intake volume should be determined by examining site-specific conditions. Site-specific conditions should be the limiting factor for intake volume; neither cost nor desired intake volume should be driving intake volume design (as noted above).

Panel Response: Cost considerations is outside of the scope of the tool and would be left to the project proponent to analyze. Regarding SSI intake volume design, see previous response.

III. Fatal Flaws – if a site is identified to have a fatal flaw, ocean desalination should not be pursued. Attempting to mitigate a fatal flaw or altering project components should not be a planning/implementation technique. Marine life mortality/impacts, both acute and chronic, are fatal flaws.

Panel Response: Fatal flaws are technology specific. The use of fatal flaws in the model is intended to determine if a SSI technology is viable or not for the specific site.

IV. Regional Specific Parameters – it is important that default parameter scores used in the assessment tool are regionally specific. In our view, a general tool that does not capture regional characteristics will not provide an adequate method/approach to assessing a site's SSI feasibility. Thus, it is critical that the tool be expanded to characterize regional differences in geology, wave action, mixing, beach slope, coastal margin slope, dominant grain size, etc. In addition, allowing users to change parameter scoring can greatly influence a site's SSI feasibility. For example, a user may manipulate parameters which do not accurately represent site-specific in an attempt to deem SSIs infeasible. Because of this, there needs to be a robust and transparent QA/QC process that would ensure any changes to the tool's scoring parameters accurately represent conditions in and around the SSI site.

Panel Response: QA/QC would be responsibility of the user of the model and should be documented. It is possible that project proponents could have the results of their model results reviewed independently.

APPENDIX A: PANEL BACKGROUND

About NWRI

For over 20 years, NWRI – a science-based 501c3 nonprofit located in Fountain Valley, California – has sponsored projects and programs to improve water quality, protect public health and the environment, and create safe, new sources of water. NWRI specializes in working with researchers across the country, such as laboratories at universities and water agencies, and are guided by a Research Advisory Board (representing national expertise in water, wastewater, and water reuse) and a six-member Board of Directors (representing water and wastewater agencies in Southern California).

Through NWRI's research program, NWRI supports multi-disciplinary research projects with partners and collaborators that pertain to treatment and monitoring, water quality assessment, knowledge management, and exploratory research. Altogether, NWRI's research program has produced over 300 publications and conference presentations.

NWRI also promotes better science and technology through extensive outreach and educational activities, which includes facilitating workshops and conferences and publishing White Papers, guidance manuals, and other informational material.

More information on NWRI can be found online at www.nwri-usa.org.

About NWRI Panels

NWRI also specializes in facilitating Independent Advisory Panels on behalf of water and wastewater utilities, as well as local, county, and state government agencies, to provide credible, objective review of scientific studies and projects in the water industry. NWRI Panels consist of academics, industry professionals, government representatives, and independent consultants who are experts in their fields.

The NWRI Panel process provides numerous benefits, including:

- Third-party review and evaluation.
- Scientific and technical advice by leading experts.
- Assistance with challenging scientific questions and regulatory requirements.
- Validation of proposed project objectives.
- Increased credibility with stakeholders and the public.
- Support of sound public-policy decisions.

NWRI has extensive experience in developing, coordinating, facilitating, and managing expert Panels. Efforts include:

- Selecting individuals with the appropriate expertise, background, credibility, and level of commitment to serve as Panel members.

- Facilitating hands-on Panel meetings held at the project's site or location.
- Providing written report(s) prepared by the Panel that focus on findings and recommendations of various technical, scientific, and public health aspects of the project or study.

Over the past 5 years, NWRI has coordinated the efforts of over 20 Panels for water and wastewater utilities, city and state agencies, and consulting firms. Many of these Panels have dealt with projects or policies involving groundwater replenishment and potable (indirect and direct) reuse. Specifically, these Panels have provided peer review of a wide range of scientific and technical areas related water quality and monitoring, constituents of emerging concern, treatment technologies and operations, public health, hydrogeology, water reuse criteria and regulatory requirements, and outreach, among others.

Examples of recent NWRI Panels include:

- **Development of Water Recycling Criteria for Indirect Potable Reuse through Surface Water Augmentation and the Feasibility of Developing Criteria for Direct Potable Reuse** for the State Water Resources control Board Division of Drinking Water (CA)
- **Evaluating Water Quality Testing at the Silicon Valley Advanced Water Purification Center for Future Potable Reuse Applications** for the Santa Clara Valley Water District (CA)
- **Developing Proposed Direct Potable Reuse Operational Procedures and Guidelines for New Mexico** for the New Mexico Environment Department (NM)
- **Monterey Peninsula Groundwater Replenishment Project** for the Monterey Regional Water Pollution Control Agency (CA)
- **Groundwater Recharge Scientific Study** for the LOTT Clean Water Alliance (WA)
- **Groundwater Replenishment System Program Review** for the Orange County Water District (CA)
- **Examining the Criteria for Direct Potable Reuse** for Trussell Technologies (CA) and WateReuse Research Foundation (VA)
- **Evaluating Potable Reuse** for the Santa Clara Valley Water District (CA)
- **Indirect Potable Reuse/Reservoir Augmentation Project Review** for the City of San Diego (CA)
- **BDOC as a Surrogate for Organics Removal in Groundwater Recharge** for the California Department of Public Health (CA)
- **Recycled Water Master Plan** for Tucson Water (AZ)
- **Groundwater Replenishment Project Review** for the Los Angeles Department of Water and Power (CA)

More information about the NWRI Independent Advisory Panel Program can be found on the NWRI website at http://nwri-usa.org/Panels.htm.

APPENDIX B: PANEL BIOGRAPHIES

PANEL CHAIR: Thomas Missimer, Ph.D., P.G.
President, Missimer Hydrological Services, Inc., and
Visiting Professor, Florida Gulf Coast University (Fort Myers, FL)

Thomas Missimer has 40 years of experience in the field of hydrogeology and is a recognized expert in artificial recharge and aquifer storage and recovery. He has managed more than 250 technical projects and is the author of nine books, 80 peer-reviewed articles, and 300 technical consulting reports. He is an editor of a newly released book on SWRO intakes and outfall published by Springer. He currently serves as Executive Editor of *Groundwater*, a technical journal for groundwater hydrogeologists. Missimer co-founded the consulting firm Missimer & Associates, Inc., and helped grow the company's revenues to exceed $25 million per year. Before that, he was Vice President and national practice leader in artificial recharge/aquifer storage and recovery technology for CDM Missimer. He currently holds a courtesy faculty appointment at Florida Gulf Coast University. Missimer's education includes degrees in Geology from Franklin and Marshall College (BA), Florida State University (MS), and University of Miami (PhD). He is a registered Professional Geologist in the states of Florida, Georgia, and Virginia, and holds certifications from the American Institute of Professional Geologists and the National Groundwater Association. He was a past member on a science advisory panel co-convened by the California Coastal Commission and Poseidon Resources that evaluated the technical feasibility of subsurface intakes at Huntington Beach, California (Phase 1) and is currently on a follow-up panel on the same site (Phase 2).

Claudio Fassardi
Senior Principal Engineer
CH2M HILL (Long Beach, CA)

Claudio Fassardi has nearly 30 years of experience in the management and execution of coastal engineering projects. He specializes in planning, field work, analysis and design to support the development of waterfront facilities, analysis of coastal processes, and climate change impact assessment and adaptation. Additionally, Fassardi has expertise in analyzing and developing solutions to natural and anthropogenic impacts to the coastal environment. As the coastal engineering lead, Fassardi was part of a multidisciplinary team that performed a site characterization and feasibility assessment for the planned West Basin Municipal Water District (WBMWD) Desalination Plant in Santa Monica Bay. Fassardi was responsible for evaluating marine conditions and site characterization, and he assisted with evaluating existing intake/discharge infrastructure, reviewing the existing intake and discharge technologies, and selecting the preferred alternatives. He managed a multidisciplinary team of geotechnical and civil engineers, assisted in the development of the intake and discharge conceptual designs, and performed preliminary analysis of brine dispersion.

Heidi Luckenbach, P.E.
Deputy Director/Engineering Manager
City of Santa Cruz Water Department

Heidi Luckenbach is a civil engineer with more than 20 years of experience in water supply planning, drinking water treatment, and distribution. She has worked for the City of Santa Cruz Water Department for 17 years. As Deputy Director, she is responsible for managing engineering services for maintenance, operation, and improvement of the water utility, including long-range water supply planning. Luckenbach previously served as Desalination Program Coordinator for seven years, during which she developed and implemented the work plan for the ***scwd^2 Regional Seawater Desalination Project***. Program elements included a seawater desalination pilot study, evaluation of intake alternatives, analysis of brine dilution, comparison of water supply alternatives, and engagement with regulatory agencies. The 2.5-million gallon per day supplemental water supply would serve several communities in North Santa Cruz County. Luckenbach received her BS in Civil Engineering from California State University, Northridge, and an MS in Environmental Engineering from University of California, Los Angeles. She is a Registered Civil Engineer in California, serves as Vice Chair of the Desalination Committee for the California Nevada Section of American Water Works Association (AWWA), and was recently a board member for the American Membrane Technology Association (AMTA).

Robert Maliva, Ph.D., P.G.
Principal Hydrogeologist
Schlumberger Water Services (Fort Myers, FL)

Robert Maliva has more than 24 years of international research and consulting experience in groundwater resources management, subsurface geology, and fluid flow investigations. Prior to joining Schlumberger Water Services, Maliva was a Principal and Senior Hydrogeologist at CDM, and he held research positions at Harvard University, University of Cambridge, and University of Miami. He specializes in the development of alternative water supplies for municipal and industrial clients and has varied expertise in hydrogeology, including: design and permitting of injection wells; aquifer storage and recovery; managed aquifer recharge systems; stratigraphy and sedimentology; and aqueous geochemical modeling. Maliva has authored or co-authored more than 70 peer-reviewed journal articles and book chapters, and he is the senior author on two books on water management. His education includes degrees in Geology from The State University of New York at Binghamton (BS), Indiana University at Bloomington (MS), and Harvard University (Ph.D.). He is a registered Professional Geologist in the states of Florida and Texas.

APPENDIX C: MEETING #2 AGENDAS

NATIONAL WATER RESEARCH INSTITUTE

Independent Advisory Panel:

West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Study – Guidance Manual Review

(Bureau of Reclamation Project No. R14AP00173)

PUBLIC MEETING #2 – Final Agenda

Tuesday, April 14, 2015

Location	**Contacts:**
Edward C. Little Water Recycling Facility 1935 S. Hughes Way El Segundo, CA (310) 414-0183	**Jeff Mosher (Cell)** 714-705-3722 **Brandi Caskey (NWRI Office)** (714) 378-3278

Meeting Objectives:

- Clarify the Panel's charge and Panel review process.
- Describe the goal and objectives of the Ocean Water Desalination Subsurface Intake Study Guidance Manual.
- Receive public input on this effort and clarify how to provide public comments.

Tuesday, April 14, 2015

9:00 am	Agenda Item #1: Welcome and Introductions • Introductions • Review Agenda • Provide Panel Framework o Charge and Review Process	Jeff Mosher, NWRI
9:30 am	Agenda Item #2: Welcome by West Basin's General Manager	Rich Nagel, West Basin
9:45 am	Agenda Item #3: Feasibility Matrix Overview	Gordon Thrupp, Geosyntec Consultants
10:00 am	Agenda Item #4: Panel Findings and Recommendations from Meeting #1	Thomas Missimer, Panel Chair
10:30 am	Agenda Item #5: West Basin's Response to the Panel's Findings and Recommendations from Meeting	West Basin

	#1	
11:00 am	Agenda Item #6: Public Comment Period	Facilitated by Jeff Mosher, NWRI
12:00 pm	Agenda Item #7: Panel Comment Period	Facilitated by Jeff Mosher, NWRI
12:15 pm	Agenda Item #8: Closing Remarks • How to Provide Comments • Next Steps in Panel Review Process	Jeff Mosher, NWRI
12:30 pm	**ADJOURN**	
12:30 pm – 1:30 pm	Guided Tour of Edward C. Little Water Recycling Facility	
12:30 pm – 4:00 pm	Panel Deliberations	Panel Members

NATIONAL WATER RESEARCH INSTITUTE

Independent Advisory Panel:

West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Study – Guidance Manual Review

(Bureau of Reclamation Project No. R14AP00173)

PANEL MEETING #2 – Final Agenda

Tuesday, April 14, 2015

Location	**Contacts:**
Edward C. Little Water Recycling Facility	**Jeff Mosher (Cell)**
1935 S. Hughes Way	714-705-3722
El Segundo, CA	**Brandi Caskey (NWRI Office)**
(310) 414-0183	(714) 378-3278

Meeting Objectives:

- Provide finding and recommendations on efforts to-date to develop the Ocean Water Desalination Subsurface Intake Study Guidance Manual.
- Provide recommendations on future work and activities.

Tuesday, April 14, 2015

12:30 pm	**WORKING LUNCH**	Panel Members, West Basin, Geosyntec, and Regulators
1:30 pm	CLOSED SESSION • Panel Discussion • Develop Framework for Panel Report • Assignments	Moderated by Thomas Missimer, Panel Chair
2:30 pm	**BREAK**	
2:45 pm	Continue with Closed Session	Moderated by Thomas Missimer
4:00 pm	**ADJOURN**	

APPENDIX D: MEETING #2 ATTENDEES

Panel Members:
- Chair: Thomas M. Missimer, Ph.D., Florida Gulf Coast University (Fort Myers, FL)
- Claudio Fassardi, CH2M HILL (Long Beach, CA)
- Heidi R. Luckenbach, P.E., City of Santa Cruz Water Department (Santa Cruz, CA)
- Robert G. Maliva, Ph.D, P.G., Schlumberger Water Services (Fort Myers, FL)

National Water Research Institute:
- Jeff Mosher, Executive Director
- Gina Vartanian, Communications Manager

West Basin Municipal Water District:
- Diane Gatza
- Eric Owens
- Justin Pickard
- Ron Wildermuth

Geosyntec Consultants:
- Rebecca Batchelder
- Mark Hanna
- Mike Kavanaugh, Ph.D.
- Gordon Thrupp, Ph.D., P.G., CH.G.

Others:
- Bryan Bundy, Calleguas Municipal Water District
- Craig Cadwallader, Surfrider South Bay
- Conner Everts. Desal Response Group
- Gerry Filteau, SPI Engineering
- Joe Geever, Consultant
- Doug McPherson, United States Bureau of Reclamation
- Peter Shellenbarger, Heal the Bay
- Bill Steele, United States Bureau of Reclamation
- Warren Teitz, Metropolitan Water District of Southern California
- Mark Williams, GEOSCIENCE

APPENDIX C-3

NWRI Panel Report of the
November 16, 2015 Meeting (Meeting #3)

NATIONAL WATER RESEARCH INSTITUTE

Draft Final Report

of the November 16, 2015, Meeting (Meeting #3) of the

Independent Advisory Panel

for

West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Study

(Bureau of Reclamation Project No. R14AP00173)

Prepared for:

West Basin Municipal Water District
17140 Avalon Boulevard
Carson, California 90746

Under Contract to:

Geosyntec Consultants
3415 S. Sepulveda Blvd, Suite 500
Los Angeles, CA 90034

November 30, 2015

DISCLAIMER

This report was prepared by a National Water Research Institute (NWRI) Independent Advisory Panel, which is administered by the NWRI. Any opinions, findings, conclusions, or recommendations expressed in this report were prepared by the Panel. This report was published for informational purposes.

ABOUT NWRI

A 501c3 nonprofit organization, the NWRI was founded in 1991 by a group of California water agencies in partnership with the Joan Irvine Smith and Athalie R. Clarke Foundation to promote the protection, maintenance, and restoration of water supplies and to protect public health and improve the environment. NWRI's member agencies include Inland Empire Utilities Agency, Irvine Ranch Water District, Los Angeles Department of Water and Power, Orange County Sanitation District, Orange County Water District, and West Basin Municipal Water District.

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Jeffrey J. Mosher, Executive Director
Gina Melin Vartanian, Editor

Publication Number: NWRI-2015-14

CONTENTS

ACRONYMS

BIG	Beach infiltration gallery
CEM	Coastline Evolution Model
CEQA	California Environmental Quality Act
CPT	Cone penetrometer test
DIG	Deep infiltration gallery
HDD	Horizontal directionally-drilled
ISTAP	Independent Scientific Technical Advisory Panel
MF	Microfiltration
MGD	Million gallons per day
NRC	National Research Center
NTU	Nephelometric turbidity unit
NWRI	National Water Research Institute
SDI	Silt density index
SIG	Seabed infiltration gallery
SLR	Sea level rise
SSI	Subsurface Seawater Intake
SWRO	Surface water reverse osmosis
TWL	Total water level
UF	Ultrafiltration
USACE	U.S. Army Corps of Engineers
USBR	United States Department of Interior, Bureau of Reclamation
WBMWD	West Basin Municipal Water District

1. PURPOSE AND HISTORY OF THE PANEL

In early 2015, NWRI formed an Independent Advisory Panel on behalf of the West Basin Municipal Water District (WBMWD) to provide expert peer review of the technical and scientific aspects of a proposed Subsurface Seawater Intake (SSI) Feasibility Guidance Manual. This review was completed in April 2015, and the Guidance Manual was subsequently used to assess the feasibility of SSIs for a proposed desalination plant in El Segundo, California. The Panel was reconvened in late 2015 to review these efforts and the conclusions made regarding intake feasibility.

1.1 Project Background

The SSI Feasibility Guidance Manual was developed by Geosyntec Consultants, under subcontract to WBMWD, with grant funding from the United States Department of Interior, Bureau of Reclamation (USBR) through USBR Project No. R14AP00173. The Guidance Manual is part of a larger WBMWD project called the "Ocean Water Desalination Subsurface Intake Study."

1.1.1 Project Description

WBMWD initiated the "Ocean Water Desalination Subsurface Intake Study" to investigate full-scale SSI technologies used to collect seawater through the ocean bottom and coastal aquifer sediments. The purpose of the study is to develop a comprehensive, systematic procedure to evaluate the technical feasibility of SSI technologies at a given project site. This project will help the industry by providing utilities/agencies with guidance on SSI technologies during the early planning phases for ocean water desalination projects (particularly in California), as well as aid regulatory agencies and non-governmental organizations by compiling the body of research on SSIs that could be used to evaluate other projects.

1.1.2 Project Scope

The Geosyntec project team used the Guidance Manual for a "Phase 1 Evaluation" of the technical feasibility of SSIs for WBMWD's proposed desalination facility, which will serve as a test case (i.e., beta test) for the application of the Manual. Subsequently, the Geosyntec project team conducted a site-specific investigation and analysis of physical parameters, including onshore stratigraphy and permeability, offshore stratigraphy (to determine the extent and continuity of clay layers), and groundwater modeling ("Phase 2 Evaluation"). The Geosyntec project team also considered other feasibility factors in accordance with the amended Ocean Plan released by the California State Water Resources Control Board in May 2015.

1.1.3 Summary of Project Components

The components of this project are summarized as follows:

- *The "Ocean Water Desalination Subsurface Intake Study."* The Study refers to the entire effort, which includes the development of the SSI Feasibility Guidance Manual and the beta test of the Guidance Manual.

- *Subsurface Seawater Intake (SSI) Feasibility Guidance Manual or "Guidance Manual."* The Guidance Manual was developed by the project team in early 2015. It was then presented at the April 2015 Panel meeting (Meeting #2) and reviewed by the Panel. The Geosyntec project team used the tool for a screening-level (Phase 1) feasibility evaluation of SSIs at the El Segundo site.

- *"Draft Final Report–Feasibility Assessment of Subsurface Seawater Intakes: Proposed Desalination Facility, El Segundo, California."* This report and its associated appendices, prepared by Geosyntec Consultants, were presented during the public portion of the November 2015 Panel meeting (Meeting #3).

1.2 Panel Background

The four-member Panel has convened three times in person at public meetings to review this effort for WBMWD. Background information about the NWRI Panel process can be found in Appendix A.

1.2.1 Panel Members

The Panel is made up of individuals with expertise in the fields of intake and well design, hydrogeology, coastal processes, evaluation of structures and vessels in the marine and coastal environments, development and implementation of alternate water supply projects (such as seawater desalination) at public agencies, and other areas relevant to the study. Panel members include:

- Chair: Thomas M. Missimer, Ph.D., Florida Gulf Coast University (Fort Myers, FL)
- Claudio Fassardi, CH2M (Long Beach, CA)
- Heidi R. Luckenbach, P.E., City of Santa Cruz Water Department (Santa Cruz, CA)
- Robert G. Maliva, Ph.D, P.G., Schlumberger Water Services (Fort Myers, FL)

Brief biographies of the Panel members can be found in Appendix B.

1.2.2 History of Panel Meetings

At Meeting #1 (held on February 26, 2015), the Panel reviewed the initial framework (i.e., assumptions, criteria, etc.) for the Guidance Manual, which consists of a desktop tool for conducting feasibility analyses of SSIs based on site-specific observations or measurements, available data from public or private sources, or assumptions based on engineering judgment or professional experience. The Panel prepared a report with principal findings and recommendations, particularly focusing on the SSI Feasibility Matrix that served as the basis for the Guidance Manual.

At Meeting #2 (held on April 14, 2015), the Panel (1) responded to the Geosyntec project team's comments on the Meeting #1 report and (2) completed their review of the Guidance Manual. The product of this effort was a second Panel report with findings and recommendations. The Geosyntec project team then used the Guidance Manual to assess the feasibility of SSIs for WBMWD's proposed desalination plant at the NRG Facility in El Segundo, California.

The Panel reconvened at Meeting #3 (held on November 16, 2015) to review additional testing and analyses conducted by the Geosyntec project team to assess the feasibility of the different SSI technologies, including a pilot of the proposed desalination project site in El Segundo. As part of this meeting, the Panel reviewed the *Draft Final Report–Feasibility Assessment of Subsurface Seawater Intakes: Proposed Desalination Facility, El Segundo, California (dated November 9, 2015)*, prepared by Geosyntec Consultants.

2. PANEL MEETING #3

The Panel met in person on November 16, 2015, at WBMWD's Edward C. Little Water Recycling Facility in El Segundo, California. It was the third meeting of the Panel. The purpose of Meeting #3 was twofold: (1) review the *Draft Final Report - Feasibility Assessment of Subsurface Seawater Intakes*, and (2) address questions from WBMWD and the Geosyntec project team. A portion of this meeting was open to the public for comment. Written comments from the public were accepted for two weeks after the meeting.

2.1 Panel Charge for Meeting #3

For Meeting #3, the Panel was charged with reviewing the *Draft Final Report–Feasibility Assessment of Subsurface Seawater Intakes* and providing comments on the following topics:

- General Screening Process.
- Hydrogeological Setting.
- Evaluation Criteria.
- Evaluation of SSI Technologies.

2.2 Background Materials

The following materials were provided electronically to the Panel in advance of Meeting #3:

- *Draft Final Report–Feasibility Assessment of Subsurface Seawater Intakes: Proposed Desalination Facility, El Segundo, California (dated November 9, 2015)* (107-page report prepared by Geosyntec Consultants).
    - *Appendix A: Subsurface Seawater Intake Feasibility Screening Tool (dated October 26, 2015)* (2-page table prepared by Geosyntec Consultants).
    - *Appendix B: Review of Existing Data and Proposed Site-Specific Investigations to Assess Feasibility of Horizontal Well Intakes (dated July 30, 2015)* (37-page memorandum from Geosyntec to WBMWD with attachments).
    - *Appendix C: Particle Size Distribution Report (dated July 30, 2015)* (2-page report prepared Cooper Testing Laboratory).
    - *Appendix D: Technical Memorandum on West Basin Case Study Hydraulic Conductivity Field Testing Summary (dated October 8, 2015)* (20-page report prepared by Geosyntec).
    - *Appendix E: Offshore Seismic Reflection Survey (dated September 10, 2015)* (46-page technical memorandum from Sea Engineering, Inc., to Geosyntec).
    - *Appendix F: Groundwater Flow Model for Proposed El Segundo Desalination Facility (dated November 4, 2015)* (20-page memo report prepared by Geosyntec).
    - *Appendix G: Coastal Processes and Seafloor Stability Analysis of Shallow Sub-Seabed Intake Systems for the West Basin Municipal Water District Sea Water*

Desalination Project (dated September 29, 2015) (100-page report prepared by Michael Baker International for WBMWD).

In addition, these materials were posted for public access in advance on of Meeting #3 on the project webpage at: www.nwri-usa.org/subsurface-intake-panel.htm#secondmeeting.

2.3 Meeting Agenda

The Panel meeting was divided into two sessions: the first session (from 9:30 am to 12:00 noon) was open to the public; the second session (from 12:00 noon to 4:00 pm) was a closed working session for Panel members and Geosyntec staff only. Members of NWRI staff, WBMWD staff, and the Geosyntec project team collaborated to develop the agendas for the two sessions (Appendix C).

The public meeting was intended to meet the following objectives:

- Clarify the Panel's charge and Panel review process.
- Describe the goals, objectives, and conclusions of the Ocean Water Desalination Subsurface Intake (SSI) Feasibility Study.
- Review the *Draft Final Report–Feasibility Assessment of Subsurface Seawater Intakes: Proposed Desalination Facility, El Segundo, California (dated November 9, 2015).*
- Receive public input on this effort and clarify how to provide public comments.

Most of the public session was devoted to presentations on the feasibility analysis of different SSI options. Presentations included:

- "Overview of Ocean Water Desalination Subsurface Intake Study," presented by Diane Gatza, Ocean Desalination Project Manager, West Basin Municipal Water District.
- "Feasibility Study of Subsurface Seawater Intakes West Basin Municipal Water District's Proposed El Segundo Desalination Facility," presented by Al Preston, Gordon Thrupp, and Mike Kavanaugh, Geosyntec Consultants.

Time was provided during the public meeting for the Panel to ask questions and engage in discussions with WBMWD staff and members of the Geosyntec project team. In addition, time was allotted for members of the public to provide written and oral comments on the presentations and on the *Draft Final Report - Feasibility Assessment of Subsurface Seawater Intakes*.

During the closed portion of the meeting, the Panel met with WBMWD staff and the Geosyntec project team to further discuss and/or clarify information shared at Meeting #3. The Panel then met in a closed (Panel-only) session to prepare an outline of findings and recommendations, which were elaborated upon and presented in this report.

2.4 Meeting Attendees

All Panel members attended this meeting in person. Other attendees included NWRI staff, WBMWD staff, Geosyntec staff, and members of the public. A complete list of meeting attendees is provided in Appendix D.

3. FINDINGS AND RECOMMENDATIONS

The findings and recommendations provided below are focused on *the Draft Final Report–Feasibility Assessment of Subsurface Seawater Intakes: Proposed Desalination Facility, El Segundo, California,* and on material presented and discussed during the meeting. The findings and recommendations are organized under the following categories:

- Panel Comments
  - General
  - General Screening Process
  - Hydrogeological Setting
  - Evaluation Criteria
  - Evaluation of SSI Technologies

- Public Comments

3.1 Panel Comments

The Panel's findings and recommendations regarding the *Draft Final Report–Feasibility Assessment of Subsurface Seawater Intakes: Proposed Desalination Facility, El Segundo, California (dated November 9, 2015)* are provided in this section.

3.1.1 General

The Panel commends WBMWD and the Geosyntec project team on the thoroughness and completeness of the draft report. The Panel found the draft report to be well-written, and the project team should be commended for making the reported data accessible to the reader. The Panel had the following general recommendations:

- It would be useful to define the terms "risk" and "risky" in the context of this report as these terms pertain to the evaluation of the feasibility of the specific SSI options. Specifically, the risk may relate to economic conditions, technical conditions, or both.

- Enhance the narrative about the other potential project sites in the 8-mile area of study (i.e., there are potential sites both north and south of the NRG facility). The draft report should convey that the results from the site near the NRG facility will be similar to the sites north and south of the facility.

- Add a discussion as to how you would address the Ocean Plan's requirement of looking at smaller facilities that can function using SSIs.

- Provide context to help the reader understand the work of the Independent Scientific Technical Advisory Panel (ISTAP) organized by the California Coastal Commission and Poseidon Resources referenced in several locations in the Final Report. For instance, the project team used ISTAP to draw inferences, but not direct conclusions. It should be emphasized that the WBMWD investigation is independent of ISTAP and that feasibility conclusions for both projects are site-specific.

- Explain the Level 1 and Level 2 evaluations in context of the terminology used in the Guidance Manual. Explain the use of these evaluations for the NRG site study.

- It would be useful to include the specific sections of the Ocean Plan that apply to this report in an appendix (exact language). Readers would be able to review the Ocean Plan provisions as they may apply to this report.

3.1.2 General Screening Process

- In Section 2.1, the inputs for the screening process are useful. Listing the specific inputs provides transparency and context for the study and the review of the results.

- In Section 2.2, Table 2.1 would benefit from the following changes and/or additions:

    - Show how the information in Table 2.1 was derived. This information could be summarized in the text or provided in an appendix. Along those lines, provide a description of the rationale that justifies the values reported in Table 2.1.

    - Add information on the scoring process in Appendix A. Consideration should be given to adding a table that shows the scores given for each option for each criteria.

    - Describe what the table means in terms of moving these technologies forward for analysis.

    - Provide rationale for not eliminating any of the technologies based on the screening results (i.e., none of the options had a fatal flaw?).

    - Reconsider keeping the "contribution" component of Table 2.1. It is not clear what this level of detail provides. It is probably useful just to list the categories (i.e., construction, operation [intake], operation [treatment], potential inland interference, and risk) in a footnote or in the text.

    - Consider using a qualitative approach for listing the results of the Level 1 analysis (i.e., "feasible" or "not feasible"; however, they were all considered feasible as of this point). Or, downplay the significance of the scores relative to the different SSI technologies. The Panel did not see much difference among the six technical options other than perhaps that a Beach Infiltration Gallery (BIG) appears to be significantly less likely to be feasible than other options.

    - Change "reason for infeasibility" to "fatal flaw," and then enter "no" for all options. Currently, these boxes are blank. Stating "no" to fatal flaws provides information to the reader.

  - Appendix A qualifies the quality of the data used for input; however, its use is not apparent in the report. The Panel suggests that the project team describes how the uncertainty of data quality informs decision making, how the quality of the data affects the certainty of the results in Table 2.1, and how it provides justification and guidance for the field investigations and studies that were performed.

- In Section 2.3, Table 2.2 is useful, but needs editing. Change the title of the table to eliminate "footprint." For horizontally directional drilled wells, the offshore area should be "not applicable" (N/A) and not "1.6 million square feet."

3.1.3 Hydrogeological Setting

The Panel believes the hydrogeological investigation was thorough and comprehensive, and offers the following recommendation:

- In Figure 3.6, discuss the error of the cone penetrometer test (CPT) hydraulic conductivity measurements. It is understood that the CPT data captures trends in the data, but may be inaccurate as to absolute values. This information would help in the review of this figure.

3.1.4 Evaluation Criteria

The Panel believes the evaluation was thorough and comprehensive, and offers the following recommendations:

- In Section 4.2.1, regarding sea level rise (SLR), use the National Research Council's 2012 report for sea level rise values.[1] Make a reference to the design life of the facility to justify the term and estimates used.

- In Figures 4.7 and 4.8 of Appendix G, review the beach profiles used in the analysis and the estimated depth of closure, as well as use more current beach profiles. The beach profiles used in the analysis diverge as they move farther from shore. Typically, beach profiles converge, or show a tendency to converge, to locate the depth of closure. It is neither obvious nor justified – other than mentioning that the Coastline Evolution Model (CEM) model was used – how these diverging profiles would converge, as shown in Figures ES-1 and ES-3 of Appendix G, to the predicted depths of closure. As part of a permit requirement, NRG has been measuring beach profiles at El Segundo since 2011, along 15 transects to about 40 to 43-foot water depth. The use of these profiles is

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[1] National Research Council (2012). *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future.* Committee on Sea Level Rise in California, Oregon, and Washington; Board on Earth Sciences and Resources; Ocean Studies Board; Division on Earth and Life Studies; National Research Council. National Academies Press, Washington, DC.

recommended in the reanalysis of the profiles used and in the estimation of the depth of closure at the NRG site.

3.1.5 Evaluation of SSI Technologies

- General:
  - The Panel generally agrees with the conclusions about feasibility; however, the rationale for the conclusions needs to be clearly stated and supported within the results developed in this study. Having clear reasoning will address potential questions by the public and regulators.
  - The report states that SSIs are not common, but SSIs are commonly used in low- to medium-capacity surface water reserve osmosis (SRWO) plants (up to 5 million gallons per day [MGD]).

- Vertical Wells:
  - Eliminate the statement in the conclusions that seawater feeding wells in Sur, Oman (Arabian Sea), have very low Silt Density Indexes (SDIs). The Panel has information to suggest otherwise.

- Slant Wells:
  - Add a statement on water quality issues related to concerns with oxidation and reduction (redox) chemistry and iron and manganese concentrations.

- Radial Collector Wells:
  - Add a statement on the redox water quality issue. There would be oxygen in the well in contact with the anoxic water that could cause issues with the precipitation of elemental sulfur.

- Horizontal Directionally-Drilled (HDD) Wells (also called drains):
  - Add a statement on water quality issues and on maintenance requirements.
  - Discuss the constructability issues of HDD with less than 20-feet depth below the seafloor.
  - The shallow Dune Aquifer may have favorable conditions, particularly a high hydraulic conductivity, which might allow for relatively high well capacities.

- Seabed Infiltration Gallery (SIG):
  - The report says this technology has a high degree of environmental impact, but the Coastal Commission says that the impact of construction is inconsequential; however, every site is different.

- Beach Infiltration Gallery (BIG)
  - Add a statement about the schedule of beach nourishment by the U.S. Army Corps of Engineers (USACE). The need for nourishment may inhibit construction and long-term operation of the project.

- Deep Infiltration Gallery (DIG)

  - There is a misstatement in the report that the tunnel in Spain intersected the karst conduits (Note: it was the HDD constructed intake that likely did this).

3.2 Public Comments

The following comments were provided by members of the public. The Panel addressed each comment below.

- Arthur Pugsley of Los Angeles Waterkeeper asked if the Geosyntec project team considered the feasibility of either removing or perforating the clayey layers to improve hydraulic connection with the ocean. He also asked if the layer(s) were removed, how many of the technologies now considered infeasible could be made feasible.

  Panel Response: It would not be possible or practical to remove the clay confining unit. It would create major environmental impacts and would be extremely expensive if it were possible.

- Jeremy Crutchfield of San Diego County Water Authority said that the infiltration galleries were dismissed because of the high-energy coastal environment and the high cost. He asked (a) are these reasons adequate for the regulatory community and (b) how do you think the environmental community will respond?

  Panel Response: The high cost of the offshore galleries is a major factor in the analysis. Also, the lengthy and difficult construction period (5 to 7 years) would have considerable impacts on shoreline businesses and roads (long-term traffic issue). It is not possible to assess the reaction of the environmental community and regulators without having a specific design to assess. A BIG is not feasible due to great difficulties in construction in a high-energy surface zone and associated costs. A SIG may be technically feasible, but would also likely be cost-prohibitive. The Ocean Plan states that economics is a feasibility factor and, therefore, their high cost should be adequate for the regulatory community. The environmental community is diverse and their responses will vary. Some groups are opposed to desalination regardless of intake type.

- Dr. Kiran R. Magiawala, a community member participating as a private citizen, submitted the following comment in writing: Is there a plan to evaluate mitigation measures for incidental intake (e.g., hatchery integration as one option – see sketch on the reverse of comment card).

  Panel Response: There is no specific mitigation plan existing at this time, but mitigation has been accomplished at the Carlsbad site in San Diego, California. The concept of the linkage with a hatchery to produce ichthioplankton and fish eggs should be explored in the future as a means of mitigation. All feasible mitigation options, as necessary, would be considered for an intake option.

- Henry C. Hunt, a hydrogeologist with Ranney Collector Wells of Columbus, Ohio, submitted the following written comments regarding Section 3.8 (Public Comments) of the Panel report based on Meeting #1:

  My comments are in relation to inaccurate comments provided in the March 20, 2015, Draft Final Report of the February 26, 2015 meeting (Meeting #1) of the Independent Advisory Panel. The comments, in particular, were made by Mark Williams, Ph.D., P.E. of GEOSCIENCE Support Services, Inc. They were made under the category of Significant Challenges: Construction:

  "3. Ranney-type collector wells have lateral lengths typically limited to approximately 46 meters or less. They also may draw a high percentage of recharge from inland supplies and require construction of a large diameter caisson, which is visually offensive in a beach environment."

  He stated that the lateral lengths in collector wells are limited to 46 meters or less. In actuality, lateral well screen lengths typically range between 200-300 feet (60-90 meters) using standardized projection techniques for a given collector well. These can be installed as natural-pack (e.g., wire-wrapped continuous slot or other design) well screens or as gravel-packed well screens.

  For a recent project in Florida, a collector well in a coastal carbonate aquifer was designed to include lateral well screens that would extend 180 to over 200 meters using a variation on the typical well screen projection technology.

  He stated that collector wells draw a high percentage of their water from inland supplies. I think any well (vertical, slant, or collector well) will obtain a certain percentage of inland water if radial flow to the well occurs. Collector wells have been built using laterals that are screened in the outer (distal) portion of the well screen and projected in a pattern preferential to the intended source of recharge to skew that percentage away from inland sources and toward the intended recharge source (rivers, streams, seawater, etc.). This, in effect, pushes the "pumping center" away from inland sources. In many riverbank filtration sites, the lateral well screens are able to develop raw water supplies of up to 80, 90, 95 percent coming from the source (surface) water, not from the inland side. It may be possible to utilize dedicated lateral well screens projected toward the landward direction to obtain inland water and return this to use inland (e.g., in aquifer storage and recovery programs) using a manifold isolation/pumping system.

  He stated that the collector well has a large diameter caisson that would be offensive to a beach environment. Collector well caissons have been constructed in public places such as on a beach (CA) or other public area with the caisson constructed at or below grade to lessen the visual impacts to the environment. This below-grade completion would be very similar to any kind of subsurface vault constructed to accept the slant well discharge pipes, vertical well vaults, or any kind of pumping station for offshore infiltration galleries that would be constructed within coastal areas. The caisson would also facilitate access to the well screens to permit future well maintenance that would be required. If the completion of slant wells can be done below grade, a below-grade completion of a collector well can be made as well.

Thank you for the opportunity to update this information to prevent misconception of this potential alternative for future water supply projects.

Panel Response: WBMWD and the Project Team should consider this comment.

APPENDIX A: PANEL BACKGROUND

About NWRI

For more than 20 years, NWRI – a science-based 501c3 nonprofit located in Fountain Valley, California – has sponsored projects and programs to improve water quality, protect public health and the environment, and create safe, new sources of water. NWRI specializes in working with researchers across the country, such as laboratories at universities and water agencies, and are guided by a Research Advisory Board (representing national expertise in water, wastewater, and water reuse) and a six-member Board of Directors (representing water and wastewater agencies in Southern California).

Through NWRI's research program, NWRI supports multi-disciplinary research projects with partners and collaborators that pertain to treatment and monitoring, water quality assessment, knowledge management, and exploratory research. Altogether, NWRI's research program has produced more than 300 publications and conference presentations.

NWRI also promotes better science and technology through extensive outreach and educational activities, which includes facilitating workshops and conferences and publishing White Papers, guidance manuals, and other informational material.

More information on NWRI can be found online at www.nwri-usa.org.

About NWRI Panels

NWRI also specializes in facilitating Independent Advisory Panels on behalf of water and wastewater utilities, as well as local, county, and state government agencies, to provide credible, objective review of scientific studies and projects in the water industry. NWRI Panels consist of academics, industry professionals, government representatives, and independent consultants who are experts in their fields.

The NWRI Panel process provides numerous benefits, including:

- Third-party review and evaluation.
- Scientific and technical advice by leading experts.
- Assistance with challenging scientific questions and regulatory requirements.
- Validation of proposed project objectives.
- Increased credibility with stakeholders and the public.
- Support of sound public-policy decisions.

NWRI has extensive experience in developing, coordinating, facilitating, and managing expert Panels. Efforts include the following:

- Selecting individuals with the appropriate expertise, background, credibility, and level of commitment to serve as Panel members.

- Facilitating hands-on Panel meetings held at the project's site or location.
- Providing written report(s) prepared by the Panel that focus on findings and recommendations of various technical, scientific, and public health aspects of the project or study.

Over the past 5 years, NWRI has coordinated the efforts of over 20 Panels for water and wastewater utilities, city and state agencies, and consulting firms. Many of these Panels have dealt with projects or policies involving groundwater replenishment and potable (indirect and direct) reuse. Specifically, these Panels have provided peer review of a wide range of scientific and technical areas related water quality and monitoring, constituents of emerging concern, treatment technologies and operations, public health, hydrogeology, water reuse criteria and regulatory requirements, and outreach, among others.

More information about the NWRI Independent Advisory Panel Program can be found on the NWRI website at http://nwri-usa.org/Panels.htm.

APPENDIX B: PANEL MEMBER BIOGRAPHIES

PANEL CHAIR: Thomas Missimer, Ph.D., P.G.
President, Missimer Hydrological Services, Inc., and
Visiting Professor, Florida Gulf Coast University (Fort Myers, FL)

Thomas Missimer has more than 40 years of experience in the field of hydrogeology and is a recognized expert in artificial recharge and aquifer storage and recovery. He has managed more than 250 technical projects and is the author of nine books, 80 peer-reviewed articles, and 300 technical consulting reports. He is an editor of a newly released book on SWRO intakes and outfall published by Springer. He currently serves as Executive Editor of *Groundwater*, a technical journal for groundwater hydrogeologists. Missimer co-founded the consulting firm Missimer & Associates, Inc., and helped grow the company's revenues to exceed $25 million per year. After that, he founded another company that was purchased by CDM and was Vice President and national practice leader in artificial recharge/aquifer storage and recovery technology for CDM. He currently holds a courtesy faculty appointment at Florida Gulf Coast University. Missimer's education includes degrees in Geology from Franklin and Marshall College (BA), Florida State University (MS), and University of Miami (PhD). He is a registered Professional Geologist in the states of Florida, Georgia, and Virginia, and holds certifications from the American Institute of Professional Geologists and the National Groundwater Association. He was a past member on a science advisory panel co-convened by the California Coastal Commission and Poseidon Resources that evaluated the technical feasibility of subsurface intakes at Huntington Beach, California (Phase 1) and is currently on a follow-up panel on the same site (Phase 2).

Claudio Fassardi
Senior Principal Engineer
CH2M (Long Beach, CA)

Claudio Fassardi has nearly 30 years of experience in the management and execution of coastal engineering projects. He specializes in planning, field work, analysis and design to support the development of waterfront facilities, analysis of coastal processes, and climate change impact assessment and adaptation. Additionally, Fassardi has expertise in analyzing and developing solutions to natural and anthropogenic impacts to the coastal environment. As the coastal engineering lead, Fassardi was part of a multidisciplinary team that performed a site characterization and feasibility assessment for the planned West Basin Municipal Water District (WBMWD) Desalination Plant in Santa Monica Bay. Fassardi was responsible for evaluating marine conditions and site characterization, and he assisted with evaluating existing intake/discharge infrastructure, reviewing the existing intake and discharge technologies, and selecting the preferred alternatives. He managed a multidisciplinary team of geotechnical and civil engineers, assisted in the development of the intake and discharge conceptual designs, and performed preliminary analysis of brine dispersion.

Heidi Luckenbach, P.E.
Deputy Director/Engineering Manager
City of Santa Cruz Water Department

Heidi Luckenbach is a civil engineer with more than 20 years of experience in water supply planning, drinking water treatment, and distribution. She has worked for the City of Santa Cruz Water Department for 17 years. As Deputy Director, she is responsible for managing engineering services for maintenance, operation, and improvement of the water utility, including long-range water supply planning. Luckenbach previously served as Desalination Program Coordinator for seven years, during which she developed and implemented the work plan for the ***scwd^2 Regional Seawater Desalination Project***. Program elements included a seawater desalination pilot study, evaluation of intake alternatives, analysis of brine dilution, comparison of water supply alternatives, and engagement with regulatory agencies. The 2.5-million gallon per day supplemental water supply would serve several communities in North Santa Cruz County. Luckenbach received her BS in Civil Engineering from California State University, Northridge, and an MS in Environmental Engineering from University of California, Los Angeles. She is a Registered Civil Engineer in California, serves as Vice Chair of the Desalination Committee for the California Nevada Section of American Water Works Association (AWWA), and was recently a board member for the American Membrane Technology Association (AMTA).

Robert Maliva, Ph.D., P.G.
Principal Hydrogeologist
Schlumberger Water Services (Fort Myers, FL)

Robert Maliva has more than 24 years of international research and consulting experience in groundwater resources management, subsurface geology, and fluid flow investigations. Prior to joining Schlumberger Water Services, Maliva was a Principal and Senior Hydrogeologist at CDM, and he held research positions at Harvard University, University of Cambridge, and University of Miami. He specializes in the development of alternative water supplies for municipal and industrial clients and has varied expertise in hydrogeology, including: design and permitting of injection wells; aquifer storage and recovery; managed aquifer recharge systems; stratigraphy and sedimentology; and aqueous geochemical modeling. Maliva has authored or co-authored more than 70 peer-reviewed journal articles and book chapters, and he is the senior author on two books on water management. His education includes degrees in Geology from The State University of New York at Binghamton (BS), Indiana University at Bloomington (MS), and Harvard University (Ph.D.). He is a registered Professional Geologist in the states of Florida and Texas.

APPENDIX C: MEETING #3 AGENDAS

NATIONAL WATER RESEARCH INSTITUTE

Independent Advisory Panel

West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Feasibility Study

(Bureau of Reclamation Project No. R14AP00173)

PEER REVIEW PUBLIC MEETING

9:30 AM - NOON

Monday, November 16, 2015

Location	**Contacts:**
Edward C. Little Water Recycling Facility 1935 S. Hughes Way El Segundo, CA (310) 414-0183	**Jeff Mosher, NWRI** 714-705-3722 (cell) **Jaime Lumia, NWRI** (714) 378-3278 (office) jlumia@nwri-usa.org

Meeting Objectives:

- Clarify the Panel's charge and Panel review process.
- Describe the goals, objectives, and conclusions of the Ocean Water Desalination Subsurface Intake (SSI) Feasibility Study.
- Receive public input on this effort and clarify how to provide public comments.

9:30 am	Agenda Item #1: Welcome and Introductions • Introductions • Panel Charge and Review Process • Review Agenda	Jeff Mosher, National Water Research Institute (NWRI)
9:45 am	Agenda Item #2: Recap of the Ocean Water Desalination Subsurface Intake (SSI) Study	Diane Gatza, West Basin
10:00 am	Agenda Item #3: Ocean Water Desalination SSI Feasibility Study • Overview of SSI Technology • Feasibility • Hydrogeologic Setting and Field Testing • Evaluation of SSIs	Geosyntec Consultants Al Preston Mike Kavanaugh Gordon Thrupp
11:30 am	Agenda Item #4: Public Comment Period	Facilitated by Jeff Mosher, NWRI

11:55 am	Agenda Item #5: Closing Remarks • How to Provide Comments • Next Steps in Panel Review Process	Jeff Mosher, NWRI
12:00 noon	**ADJOURN PUBLIC MEETING**	
12:00 noon – 1:00 pm	Guided Tour of Edward C. Little Water Recycling Facility. **Members of the public are invited to participate.**	
12:00 pm – 4:00 pm	Closed Meeting: Panel Deliberations	Panel Members

NATIONAL WATER RESEARCH INSTITUTE

Independent Advisory Panel

West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Feasibility Study

(Bureau of Reclamation Project No. R14AP00173)

Agenda
PANEL MEETING
Monday, November 16, 2015

Location
Edward C. Little Water Recycling Facility
1935 S. Hughes Way
El Segundo, CA
(310) 414-0183

Contacts:
Jeff Mosher, NWRI
714-705-3722 (cell)
Jaime Lumia (NWRI)
(714) 378-3278 (office)
jlumia@nwri-usa.org

Meeting Objectives:
- Provide finding and recommendations on efforts to-date to develop the Ocean Water Desalination Subsurface Intake Study Guidance Manual.
- Provide recommendations on future work and activities.

Monday, November 16, 2015

12:00 noon	**WORKING LUNCH**	Panel Members, West Basin, Geosyntec, and Regulators
1:00 pm	CLOSED SESSION • Panel Discussion • Develop Framework for Panel Report • Assignments	Moderated by Thomas Missimer, Panel Chair
2:00 pm	**BREAK**	
2:15 pm	Continue with Closed Session	Moderated by Thomas Missimer
3:30 pm	Debrief session with Geosyntec	
4:00 pm	**ADJOURN**	

APPENDIX D: MEETING #3 ATTENDEES

Panel Members:

- Chair: Thomas M. Missimer, Ph.D., Florida Gulf Coast University (Fort Myers, FL)
- Claudio Fassardi, CH2M (Long Beach, CA)
- Heidi R. Luckenbach, P.E., City of Santa Cruz Water Department (Santa Cruz, CA)
- Robert G. Maliva, Ph.D, P.G., Schlumberger Water Services (Fort Myers, FL)

National Water Research Institute:

- Jeff Mosher, Executive Director
- Suzanne Faubl, Water Resources Scientist and Project Manager

West Basin Municipal Water District:

- Diane Gatza
- Eric Owens
- Justin Pickard
- Ron Wildermuth

Geosyntec Consultants:

- Mike Kavanaugh, Ph.D.
- Al Preston, Ph.D., P.E.
- Gordon Thrupp, Ph.D., P.G., CH.G.

Others:

- Bryan Bondy, Calleguas Municipal Water District
- Craig Cadwallader, Surfrider Foundation, South Bay Chapter
- Jeremy Crutchfield, San Diego County Water Authority
- Saied Delagah, United States Bureau of Reclamation
- Tom Ford, The Bay Foundation
- Mark Hanna, Geosyntec
- Rita Kampalath, Heal the Bay
- Kiran Magiawala, Community Member
- Arthur Pugsley, LA Waterkeeper
- George Reppogg, Resident (Manhattan Beach)
- Pat Stahl, Resident
- Stan Williams, Poseidon Water

APPENDIX D
Response to Comments

APPENDIX D-1

Response to Comments in the NWRI Panel Report of the February 26, 2015 Meeting
(Meeting #1)

Response to comments from the NWRI Draft Final Report of the February 26, 2015, Meeting (Meeting #1) of the Independent Advisory Panel for West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Study – Guidance Manual Review

In 2015, National Water Research Institute (NWRI) formed an Independent Advisory Panel (Panel) on behalf of the West Basin Municipal Water District (WBMWD) to provide expert peer review of the technical and scientific aspects of a DRAFT Subsurface Seawater Intake (SSI) Feasibility Guidance Manual (Manual), which was developed by Geosyntec Consultants, under contract to WBMWD, with grant funding from the United States Department of Interior, Bureau of Reclamation (USBR) under USBR Project No. R14AP00173. The Guidance Manual is also a part of a larger WBMWD study, the "Ocean Water Desalination Subsurface Intake Study." The Panel issued a draft report on March 20, 2015 which included a number of comments on the Draft Manual. Geosyntec and WBMWD have reviewed the comments and will be making changes to Manual to reflect the expert opinions of the Panel members. The table below summaries the comments provided by the Panel in their draft report as well as the planned approach to incorporating the comments into the Manual.

#	Panel Comment	Response to Comment
1	The Panel recognizes WBMWD and Geosyntec for their effort in preparing for the meeting. The Panel appreciates the level of organization and information provided for the Panel to conducts its review.	Noted
2	The meeting presentations were informative and helpful in conducting this Panel review (with public input) of the Guidance Manual framework.	Noted
3	WBMWD needs to be clear as to the purpose and users of the Guidance Manual (as well as be clear in the documentation as they develop this manual). • Although the Guidance Manual is geared towards California, will it be general enough to use in other regions? • A statement is needed as to how it should be used, who should use it (i.e., the technical backgrounds of users), and what level of effort is required. • Be clear that the Guidance Manual framework is a cursory feasibility analysis performed with a desktop tool with limited information. It is a tool to provide guidance as to which options may be most appropriate for a given site. It is not a final determination. • Use of the Guidance Manual will standardize SSI evaluations in terms of consistency in SSIs evaluated and the evaluation criteria used. • The Guidance Manual is a tool to demonstrate that all SSI technologies have been considered and those eliminated had justification for being eliminated.	Explanation about intended user and purpose of tool will be added. The guidance tool is based on CEQA definition of feasibility. Information will be added in the tool and the final guidance document to explain that if it is used in a different state or country, the feasibility definition and regulatory requirements might be different. Discussion of how these requirements may vary will be included in the final guidance manual.
4	The Panel suggests that including practical issues (e.g., beach stability) in the Guidance Manual is important. In addition, input parameters should be data that could be obtained through a literature and database review and site inspection.	Noted
5	The intake type is linked to economics (i.e., to the cost of the project and the cost of water to consumers). • Describe in the Guidance Manual that proponents should recognize that economic, environmental, social, and regulatory issues should also be factored into the decision-making process, perhaps not at Level 1, but at subsequent levels. • Proponents should consider conducting an initial feasibility analysis (i.e., this Guidance Manual) followed by an economic and regulatory and environmental impact analysis to assess the full feasibility of each SSI and whether or not a given option might face insurmountable regulatory challenges. • Please refer to the modified flowchart in Appendix E.	Agreed that the user may consider doing economic/env/social/reg feasibility analysis before levels 2 and 3. In some cases, the user may decide to conduct levels 2 and/or 3 investigation before the other analyses, depending on specific circumstances. This should be at the discretion of the user. The flow chart will be updated to reflect this option.
6	The issue of risk of pursuing SSI options with limited experience is important. There is a need for pilot projects of different SSIs to reduce this risk and increase knowledge and confidence.	Agreed. Levels 2 and 3 can include pilot testing.
7	The Panel suggests that the Guidance Manual could be beta tested on one or more existing facilities as a validation of the Guidance Manual. The tool could show that the technology used for an existing facility selected is ranked high, but not necessarily the highest.	The matrix will be beta tested by applying it to West Basin's potential desalination site.
8	If the Guidance Manual is beta tested with existing facilities, the results could be used to validate the "weightings" addressed in Section 3.2.	Noted
9	The definition for "feasibility" is derived from the feasibility criteria established by the California Coastal Commission (Seawater Desalination and the California Coastal Act, 2004). Is this definition consistent with the use of the tool for other regions outside of California?	See response to comment #2.
10	The Panel has the following recommendations on terminology: • The title of the project of the study is mentioned as: "Ocean Water Desalination Subsurface Intake Study Guidance." Consider the title: "Seawater Subsurface Intake (SSI) Feasibility Guidance Manual." • WBMWD and the project team need to be consistent in using a consistent phrase such as "subsurface seawater intake" and not other variations. • The Panel suggests that description "Subsurface Seawater Intake (SSI) Feasibility Matrix" may be a better phrase than "Screening Framework" when describing the Matrix.	Recommended terminology will be adopted (subsurface seawater intake)

#	Panel Comment	Response to Comment
11	An explanation is needed of the weights that are included in the final version of the Guidance Manual, including a description of the methodology and justification of the individual weights.	A narrative explanation of the weights will be provided in the final guidance manual.
12	A weighting based on Southern California or California needs may not be as applicable to users in other regions. If it is to be a more general tool, then the basis for weighting needs to be general (e.g., eliminate California Environmental Quality Act [CEQA] definitions).	CEQA references will be removed (see later comments).
13	Weights should be fixed by the Guidance Manual and should not allow the user to manipulate the numbers. Validating the weights based on a review of existing facilities would be a benefit if they are fixed. However, there could be an option to override the default weights if the user has more specific information. Users of the Guidance Manual may not understand, agree with, or actually disagree with the weights; therefore, the value of the tool may be diminished. WBMWD should consider this as a potential devaluing of the overall exercise and consider either a robust explanation of weights (as described above), or the ability of the user to change the weights after using the tool with "recommended weighting based on professional experience."	The matrix will have default weighting, but the user may change the weights if they have reason to do so. This will not affect the fatal flaw analysis, but will allow the user to customize the challenge section based on their understanding of their site. However, a note will be included that states that only the default weights have been peer reviewed, and therefore the results that come from altered weights are not based on peer reviewed information.
14	The Panel suggests qualifying the user input by adjusting weights on the basis of the input source. A risk factor would be assigned to the inputs, which in turn would be used to adjust the corresponding weights. For example, if the input is derived from a site-specific measurement or an observation, the input would be considered as high quality, if derived from regional estimates, literature review, and so on. The input would be considered of medium quality, and if the input is based on assumptions, anecdotal evidence, or any unsupported source, then the input would be considered of low quality. Also, uncertainly in the available data contributes to risk/uncertainty. The weightings could be adjusted based on the following assessment: • High quality input = low risk. • Medium quality input = medium risk. • Low quality input = high risk. The user would need to specify the source of the input, and the tool would perform the background calculation. It would be useful at the end, when the scores are displayed, to show the level of uncertainty that was factored in the scores of the SSIs. This element could provide guidance into what investigations need to be performed to remove uncertainty.	The option to rate quality of data and inputs (low, medium and high) will be added. This will allow the user to indicate the certainty of the data, and the results will include flags highlighting uncertain data.
15	Instead of providing a list of parameters, it may be possible to describe these items with a list of questions as questions can provide the context for better understanding the input required and limit misinterpretation. For example: • "What is the required capacity of the desalination plant?" • "What is the typical significant wave height at the depth of closure?" • "What is the top elevation of the beach relative to…?"	Recommended change will be made. Requests for inputs will be questions.
16	The Panel would like more clarification as to what some of the inputs encompass. For instance, how were the "Number of Units" calculated? Terminology or descriptive details should be provided in the Matrix to assist users when addressing these inputs.	More detailed descriptions of each input will be provided in the final guidance manual.
17	Regarding "Number of Units": • It is recommended that the Number of Units be removed as an input. The Panel feels that the Number of Units should be calculated by the Guidance Manual (based on the input provided) rather than by the user. For example, using the available beach front (user input), the toolbox would calculate the number of conventional vertical wells and production that could be achieved on the basis of an estimate of well productivity (default provided by the toolbox, but adjustable by the user), well spacing (default provided by the toolbox, but adjustable by the user), redundancy (default provided by the toolbox, but adjustable by the user), etc. If the resultant production is less than required to match or exceed the design capacity of the desalination plant, then the technology would be flagged as unfeasible. The toolbox should perform similar calculations and provide guidance for input parameters for all the other SSIs. • To evaluate number of units and land take per unit (beach front and area), one would need to know the capacity per each type of unit and land take per unit for each intake option. Using vertical wells as an example, given a required capacity (+/- a safety factor) and well capacity (gallons per minute/well), the number of wells could be calculated and given a well spacing and well pad area, the total land take could be calculated. This information would be needed for each SSI option. There might be a default value and option to enter a site-specific estimated value.	Number of units will be removed as an input and instead calculated from other inputs.
18	Guidance for the input on "Land per Unit (Linear Beach Front)" is needed, or this could be calculated (see above bullet).	See previous response.

#	Panel Comment	Response to Comment
19	For the required input "Significant Wave Height," include additional sub-input like "Wave Period" and "Wave Direction." This information would be used to assess the individual SSIs. However: • The initial thought was to input several wave parameters to help assess beach dynamics, but this could be simplified if the user replies to the few questions (see next sub-bullet), which should help in determining the dynamics of the beach. • This could be simplified by entering the typical significant wave height and peak wave period at the depth of closure. The depth of closure is the depth beyond which sediment transport or bottom changes are negligible. Because a seabed infiltration gallery or the seaward end of a water tunnel would be constructed in this area, the wave height could make construction a challenge.	Response pending further information from the panel.
20	The Panel recommends using turbidity (nephelometric turbidity units [NTU]) rather than silt density index (SDI) as an input. • Turbidity will tell you how much silt is in the water and if it will cause plugging of a seabed infiltration system. • Use the Slow Sand Filter Manual as reference to develop a threshold for turbidity (i.e., 50 NTU is the maximum value available for a slow sand filter). • SDI is not a measure of what will cause the fatal flaw because it cannot be related to the operation of the intake, but the surface water reverse osmosis process. As discussed below with reference to Criteria 15, all SSI types are capable of producing low SDI water and there is no one preferred option in this respected. A more important issue is the sensitivity of the intake to turbidity, which would be greatest for gallery type systems.	Comment will be incorporated. NTU will be added as a criteria in the Operation (Intake) section. SDI will be kept as a criteria for Operation (Treatment) section.
21	The beach needs to be characterized; therefore, the Panel suggests questions like: • Is the beach artificial? • If the beach is artificial, how often is it nourished? • What is the beach width at mean higher high water (MHHW)? • What is the beach top elevation (relative to some common datum used throughout)? • What is the beach slope? • What is the depth of closure (depth beyond which there is no significant sediment transport or bottom changes)?	Response pending further information from the panel.
22	"Depth to bedrock" (challenge: project proponents will not be drilling into bedrock to put in a structure like a beach gallery).	Response pending further information from the panel.
23	"Erosion rate and/or return time for nourishment" (challenge: beach stability is important as it impacts the intake structure most). "Erosion rate" (e.g., in feet per year) may be difficult to determine. In any case, using the erosion rate with the beach width an estimate of the "life" of the beach could be computed (e.g., how many years until no beach or nourishment is required). This set of questions/answers should allow a determination as to how active or dynamic the beach is and factor that in in the scoring later, without trying to figure this out through wave conditions. The "rate of change of beach width over 30 years" should be removed, and replaced by the "erosion rate," which should be determined from measurements or literature. No estimate of "rate of change of beach width over 30 years" can be made from aerial photos alone (i.e., photos may not be available for 30 years, the beach may have been nourished, structures are installed, and the beach width depends on the tide, a photo may be taken at high tide showing a narrow beach and vice versa). While the analysis of photos to determine erosion rates is valid, it requires a level of analysis that is beyond what the typical user of the toolbox could do. Therefore, the Panel suggests the user input estimates made by others and published in the literature or reports by agencies. This refers to Challenge 13 (protection from erosion or scour), too.	We propose to address this as a beach stability term instead of erosion. We have requested additional input from the panel on qualifying beach stability (see response to comment #21).
24	Water levels relative to a common datum (e.g., NAVD88) used throughout should be included. For example: • What is the 100-year total water level (TWL)? • What is the MHHW? • What is the mean lower low water (MLLW)? • What is the 100-year TWL by mid-century (to account for the life of the facility [e.g., 30 to 40 years] and sea level rise due to climate change)? These water levels should be used to assess the challenge, feasibility, and other aspects of beach-based SSIs. At the same time, the elevation of the land where facilities could be installed should be defined, such as: • What is the elevation of the land beyond the beach where components of SSIs could be constructed?	Response pending further information from the panel.
25	Requirements for the seven SSI options are needed. That is, the tool can make background calculations based on user inputs and values provided within the tool, like productivity, spacing, required area, and redundancy. Reasonable default values (or a range of values) are needed to help provide guidance on which well will work and how	Default values will be provided, with the option for user override.

#	Panel Comment	Response to Comment
	many wells are needed. There should be an override option in case the user has more specific information available.	
26	There is a large variety of coastal features to consider for Fatal Flaw #1 (land type makes construction of SSI infeasible). For example: Beach, Estuary, Bay, Wetland, Cliff, Bluff, Inlet, Lagoon, Reef, Flood Plain, Dune, Spit, etc. These could combine to define a specific coast type that may or may not be suitable for a particular SSI. For example, a beach could be in a bay and thought to be protected, but if the bay is like Santa Monica Bay, the location on the bay would be important in determining if the SSI would be exposed to large waves. A beach could be backed by a cliff or bluff, or be on a spit, and the beach may be fronted by a reef. All these scenarios would need to be defined if a flaw to a particular SSI is to be determined.	Response pending further information from the panel.
27	The Panel feels that reference to CEQA in Fatal Flaw #4 is too California-specific and may be speculative at this stage of the review. The Panel recommends that WBMWD use a more general description (such as "state environmental review" or "regulatory review"). CEQA could then be referenced as an example. In addition, regulatory approval varies by intake type. A type-by-type evaluation of intakes will be needed based on state requirements.	The CEQA fatal flaw will be removed.
28	The Panel recommends including a fatal flaw that relates to sea level and/or elevation of the land. This effort may include defining what land elevation is not acceptable and where. Also, factor in flooding events and sea level rise, such as the 100-year flood and SLR due to climate change by mid-century or hurricane surge analysis for parts of the United States.	Issues of sea level rise or flooding are mitigatable and therefore they will not be included as fatal flaws.
29	Regarding Fatal Flaw #2 (insufficient beach front available to construct SSI): How is this computed and who computes it? Background calculations per user input and toolbox defaults could be used to compute this to determine if this is a fatal flaw or not.	More information will be provided and default values will be provided with the option for user override.
30	Similar for Fatal Flaw #3 (insufficient land available to construct SSI) and the proposed Fatal Flaw related to water level. If the top elevation of the beach is below the 100-year TWL, then beach-based SSIs like vertical well beach structures may not be a good idea.	See response to #28.
31	Challenge #5 (limited area for drilling equipment). This challenge only deals with the staging area for drilling, but what about other staging areas for other land use considerations? A beach gallery will take up more space than a well. An offshore gallery may require the construction of a trestle that could impact the beach for months or years.	This criteria will be expanded to include all staging requirements.
32	Challenge #8 (wave limit for construction). Use two options instead of three. The two options include: less than 3 feet (zero points, feasible) and greater than 3 feet (2 points, unfeasible, too expensive, significant construction downtime). For Beach Infiltration Gallery, note that waves break as a function of depth with a ratio of height at breaking = 0.78 x depth, so the depth at the seaward end of the beach infiltration gallery will control the wave height at that location. Furthermore, a cofferdam may be built to protect/isolate the construction area from the waves (in which case waves would not be relevant).	Scoring system will be changed for this criteria (though we will use the term "challenge" instead of "feasibility"). Agreed that a coffer dam would resolve the wave issue, hence the wave height being a challenge rather than a fatal flaw. The ratio will be provided by the tool to inform the user for input. For beach gallery, it will be possible to estimate the wave height by multiplying the depth at the seaward end of the beach gallery by 0.78.
33	Challenge #9 (depth to seabed). The Panel recommends adding the phrase "at planned construction site." Note that greater than 35 feet is not feasible; the Matrix cites 50 feet for slant wells.	Comment will be incorporated. Should not apply to slant wells.
34	The Panel noticed an inconsistency in the scoring with Challenge #10 (land type). For example, for radial collectors, a rocky coastline is considered a fatal flaw, while it is rated a (1) in Challenge 10. Cliffs are also listed as (2) and a fatal flaw.	This will be corrected.
35	Challenge #12 (protection against sea level rise). Specify 30 years from what date (likely from the initiation of construction, which could reach to 40 years or greater from the time of project initiation). The SLR projection should account for the planning/design period, the construction period, and the lifetime of the facility. Refer to SLR projections by the National Research Council for California, Oregon, and Washington.	Will clarify that it is 40 years from project initiation. The NRC study is cited in the reference.
36	Challenge #13 (protection from erosion or scour). Looking at historical aerial photos is reasonable, but it is also important to consider beach nourishment. Maybe this challenge should be redesigned to consider whether it is a stable or unstable beach. An important criteria would be if the beach needs nourishment (if it does, it is an eroding beach and would score a 2). Conversely, if the beach is receiving too much nourishment, the site will end up stranded. Also, see the discussion in Section 3.3 (List of Inputs) on "Erosion rate and/or return time for nourishment."	See response to #23.
37	Challenge #14 (clogging). This challenge is unlikely to be useful for screening due to a lack of information. Because more information is needed, it might be moved to Level 2. Alternatively, this challenge could be called "geochemical stability," with SSI rates based on the likelihood of mixing of waters with different chemistries (particularly redox conditions). Gallery types systems would rank (0), whereas vertical wells would receive a (2) and perhaps other types a (1).	If the user has no information on any of the parameters (saturation index, sedimentation rate or turbidity) the proposed default values will be used for each SSI, but there would be a flag for uncertainty. More information can be added during level 2 and 3.

#	Panel Comment	Response to Comment
38	Challenge #15 (fouling). Replace this challenge with source water turbidity sensitivity. As previously noted, all SSI types can potentially provide very low SDI water. Thresholds will be needed for seabed and beach infiltration galleries.	Comment will be incorporated. NTU will be included as a criteria in the Operation (Intake) section. SDI will be kept as a criteria for Operation (Treatment) section.
39	Challenge #16 (poor feedwater requiring additional permits). How will this challenge be practically applied in the absence of test well data? The SSIs would not differ from one another based on these criteria, and data will be hard to obtain. Can this be removed from the Guidance Manual, or does it belong in Level 2?	If the user has no information on this, it will rank as a zero, but there would be a flag for uncertainty. More information can be added during level 2 and 3.
40	Challenges #17-20. Why are these environmental challenges being considered when the guidance is focused on technical feasibility and not environmental feasibility? Also, these types of inputs need to be "well-type specific" and not generic inputs. However, it was noted that these only flag negative conditions (only scores of 2) and might still be worth considering in the Guidance Manual. In addition, remove references to CEQA.	Environmental Challenges category will be removed. Challenges in this category that are technical in nature (i.e. pumping) will remain, but be moved to a different category.
41	Challenge #20 (contaminant plumes). Horizontal wells under the seabed will not be affected by landward contamination. It should be "not applicable."	Agreed. Change will be made.
42	Challenges #21 and #22. It was pointed out that precedents as far as capacity and units may not be of great value as SSIs tend to have a modular design and are readily scalable. As a hypothetical example, the largest beach gallery capacity to date is, say, 5 million gallons per day (MGD), which is not really a negative when considering a 10-MGD system, as there is no reason why the former could not have been made larger. Perhaps a more useful criterion is the number of (successful) operational systems with a capacity of 1 or 5 MGD or greater.	Scaling up significantly will inherently create some uncertainty and therefore risk.
43	In either the Risk section or Operations section, WBMWD should add challenge criteria "Maintainability." The input would be system-type specific, focusing on whether the user can readily and cost-effectively maintain these systems.	General ease of maintenance will be added in "operations" category
44	Add "Practical Ability to Pilot Test" as a challenge in the Risk Section to consider economics. For example, it is relatively inexpensive to pilot test a vertical well (Score = 0), versus an off-shore gallery, water tunnel, or radial collector system (Score = 2), which can be impractical (i.e., too expensive) to pilot test. Other SSI types would be intermediate.	Practical ability to Pilot Test will be added under "risk" category.
45	The Panel would like to note that higher scores, traditionally, represent the better option. Perhaps WBMWD should consider reversing the scoring system so that zero is "highly challenging" and 2 is "not challenging/slightly challenging."	Higher score means higher challenge. It could be confusing either way, change is not considered necessary.
46	A single weight should be provided for each Challenge in the Scoring Matrix. Currently, weights are listed for each SSI. That is, Challenge "Area available for drilling" should be weighted "1" for each SSI. This change would simplify the table/spreadsheet. After the "Challenge" column, add another column on "weight" and then include scores.	Weights depend on the SSI.
47	Is the "Summary of Max Scores for Each SSI" showing the weighted scores? It needs to be clear.	This will be clarified.
48	Thresholds can be dealt with qualitatively. However, there is a need to include an interpretation of the normalized score.	More explanation of the normalized score will be provided.
49	In the flow chart, the purple box with "Refine Site Characteristics" should automatically move to "Apply Feasibility Matrix Challenges." See the modified flow chart in Appendix E for the Panel's edits.	No, it needs to go back to evaluate fatal flaws, because refined information may cause an SSI to become disqualified when it was not earlier.
50	If a SSI has a fatal flaw, then it would logically no longer be considered. Hence, there is no need for additional Level 2 and 3 testing.	Yes, that was the intention. Wording will be clarified to make sure that is clear.
51	The Panel notes that the Guidance focuses only on technical feasibility. Before the Level 2 and 3 analyses, the Guidance Manual should point users towards evaluating for environmental and economic challenges to assess whether the options should be further considered. It is strongly suggested that it be recommended that an initial economic and regulatory analysis be performed before proceeding to field testing (i.e., if it is clear that an option would be too expensive or could never be permitted, than it makes no sense to do any testing).	See response to comment #5.
52	The Panel would like a better description of the value added by Level 2 and 3.	More description will be provided.
53	The Panel recommends separating the Level 2 and Level 3 information into different tables in the Matrix, including separating them in the flow chart (see Appendix E). Once they are separated, be more specific and individualize the information provided.	This comment will be incorporated.
54	Level 3 would include constructing and operating a pilot test well as a challenge.	The practicality of pilot testing will be added as a challenge.

#	Panel Comment	Response to Comment
	Warren Teitz of Metropolitan Water District of Southern California congratulated WBMWD for taking a leadership role in developing a new water supply for the State of California. WBMWD took a leadership role with recycling, and now they are doing so with desalination. The work that this Panel is doing is very important and will help agencies in California wrestle with the issue of subsurface intakes. Panel Response: Noted.	No recommended action.
	Dana Murray of Heal The Bay works with marine and coastal environmental issues in California. She provided the following questions for consideration: • Will this guidance be undertaken for open ocean intakes as well? Can you integrate open ocean intakes into the SSI Guidance Manual effort to determine the best options for different sites? • How will you allow for adjustments when looking at the challenges? What feedback and/or input will you consider? • Will you look at the impact on coastal and marine spatial planning in California? • Who will undertake quality assurance/quality control to verify the accuracy of inputs? Panel Response: These questions should be addressed by WBMWD as they are not a part of the Panel review of the proposed framework of the SSI Guidance Manual.	No recommended action.
	Richard Bell of the Municipal Water District of Orange County (MWDOC) thanked WBMWD for the leadership and great work they have been doing for years. This is a neat process and great tool. He noted that MWDOC constructed a slant well several years ago, and wanted to ask if mitigation or design protective measures were considered as part of the SSI Guidance Manual. For example, putting in a well head on a beach may involve dealing with liquefaction, so protective measures may be needed against earthquakes. Another issue that can come up long after a project is built is the listing of endangered species in your site area. He asked how we can work with Fish and Game to mitigate these issues. He also noted issues pertaining to the draw of water and water rights, and cautioned to not just look at required capacity but rather what the resource can produce. Panel Response: Mr. Bell is encouraged to submit written comments with additional detail.	No recommended action.
	Jeff Barry of GSI Water Solutions has been involved in large projects like this, including evaluating feasibility. He suggested that WBMWD consider creating “off ramps” for people going through the feasibility process (that is, places to go where you can identify fatal flaws early). He suggested setting up the process in tiers, which can help users eliminate options earlier in the process. Panel Response: Noted.	No recommended action.
	John Loveland of Poseidon congratulated WBMWD for undertaking this process. He noted that Poseidon has been engaged in a similar collaborative process with the California Coastal Commission and has vetted most of the issues spoken about today. They have worked on their own process for 18 months and have published a feasibility study. He also noted that members of the Panel and technical project team have been drawn from Poseidon’s own expert panel. Keep this transparent, he stated, because WBMWD may receive a lot of questions on their process, as Poseidon did. In response, Jeff Mosher of NWRI acknowledged that Poseidon’s effort had a specific project site, but that WBMWD’s effort is more of a general project to develop a screening tool that has wide use throughout the United States. Mosher also acknowledged that some of the same experts were drawn from Poseidon’s project and are using their knowledge to inform WBMWD’s project. Panel Response: Noted.	No recommended action.
	Tom Seacord of Carollo Engineers noted that the State Water Resources Control Board is finalizing amendments to the California Ocean Plan. He wondered if the manual would be flexible enough to insert future inputs based on new information from the State Board’s amendment plan. Diane Gatza of WBMWD responded that they are following the State Board process closely and if new criteria come out before the Guidance Manual is finalized, then it can be included in this effort. Seacord then asked if there is a way to include additional inputs or fatal flaws once the Guidance Manual is finalized. Gatza replied that it is a great comment that requires further consideration. Panel Response: Noted.	No recommended action.

#	Panel Comment	Response to Comment
	Tom Luster of the California Coastal Commission (see panel report for full comments. Too long to include here) Panel Response: The Panel agrees that qualifying the use of the tool when it is used by a project proponent in their planning process would be a benefit for users and those reviewing the results. A significant amount of work will be put into completing Level 1 of the tool to understand the location and production capability of each SSI. As a result, it would be beneficial for the results to be useful for regulatory agencies. However, the tool results should be considered in the context that the tool is an initial screening/guidance tool. One suggestion is that project proponents should review the Level 1 results with regulatory agencies to get comments prior to eliminating any SSIs from considerations and before embarking on to Level 2. The Panel recognizes the benefits of SSIs and it is assumed that a tool user would also understand the benefits. As a result, the tool would not need to highlight these benefits versus a conventional open ocean intake. Some of these concerns can be addressed in the description/narrative for the tool. The Panel agrees that the use of CEQA be removed from the Matrix as described in the Panel's responses. In addition, the Panel made specific comments on components of the Matrix, including "Fatal Flaws," "Challenge Ranking," and "Scoring Ranking," so that the tool reflects current experience and can provide reasonable results.	No recommended action beyond the original comments from the panel.
	Mark Williams, Ph.D., P.E., of GEOSCIENCE Support Services, Inc., submitted the following comments: FATAL FLAWS: 1. The inputs and fatal flaws are too simplistic and cannot be generally applied to all SSI and all sites. For example, to reject a site because it lies on a cliff is not sufficient as the site may be engineered to be acceptable (e.g., Marina Coast). Many of the proposed fatal flaw determinations listed cannot be practically evaluated to any reliable extent at this early stage and may be more appropriately evaluated during later (Level 2 or 3) evaluations. Panel Response: The tool is intended as an initial screening tool. In addition, the site-specific nature of each alternative would need to be reflected in the use of the tool. As such, the Panel agrees that potential engineering solutions to allow for specific SSIs to be viable should be a part of the process. In addition, if the tool is made too complex by covering many details it could become problematic to implement. 2. There is no theoretical upper limit of the yield and sustainability of slant wells or some of the other SSI types used as a source of feed water supply to ocean desalination plants. Research and field testing over the past 9 years suggest that slant wells extracting water from subsea alluvial aquifers can provide a high yielding and long-lasting sustainable water supply when designed, constructed, and maintained properly. Furthermore, the total yield is a function of scale, and the reliability is guaranteed by the ocean source. Panel Response: WBMWD and the Project Team should consider this comment.	Expanded explanation of objective of the tool will help to address this--- as suggested by some of the Panel's comments. The tool does not put an upper limit to the yield of slant wells.
	Mark Williams, Ph.D, P.E of GEOSCIENCE Support Services, Inc. 1. Many of the Significant Challenges for Construction are not relevant at all or are not relevant at this preliminary screening stage. For example, in Monterey and Dana Point projects, drilling footprints were all well under 10,000 square feet with staging nearby the site. Access and construction were all challenging, but certainly did not prevent successful construction of the two projects. This will be the case, to some extent, for most coastal sites. Panel Response: The tool is intended to evaluate the feasibly of SSI options for the proposed full-scale project.	No recommended action.
	Mark Williams, Ph.D, P.E of GEOSCIENCE Support Services, Inc. 2. It does not make sense to have such general statements in this section. It appears that the authors have selected a handful of topics and tried to apply to all SSI types and all site conditions. Potential subsurface intakes are quite site-specific and subject to a number of factors. These projects usually have high visibility with a good deal of public attention. As such, siting considerations need to consider a number of factors other than just feed water production and proximity to the desalination plant. For example, along the coast of California, these factors include the normal permitting land acquisition and access factors, but are also dependent upon a number of environmental and operational factors, which if not complied with, could prohibit the project altogether. For example, many of these projects are tied to a maximum percentage of feed water derived from inland water supplies, which if not met, may require expensive mitigation or provision of supplemental supplies, all of which add to	We agree with some of this comment. We agree that the ratio of seawater and inland groundwater flow to an SSI is site-specific. As indicated in many cases this influences cost, but not technical feasibility. Evaluation of this when needed could be a component of Level 2 or 3 analysis. We will include this as an informational note.

#	Panel Comment	Response to Comment
	the cost of supplied desalination product water. Panel Response: WBMWD and the Project Team should consider this comment.	
	Mark Williams, Ph.D, P.E of GEOSCIENCE Support Services, Inc. 3. Ranney-type collector wells have lateral lengths typically limited to approximately 46 meters or less. They also may draw a high percentage of recharge from inland supplies and require construction of a large diameter caisson, which is visually offensive in a beach environment. Horizontal directionally drilled wells could potentially be used for subsurface supply; however, the main disadvantage is the inability to place an engineered artificial filter pack around the well screen, which may result in clogging and limited well production in fine-grained alluvial formations. Panel Response: WBMWD and the Project Team should consider this comment.	Agree. Comment noted. We will include as information in Tech Memo on technology overview.
	Mark Williams, Ph.D, P.E of GEOSCIENCE Support Services, Inc. 1. You cannot just select a range of aquifer parameters as a criteria for discrediting a subsurface intake. Groundwater modeling of site-specific areas and for site-specific feedwater supplies needs to be part of the selection. To say that the transmissivity has to be a certain value is pointless unless you consider other factors, specifically benthic zone leakance values. Panel Response: WBMWD and the Project Team should consider this comment.	We agree that site specific Level 2 and 3 evaluation, including groundwater modeling, can be conducted to refine feasibility assessment of an SSI. We agree that conductance (leakance) of the interval between the SSI collector and the sea is an important factor. This is influenced by both as thickness and vertical hydraulic conductivity of this interval (including the sea floor). We will emphasize and clarify this issue.
	Mark Williams, Ph.D, P.E of GEOSCIENCE Support Services, Inc. 2. To maintain feed water production, planned rehabilitation should be performed with all subsurface intake types based on efficiency and yield decline. All wells (vertical and angled) need redevelopment from time to time to maintain performance. This periodic redevelopment typically consists of mechanical and/or chemical redevelopment using the same "tried and true" methods developed in the water well industry for vertical wells over the past 70 years. As access to the wellhead area is required, provision must be made during siting to minimize disturbance during routine maintenance. Panel Response: WBMWD and the Project Team should consider this comment.	Comment noted. Added a criteria "Ease of maintenance" as also suggested by the Panel. We will add discussion, also in the technology overview memo companion document.
	Mark Williams, Ph.D, P.E of GEOSCIENCE Support Services, Inc. 3. As a general rule, with all wells, when well efficiencies decline to 50 percent of the maximum value (at the design production rate), it is a good idea to take the well out of service and perform a video inspection and rehabilitation plan. Based on limited data from the Dana Point Test Slant Well, it is expected that in wells properly designed, developed, and consisting of corrosion resistant steels, the frequency between well rehabilitation would be on the order of 3 to 5 years. However, depending on other constituents in the groundwater (e.g., iron and manganese), rehabilitation frequency may vary. Panel Response: WBMWD and the Project Team should consider this comment.	Agreed. Comment noted.

APPENDIX D-2

Response to Comments in the NWRI Panel Report of the April 14, 2015 Meeting (Meeting #2)

Response to comments from the NWRI Draft Final Report of the April 14, 2015, Meeting (Meeting #2) of the Independent Advisory Panel for West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Study – Guidance Manual Review

In 2015, National Water Research Institute (NWRI) formed an Independent Advisory Panel (Panel) on behalf of the West Basin Municipal Water District (WBMWD) to provide expert peer review of the technical and scientific aspects of a DRAFT Subsurface Seawater Intake (SSI) Feasibility Guidance Manual (Manual), which was developed by Geosyntec Consultants, under contract to WBMWD, with grant funding from the United States Department of Interior, Bureau of Reclamation (USBR) under USBR Project No. R14AP00173. The Guidance Manual is also a part of a larger WBMWD study, the "Ocean Water Desalination Subsurface Intake Study." The Manual was presented on February 26, 2015 at public meeting coordinated by NWRI. After this meeting, the Panel issued a draft report on March 20, 2015 which included a number of comments on the Draft Manual. Geosyntec and WBMWD reviewed the comments and proposed revisions to the Manual to reflect the expert opinions of the Panel members. These proposed revisions, along with requests for clarifications to a number of the panel comments were presented at a second public meeting, held April 14, 2015. After this second meeting, the Panel issued a draft Final Report on May 1, 2015. The table below summarizes the comments provided by the Panel in their draft final report as well as the approach taken to incorporating the comments into the Manual. Additionally, upon further review of matrix by the West Basin Project Team, a few additional modifications were made to the matrix, and these are provided for reference as well.

Reference to Previous Comment Table	Comment	Response
General	The Panel understands it is reviewing the project team's responses to the Panel's report from the first meeting, and the project team will be responsible for incorporating the Panel's comments into the final product.	Noted
General	The Panel acknowledges an updated matrix was not prepared for the second meeting.	Noted
General	Emphasize in the Guidance Manual that it is a screening tool, and is not meant to be used for a final decision.	Emphasis will be added
Item 3	The Panel recommends removing some of the California-specific material to make the Guidance Manual more beneficial to a broad range of locations.	Language will be added to provide guidance to users in other regions
Item 9	On the Definition of Feasibility • The Panel recommends defining "feasibility" without referring to the California Environmental Quality Act (CEQA). • Clarify that the user should conduct economic and environmental analyses outside of the technical feasibility assessment.	The definition of feasibility will remain based on California law (either CEQA of California Coastal Act), information will be added in the tool and the final guidance document to explain that if it is used in a different state or country, the feasibility definition and regulatory requirements might be different.
Item 14	Regarding transparency when adjusting the weights: o The Panel suggests stating in the Guidance Manual that users must provide justification (e.g., appropriate data) when changing the default weights. o The Panel recommends providing users with details on the rationale used to develop the weightings. Communities and/or stakeholders may want guidance on how the weighting works to ensure it is not being manipulated by the user.	These changes will be made
Item 14	• Regarding the quality of input: o The Panel agrees it is appropriate to use "low," "medium," and "high" to qualify the quality of data. o Clarify how the final ranking will be determined (i.e., weighed by the quality of the data; if data based on actual data or assumptions, this is where uncertainties can be accounted for) and how this will be made clear to the user (e.g., flags will be used to qualify the ranking of the SSIs based on input provided by the user).	The quality of data accounting will not influence the weighting, but there will be flags to alert the user to scoring based on uncertain data. This will be made clear to the user. The quality of date is evaluated as follows: Low quality input = input derived from assumptions, anecdotal evidence, default value, or unsupported source (orange flag) Medium quality input = input derived from regional estimates, literature review, similar sites (yellow flag) High quality input = input derived from site-specific measurement or site-specific information (green flag)
Item 19	The Panel recommends characterizing the wave climate. o Use the average wave height at the depth of closure (defined as the depth beyond which sediment transport or bottom changes are negligible). o To score depth of closure: § All SSIs except the offshore gallery receive a score of 0. § Water depth of less than 10 feet, and less than 1,000 feet from the shore (receives a score of 0) § Water depth of 10-20 feet, and less than 2,000 feet from shore (receives a score of 1). § Water depth of greater than 20 feet, and greater than 2,000 feet from shore (receives a score of 2).	We will include an NA (not applicable) provision for inputs that do not apply to a particular SSI (all except SIG in this case). We will add this input as recommended. This was used instead of scouring potential and only applied to SIG (previously scouring potential was applied to HDD and Beach gallery as well).

Reference to Previous Comment Table	Comment	Response
		The criteria was modified to cover all combinations of distances and depths § Water depth of less than 10 feet, and less than 1,000 feet from the shore (receives a score of 0) § Water depth of 10-20 feet, **OR between 1,000 and 2,000 feet** from shore (receives a score of 1). § Water depth of greater than 20 feet, **OR** greater than 2,000 feet from shore (receives a score of 2).
Items 21 and 23	When characterizing beach stability, the Panel recommends using the following: o Stable Beach (receives a score of 0): § Beaches that are not nourished and with no significant seasonal beach profile changes. o Unstable Beach: § Beaches that could exhibit peak annual mean sea level (MSL) shoreline changes greater than 15 feet/year, or have been re-nourished in the past 10 years (receives a score of 2). § Beaches that could exhibit peak annual mean sea level (MSL) shoreline changes of less than 15 feet/year, or has been re-nourished in the last 10 years (receives a score of 1).	We will include this recommended input, but it seems recommended scoring by Panel for Items 21 & 23 needs to be updated to new convention where high score is less challenge: Stable Beach = 2. Most unstable = 0, less unstable = 1. The criteria was changed to § Beaches that could exhibit peak annual mean sea level (MSL) shoreline changes **greater** than 15 feet/year, **AND** have been re-nourished in the past 10 years (receives a score of 2). § Beaches that could exhibit peak annual mean sea level (MSL) shoreline changes greater than 15 feet/year, **OR** has been re-nourished in the last 10 years (receives a score of 1).
Item 22	• The Panel recommends scoring “depth to bedrock” as follows: o A depth of 0-10 feet receives a score of 2. o A depth of 10-20 feet receives a score of 1. o A depth of greater than 20 feet receives a score of 0.	Depth to bedrock is not needed because the input for transmissivity addresses both depth to bedrock and hydraulic conductivity. Depth to bedrock was added as a challenge for construction (see response to item # 26).
Item 24	On Water Levels Relative to Common Datum • Because it is a design issue, the Panel suggests eliminating it from the matrix. If it is not eliminated, then the scheme will need to be considered.	This input will not be included.
Item 24	Should “vulnerability to sea level changes” be included in the criteria?	Yes this will be included. The predicted mean sea level in 40 years is included to asses “vulnerability to sea level changes”.
Item 26	The Panel recommends using a limited number of categories (with a “yes/no” response), such as: o Shallow bedrock (less than 5 feet) (which is a fatal flaw for all the SSI options). o Narrow beach (less than 50 feet) backed by cliffs (which is a fatal flaw for all the SSI options except offshore galleries). o Rocky shoreline (which is a fatal flaw for all the SSI options except offshore galleries). o Inlet (which is a fatal flaw for all the SSI options except offshore galleries). • In addition, for each SSI category, a decision will need to be made as to whether a “yes” response is a fatal flaw.	Agreed. We will focus the yes/no inputs for fatal flaw evaluation (e.g. both shallow bedrock and rocky coastline are not needed). We added inlet as a fatal flaw for all SSIs except SIG and water tunnel The threshold value for depth to bedrock was defined depending on SSI as follows: < 5 ft – fatal flaw for beach infiltration gallery, seabed infiltration gallery and water tunnel < 10 ft – fatal flaw for HDD wells < 25 ft – fatal flaw for vertical wells and Ranney wells < 100 ft – fatal flaw for slant wells Criteria #9 was adapted to reflect this change in land type definition. The threshold value for depth to bedrock was defined depending on SSI as follows:

Reference to Previous Comment Table	Comment	Response
		< 15 ft – challenging for beach infiltration gallery, seabed infiltration gallery and water tunnel < 25 ft – challenging for HDD wells < 50 ft – challenging for vertical wells and Ranney wells < 200 ft – challenging for slant wells
Item 35	The Panel agrees to using “40 years from project initiation” as the date to assess sea level rise. Forty years would include 8 years for planning and permitting, 2 years for construction, and 30 years for operation.	40 years will be used
Item 48	The Panel agrees on eliminating the categories from normalization.	Categories will be eliminated
Item 48	Typically, the higher the score, the better the feasibility. But in this matrix, the higher score represents lower feasibility. Because of the potential for confusion and/or misinterpretation, the Panel recommends that the scoring be changed so that the higher score reflects higher feasibility/opportunity. o If changed, use a default of 2 for high-end and 0 for low-end.	Scoring will be reversed
Item 48	The Panel suggests the following parameters for normalization: o The score should be a measure of better feasibility/opportunity. o Adjust weighting so that the maximum score is 100. o View the weightings as a value judgment (i.e., on a scale of 1-5). Weightings must have meaning. o Weights should be uniform across the categories and technologies.	These suggestions will be implemented. Though weights will be consistent, when the criteria is not relevant to a particular SSI, a default score of zero will be assigned.
Item 48	The Panel is especially concerned that the scoring system results are very sensitive to the weights used, which can bias the results towards a few SSIs. In particular, the original scoring and weighting system tends to conclude that the water tunnel and beach galleries are the best choices because, for a given set of user inputs, it is least sensitive to near shore and beach conditions (e.g., the sum of their weights is less than for the other SSIs). This bias could be reduced once categories of maintainability and the ability to pilot test are added (and given an appropriate weight), which factors would favor vertical wells. The sensitivity of the scoring system to the effects of weighting must be further evaluated. Can the system score a vertical well, slant well, or radial collector as the best choice knowing where these systems are likely to be suitable? Regardless of which weighting system is used, the mathematical component that can cause biasing and the weighting factor/scores cannot be in same range. If this is the case, the mathematical component will bias the results.	This issue will be evaluated and scores/weights adjusted as needed to remove bias in the matrix. The weights were revised. A single weight was assigned for each challenge and applies to all SSIs. The scores/weights were evaluated based on default inputs. The normalized challenge scoring with default inputs is as follows (from most to least feasible): Vertical wells > Ranney wells > Slant wells > Horizontal wells > Beach infiltration gallery > Seabed infiltration galley > Water tunnel. This order corresponds to the default expected technical feasibility of the SSIs, illustrating that the matrix is not biased towards galleries and water tunnel.
Item 48	The Panel recommends beta testing the matrix. The City of Santa Cruz could be used as a potential beta test case.	Beta testing will be implemented to the extent practicable.
	Joe Geever, environmental consultant, stated that the environmental community is interested in identifying the best combination of siting and technology to minimize the impact of desalination SSIs on the environment and fish mortality. He was pleased that WBMWD is addressing a concern of the environmental community. He also commented that many projects look at existing intake structures that have been or will be abandoned; conducting an economic feasibility on the use of an existing intake vs. constructing a new intake is not an “economic” analysis but rather a “financial” analysis. He also felt it is reasonable to look at the frequency and the need for maintenance. He used a gallery in Long Beach, California, as an example of maintenance issues leveling off.	Noted
	Craig Cadwallader of Surfrider South Bay questioned if the Guidance Manual will have “location specific” defaults (such as California-specific or regional-specific) as pre-loaded options. He would like credible, generally agreed-upon defaults that can be plugged in for the location and not come back flagged as outside the parameters. Can multiple defaults be set up so that they are reasonable, but location-specific?	Where defaults vary by region, guidance will be provided for how to select an appropriate default for the region in question. The default inputs which are California specific will be flagged in the matrix and listed in the guidance manual. The user will be referred to other documentations determine an appropriate default for the region in question.

Reference to Previous Comment Table	Comment	Response
	Peter Shellenbarger of Heal the Bay, commented that he is concerned about the limitations of the inputs. If "desired intake volume" is a constraint, and the project cannot be achieved by an SSI, then it can only be achieved by surface intakes. He feels that the ability to use SSIs should limit the size of the project. He noted that desalination facilities should be sited in areas where SSI is capable to prevent impacts on marine life. He also commented on changing the default settings of the weighting. He felt that regional default parameters are needed to represent current local conditions. But if the weights are changed by users, then the changes need to be reviewed to ensure they are appropriate.	The intent of this tool is to be able to evaluate a given project with a defined intake volume.
	I. User Inputs – the tool would allow users to control two inputs used to evaluate a site's feasibility for SSIs: (1) desired intake flow rate, (2) site-specific characteristics. Allowing users to manipulate the assessment tool can greatly influence its outputs and may allow users to always identify SSIs as infeasible. For example, users could strategically choose a desired intake volume that is not supported by site characteristics; this could be used as a technique to always deem SSIs as infeasible. This type of control over the tool is concerning. The assessment tool could be incorrectly used to justify co-locating ocean desalination facilities at power plants that use or in the past used ocean intakes for cooling. The Once-Through Cooling (OTC) Policy clearly identifies the marine impacts of OTC, reflected in the phasing out of OTC. Co-locating ocean desalination facilities at coastal power plants completely negates the spirit and intended outcome of the OTC policy. We believe a more appropriate method for the SSI assessment tool would be to only assess a site's feasibility based upon site-specific characteristics (i.e., not including desired intake volume in the tool). This would be the only way to identify if a site is capable of supporting SSIs. Including desired intake volume greatly clouds the tool's ability to identify areas capable of supporting SSIs. In addition, we believe that before ocean desalination is pursued, a general statewide study needs to be conducted identifying the areas along California's coast capable of supporting SSIs. The assessment tools being developed should then be applied to refine the statewide analysis and help determine if ocean desalination should be pursued at a specific site.	The intent of this tool is to be able to evaluate a given project with a defined intake volume. Intake volume would be set based on needs of the project proponent, not to disqualify SSIs
	II. Site-specific conditions should always be incorporated into SSI intake volume design – When ocean desalination is pursued, intake volume should be determined by examining site-specific conditions. Site-specific conditions should be the limiting factor for intake volume; neither cost nor desired intake volume should be driving intake volume design (as noted above).	Intake volume is defined by project needs, not by site conditions
	III. Fatal Flaws – if a site is identified to have a fatal flaw, ocean desalination should not be pursued. Attempting to mitigate a fatal flaw or altering project components should not be a planning/implementation technique. Marine life mortality/impacts, both acute and chronic, are fatal flaws.	Determining whether desalination should be pursued at a given site is beyond the scope of this tool. This tool is only for evaluating the feasibility of SSIs
	IV. Regional Specific Parameters – it is important that default parameter scores used in the assessment tool are regionally specific. In our view, a general tool that does not capture regional characteristics will not provide an adequate method/approach to assessing a site's SSI feasibility. Thus, it is critical that the tool be expanded to characterize regional differences in geology, wave action, mixing, beach slope, coastal margin slope, dominant grain size, etc. In addition, allowing users to change parameter scoring can greatly influence a site's SSI feasibility. For example, a user may manipulate parameters which do not accurately represent site-specific in an attempt to deem SSIs infeasible. Because of this, there needs to be a robust and transparent QA/QC process that would ensure any changes to the tool's scoring parameters accurately represent conditions in and around the SSI site.	Default parameters are only used when no site specific data is available. Guidance will be provided for how to locate site specific data. If default values are used, there will be flags that highlight the uncertainty of the results
Additional modifications		
List of Inputs	We modified input "What is the required design intake capacity of the desalination plant?" by "What is the intake rate for the project"	
	The definition of feedwater and source water was added at the bottom of the list of inputs. The two terms are used as follows: Feedwater = water entering the pipe, after collection through the SSI Source water = water collected by the SSI	
	The question for input for typical wave height was modified to "What is the typical significant wave height at the planned **construction** site?" (input used in criteria # 7)	

Reference to Previous Comment Table	Comment	Response
Criteria #17 " Potential to disrupt existing/planned groundwater pumping or injection will make permitting/approval challenging"	The criteria for was modified to "Is the inland groundwater level in the coastal aquifer above the sea water level?" Yes – score 0 (highly challenging) No – score 2 (low challenge)	

APPENDIX D-3

Response to Comments in the NWRI Panel Report of the November 16, 2015 Meeting (Meeting #3)

Response to comments from the NWRI Draft Final Report of the November 16, 2015 Meeting (Meeting #3) of the Independent Advisory Panel for West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Study

Following the third public meeting (meeting #3) on November 16, 2015 on the West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Study, the Independent Advisory Panel (IAP) issued a draft final report on November 20, 2015 which comments from the IAP and the public on the Draft Final – Feasibility Assessment Of Subsurface Seawater Intakes. The table below summarizes the comments provided by the IAP and the public in the IAP's draft final report and the responses to comments prepared by Geosyntec and West Basin.

#	Panel Comment	Response to Comment
General Comments		
1	The Panel commends WBMWD and the Geosyntec project team on the thoroughness and completeness of the draft report. The Panel found the draft report to be well-written, and the project team should be commended for making the reported data accessible to the reader.	Noted
2	It would be useful to define the terms "risk" and "risky" in the context of this report as these terms pertain to the evaluation of the feasibility of the specific SSI options. Specifically, the risk may relate to economic conditions, technical conditions, or both.	Clarifications between technical and/or economic risks were added throughout the report.
3	Enhance the narrative about the other potential project sites in the 8-mile area of study (i.e., there are potential sites both north and south of the NRG facility). The draft report should convey that the results from the site near the NRG facility will be similar to the sites north and south of the facility.	Added some clarification to the text in the Executive Summary and added clarifying footnotes in Sections 5.1, 5.2, 5.3, and 5.4.
4	Add a discussion as to how you would address the Ocean Plan's requirement of looking at smaller facilities that can function using SSIs.	Added statements to intro and executive summary that the demand and need for desal (and required capacity) are based on West Basin's Urban Water Management Plan and Desal Program Master Plan in accordance with Chapter III.M.2.b.(2)
5	Provide context to help the reader understand the work of the Independent Scientific Technical Advisory Panel (ISTAP) organized by the California Coastal Commission and Poseidon Resources referenced in several locations in the Final Report. For instance, the project team used ISTAP to draw inferences, but not direct conclusions. It should be emphasized that the WBMWD investigation is independent of ISTAP and that feasibility conclusions for both projects are site-specific.	Added explanatory footnote in introduction (Section 1.4) and executive summary
6	Explain the Level 1 and Level 2 evaluations in context of the terminology used in the Guidance Manual. Explain the use of these evaluations for the NRG site study.	An explanation of the terminology was added in Section 1.4. The use of these evaluations was explained in Sections 2.2 and 3.2.
7	It would be useful to include the specific sections of the Ocean Plan that apply to this report in an appendix (exact language). Readers would be able to review the Ocean Plan provisions as they may apply to this report.	The Ocean Plan was added as Appendix A and references in the text were added.
Section 2 - General Screening Process		
8	In Section 2.1, the inputs for the screening process are useful. Listing the specific inputs provides transparency and context for the study and the review of the results.	Noted
9	Show how the information in Table 2.1 was derived. This information could be summarized in the text or provided in an appendix. Along those lines, provide a description of the rationale that justifies the values reported in Table 2.1.	The complete sets of tool's inputs and outputs are provided in Appendix D.
10	Add information on the scoring process in Appendix A. Consideration should be given to adding a table that shows the scores given for each option for each criteria.	The complete sets of tool's inputs and outputs are provided in Appendix D (see response to comment #9).
11	Describe what the table means in terms of moving these technologies forward for analysis.	This means that further site specific analysis is required for all of them, as stated in Sections 2.1 and 2.2.
12	Provide rationale for not eliminating any of the technologies based on the screening results (i.e., none of the options had a fatal flaw?).	Additional explanation was added in Section 2.2. Two of the fatal flaws being related to siting challenges, and the assumptions used in the initial screening being that there are constraints on siting, this lead to no fatal flaws.
13	Reconsider keeping the "contribution" component of Table 2.1. It is not clear what this level of detail provides. It is probably useful just to list the categories (i.e., construction, operation [intake], operation [treatment], potential inland interference, and risk) in a footnote or in the text.	The "contribution" was removed from Table 2.1 and a foot note was added to Table 2.1 with the list of categories.
14	Consider using a qualitative approach for listing the results of the Level 1 analysis (i.e., "feasible" or "not feasible"; however, they were all considered feasible as of this point). Or, downplay the significance of the scores relative to the different SSI technologies. The Panel did not see much difference among the six technical options other than perhaps that a Beach Infiltration Gallery (BIG) appears to be significantly less likely to be feasible than other options.	The uncertainty of the inputs used in the evaluation was used to calculate errors on the resulting scores. A graph with error bars was added to complement Table 2.1 and a discussion of the significance of the scores was added.
15	Change "reason for infeasibility" to "fatal flaw," and then enter "no" for all options. Currently, these boxes are blank. Stating "no" to fatal flaws provides information to the reader.	The suggested change was applied.

#	Panel Comment	Response to Comment
16	Appendix A qualifies the quality of the data used for input; however, its use is not apparent in the report. The Panel suggests that the project team describes how the uncertainty of data quality informs decision making, how the quality of the data affects the certainty of the results in Table 2.1, and how it provides justification and guidance for the field investigations and studies that were performed.	This feature was added to the tool and to the results presented in the report (see response to comment #14).
17	In Section 2.3, Table 2.2 is useful, but needs editing. Change the title of the table to eliminate "footprint." For horizontally directional drilled wells, the offshore area should be "not applicable" (N/A) and not "1.6 million square feet."	Footprint was not in the Table title, but title of section 2.3 was modified to eliminate footprint. The offshore area of HDD refers to the area of the seafloor under which HDD wells would be constructed (1,000 ft long and 100 ft spacing between drains). A footnote was added to Table 2.2 to clarify this.
Section 3 - Hydrogeological Setting		
18	The Panel believes the hydrogeological investigation was thorough and comprehensive	Noted
19	In Figure 3.6, discuss the error of the cone penetrometer test (CPT) hydraulic conductivity measurements. It is understood that the CPT data captures trends in the data, but may be inaccurate as to absolute values. This information would help in the review of this figure.	Explanation added as footnote in Section 3.2.2 and as note on Figure 3.6
Section 4 – Evaluation Criteria		
20	The Panel believes the evaluation was thorough and comprehensive	Noted
21	In Section 4.2.1, regarding sea level rise (SLR), use the National Research Council's 2012 report for sea level rise values.[1] Make a reference to the design life of the facility to justify the term and estimates used.	The reference was added to Section 4.2.1.
22	In Figures 4.7 and 4.8 of Appendix G, review the beach profiles used in the analysis and the estimated depth of closure, as well as use more current beach profiles. The beach profiles used in the analysis diverge as they move farther from shore. Typically, beach profiles converge, or show a tendency to converge, to locate the depth of closure. It is neither obvious nor justified – other than mentioning that the Coastline Evolution Model (CEM) model was used – how these diverging profiles would converge, as shown in Figures ES-1 and ES-3 of Appendix G, to the predicted depths of closure. As part of a permit requirement, NRG has been measuring beach profiles at El Segundo since 2011, along 15 transects to about 40 to 43-foot water depth. The use of these profiles is recommended in the reanalysis of the profiles used and in the estimation of the depth of closure at the NRG site.	Footnote added in Section 4.2.3 discussing this issue and recommending periodic updates to the bathymetric profiles with data from the NRG bathymetric surveys to refine the estimation of depth of closure.
Section 5 – Evaluation of SSI Technologies		
23	The Panel generally agrees with the conclusions about feasibility; however, the rationale for the conclusions needs to be clearly stated and supported within the results developed in this study. Having clear reasoning will address potential questions by the public and regulators.	Noted
24	The report states that SSIs are not common, but SSIs are commonly used in low- to medium-capacity surface water reserve osmosis (SRWO) plants (up to 5 million gallons per day [MGD]).	Agreed, but SSIs that produce on the order of 40 MGD are not common.
25	Vertical Wells: Eliminate the statement in the conclusions that seawater feeding wells in Sur, Oman (Arabian Sea), have very low Silt Density Indexes (SDIs). The Panel has information to suggest otherwise.	In Section 4.3.3 it is stated that Vertical wells generally provide feed water with an SDI value of 0.3-1 (Bartak et al., 2012), and were shown to provide feed water of better quality than other SSIs (Rachman et al., 2014). The Oman facility is a very different setting.
26	Slant Wells: Add a statement on water quality issues related to concerns with oxidation and reduction (redox) chemistry and iron and manganese concentrations.	A paragraph was added in Section 5.2.
27	Radial Collector Wells: Add a statement on the redox water quality issue. There would be oxygen in the well in contact with the anoxic water that could cause issues with the precipitation of elemental sulfur.	A paragraph was added in Section 5.3.
28	Horizontal Directionally-Drilled (HDD) Wells: Add a statement on water quality issues and on maintenance requirements.	A paragraph was added in Section 5.4.
29	Horizontal Directionally-Drilled (HDD) Wells: Discuss the constructability issues of HDD with less than 20-feet depth below the seafloor.	Added supporting quotations from three publications regarding problems installing HDDs in unconsolidated sediments with cobbles.
30	Horizontal Directionally-Drilled (HDD) Wells: The shallow Dune Aquifer may have favorable conditions, particularly a high hydraulic conductivity, which might allow for relatively high well capacities.	We agree that the shallow sediments generally have high hydraulic conductivity, however presence of cobbles and gravel above the clay interval, which occurs approximately 20 ft below the sea floor, presents a serious challenge for installation of HDD wells.

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[1] National Research Council (2012). *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future.* Committee on Sea Level Rise in California, Oregon, and Washington; Board on Earth Sciences and Resources; Ocean Studies Board; Division on Earth and Life Studies; National Research Council. National Academies Press, Washington, DC.

#	Panel Comment	Response to Comment
31	Seabed Infiltration Gallery (SIG): The report says this technology has a high degree of environmental impact, but the Coastal Commission says that the impact of construction is inconsequential; however, every site is different.	Added "potentially" to environmentally damaging maintenance in Sections 4.5.2 and 5.6. Maintenance and construction has potential to destroy and disrupt benthic organisms. And temporary increase in turbidity could also impact pelagic biota.
32	Beach Infiltration Gallery (BIG) Add a statement about the schedule of beach nourishment by the U.S. Army Corps of Engineers (USACE). The need for nourishment may inhibit construction and long-term operation of the project.	This was added to section 5.5
33	Deep Infiltration Gallery (DIG) There is a misstatement in the report that the tunnel in Spain intersected the karst conduits (Note: it was the HDD constructed intake that likely did this).	The statement was removed.
Public Comments		
	Arthur Pugsley of Los Angeles Waterkeeper asked if the Geosyntec project team considered the feasibility of either removing or perforating the clayey layers to improve hydraulic connection with the ocean. He also asked if the layer(s) were removed, how many of the technologies now considered infeasible could be made feasible. Panel Response: It would not be possible or practical to remove the clay confining unit. It would create major environmental impacts and would be extremely expensive if it were possible.	
	Jeremy Crutchfield of San Diego County Water Authority said that the infiltration galleries were dismissed because of the high-energy coastal environment and the high cost. He asked (a) are these reasons adequate for the regulatory community and (b) how do you think the environmental community will respond? Panel Response: The high cost of the offshore galleries is a major factor in the analysis. Also, the lengthy and difficult construction period (5 to 7 years) would have considerable impacts on shoreline businesses and roads (long-term traffic issue). It is not possible to assess the reaction of the environmental community and regulators without having a specific design to assess. A BIG is not feasible due to great difficulties in construction in a high-energy surface zone and associated costs. A SIG may be technically feasible, but would also likely be cost-prohibitive. The Ocean Plan states that economics is a feasibility factor and, therefore, their high cost should be adequate for the regulatory community. The environmental community is diverse and their responses will vary. Some groups are opposed to desalination regardless of intake type.	
	Dr. Kiran R. Magiawala, a community member participating as a private citizen, submitted the following comment in writing: Is there a plan to evaluate mitigation measures for incidental intake (e.g., hatchery integration as one option – see sketch on the reverse of comment card). Panel Response: There is no specific mitigation plan existing at this time, but mitigation has been accomplished at the Carlsbad site in San Diego, California. The concept of the linkage with a hatchery to produce ichthioplankton and fish eggs should be explored in the future as a means of mitigation. All feasible mitigation options, as necessary, would be considered for an intake option.	
	Henry C. Hunt, a hydrogeologist with Ranney Collector Wells of Columbus, Ohio, submitted the following written comments regarding Section 3.8 (Public Comments) of the Panel report based on Meeting #1: My comments are in relation to inaccurate comments provided in the March 20, 2015, Draft Final Report of the February 26, 2015 meeting (Meeting #1) of the Independent Advisory Panel. The comments, in particular, were made by Mark Williams, Ph.D., P.E. of GEOSCIENCE Support Services, Inc. They were made under the category of Significant Challenges: Construction: "3. Ranney-type collector wells have lateral lengths typically limited to approximately 46 meters or less. They also may draw a high percentage of recharge from inland supplies and require construction of a large diameter caisson, which is visually offensive in a beach environment." He stated that the lateral lengths in collector wells are limited to 46 meters or less. In actuality, lateral well screen lengths typically range between 200-300 feet (60-90 meters) using standardized projection techniques for a given collector well. These can be installed as natural-pack (e.g., wire-wrapped continuous slot or other design) well screens or as gravel-packed well screens. For a recent project in Florida, a collector well in a coastal carbonate aquifer was designed to include lateral well screens that would extend 180 to over 200 meters using a variation on the typical well screen projection technology.	The radial collector wells assessed in this report with modeling have laterals extending 300 feet from the caisson, and the laterals are oriented seaward only to minimize inland flow, as described in details in Appendix I.

#	Panel Comment	Response to Comment
	He stated that collector wells draw a high percentage of their water from inland supplies. I think any well (vertical, slant, or collector well) will obtain a certain percentage of inland water if radial flow to the well occurs. Collector wells have been built using laterals that are screened in the outer (distal) portion of the well screen and projected in a pattern preferential to the intended source of recharge to skew that percentage away from inland sources and toward the intended recharge source (rivers, streams, seawater, etc.). This, in effect, pushes the "pumping center" away from inland sources. In many riverbank filtration sites, the lateral well screens are able to develop raw water supplies of up to 80, 90, 95 percent coming from the source (surface) water, not from the inland side. It may be possible to utilize dedicated lateral well screens projected toward the landward direction to obtain inland water and return this to use inland (e.g., in aquifer storage and recovery programs) using a manifold isolation/pumping system. He stated that the collector well has a large diameter caisson that would be offensive to a beach environment. Collector well caissons have been constructed in public places such as on a beach (CA) or other public area with the caisson constructed at or below grade to lessen the visual impacts to the environment. This below-grade completion would be very similar to any kind of subsurface vault constructed to accept the slant well discharge pipes, vertical well vaults, or any kind of pumping station for offshore infiltration galleries that would be constructed within coastal areas. The caisson would also facilitate access to the well screens to permit future well maintenance that would be required. If the completion of slant wells can be done below grade, a below-grade completion of a collector well can be made as well. Thank you for the opportunity to update this information to prevent misconception of this potential alternative for future water supply projects. Panel Response: WBMWD and the Project Team should consider this comment.	

APPENDIX E
Inputs and Outputs of Screening Guidance Tool

Appendix E
Subsurface Seawater Intake Feasibility Screening Tool Inputs
Subsurface Seawater Intake Study
West Basin Municipal Water District

		Value	Units	Data Quality	Default values?
1)	**What is the design intake rate for the project?**				
		48	MGD		No
2)	**Is there a cliff at the coastline?**				
		No		High	No
3)	**Is the planned construction at an inlet?**				
		No		High	No
4)	**What is the depth to bedrock at the planned construction site?**				
		200	ft	High	No
5)	**What is the width of the beach at the planned construction site?**				
		400	ft	Medium	No
6)	**What is the length of the available beach front?**				
		43,425	ft	Medium	No
7)	**What is the area of available land onshore?**				
		17,802,000	sq ft	Medium	No
8)	**What is the area of available land offshore?**				
		125,042,000	sq ft	Medium	No
9)	**What is the available area for drilling, construction and staging?**				
		463,000	sq ft	Medium	No
10)	**What is the linear beach front required per unit?**				
	Vertical Wells	100	ft/well	Low	Yes
	Slant Wells	600	ft/cluster of 3 wells	Low	Yes
	Radial Collectors	350	ft/group of collectors	Low	Yes
	Horizontal Wells	140	ft/fan of 10 drains	Low	Yes
	Beach Infiltration Gallery	0.0033	ft/per sq ft	Low	Yes
11)	**What is the area required per unit?**				
	Vertical Wells	250	sq ft/well	Low	Yes
	Slant Wells	5,000	sq ft/cluster of 3 wells	Low	Yes
	Radial Collectors	5,000	sq ft/group of collectors	Low	Yes
	Horizontal Wells	100,000	sq ft/drain	Low	Yes
	Beach Infiltration Gallery	6,950	sq ft/MGD	Low	Yes
	Seabed Infiltration Gallery	6,950	sq ftMGD	Low	Yes
12)	**What is the expected capacity per unit?**				
	Vertical Wells	1	MGD/well	Low	Yes
	Slant Wells	5	MGD/cluster of 3 wells	Low	Yes
	Radial Collectors	5	MGD/group of collectors	Low	Yes
	Horizontal Wells	3	MGD/drain	Low	Yes
	Beach Infiltration Gallery	0.1	gpm/sq ft	Low	Yes
	Seabed Infiltration Gallery	0.05	gpm/sq ft	Low	Yes
	Water Tunnel	1.8	gpm/ft	Low	Yes
13)	**What is the topography in the vicinity of the planned construction site?**				
		flat		High	No
14)	**What is the seabed slope at the planned construction site?**				
		low slope		High	No
15)	**What is the depth to seabed at the planned construction site?**				
		20	ft	High	No
16)	**What is the transmissivity of the sediments underlying the planned construction site?**				
	Vertical Wells	130,000	gpd/ft	Medium	No
	Slant Wells	130,000	gpd/ft	Medium	No
	Radial Collectors	20,000	gpd/ft	Medium	No
	Horizontal Wells	5,000	gpd/ft	Medium	No
	Water Tunnel	12,000	gpd/ft	Medium	No
17)	**What is the leakance of the sediment overlying the planned SSI site?**				
	Vertical Wells	0.05	1/d	Medium	No
	Slant Wells	0.05	1/d	Medium	No
	Radial Collectors	0.1	1/d	Medium	No
	Horizontal Wells	0.15	1/d	Medium	No
	Water Tunnel	0.06	1/d	Medium	No

Appendix E
Subsurface Seawater Intake Feasibility Screening Tool Inputs
Subsurface Seawater Intake Study
West Basin Municipal Water District

		Value	Units	Data Quality	Default values?
18)	**What is the typical significant wave height at the planned construction site?**				
	Beach Infiltration Gallery	2.5	ft	Medium	No
	Seabed Infiltration Gallery	2.5	ft	Medium	No
	Water Tunnel	2.5	ft	Medium	No
19)	**What is the water depth at the seaward end of the gallery?**				
	Beach Infiltration Gallery	3	ft	Low	Yes
20)	**What is the water depth at the depth of closure?**				
	Seabed Infiltration Gallery	5	ft	Low	Yes
21)	**What is the distance of the depth of closure from the shore?**				
	Seabed Infiltration Gallery	500	ft	Low	Yes
22)	**Has the beach been re-nourished in the last 10 years?**				
		Yes		High	No
23)	**What is the beach peak annual mean sea level (MSL) shoreline change?**				
		20	ft	Medium	No
24)	**Is the inland groundwater level of the coastal aquifer above sea water level?**				
		Yes		High	No
25)	**Is there existing contaminant plume(s) in the vicinity (less than 5,000 ft from planned construction thesite)?**				
		Yes		High	No
26)	**Is the planned SSI infrastructure located within the 40 year (from project initiation) potentially impacted area by sea level rise?**				
		No		Low	Yes
27)	**What is the sedimentation rate at the planned construction site?**				
	Horizontal Wells	6	mm/yr	Medium	No
	Beach Infiltration Gallery	6	mm/yr	Medium	No
	Seabed Infiltration Gallery	6	mm/yr	Medium	No
28)	**What is the source water turbidity?**				
	Vertical Wells	Potential for clogging is high	NTU	Low	Yes
	Slant Wells	Potential for clogging is medium	NTU	Low	Yes
	Radial Collectors	Potential for clogging is medium	NTU	Low	Yes
	Horizontal Wells	5	NTU	Medium	No
	Beach Infiltration Gallery	5	NTU	Medium	No
	Seabed Infiltration Gallery	5	NTU	Medium	No
	Water Tunnel	5	NTU	Medium	No
29)	**What is the Silt Density Index (SDI_{15}) value of the feedwater?**				
	Vertical Wells	1		Low	Yes
	Slant Wells	1		Low	Yes
	Radial Collectors	1		Low	Yes
	Horizontal Wells	3		Medium	No
	Beach Infiltration Gallery	3		Medium	No
	Seabed Infiltration Gallery	3		Medium	No
	Water Tunnel	3		Medium	No
30)	**Will the source water be considered extremely impaired source by DDW?**				
		Yes		Medium	No
31)	**What is the Saturation Index of selected precipitates in the source water?**				
	Vertical Wells	Potential for clogging is high		Low	Yes
	Slant Wells	Potential for clogging is medium		Low	Yes
	Radial Collectors	Potential for clogging is medium		Low	Yes
	Horizontal Wells	Potential for clogging is high		Low	Yes
	Water Tunnel	Potential for clogging is low		Low	Yes

Notes:

d = day
DDW = Division of Drinking Water
ft = feet
gpd = gallon per day
gpm = gallon per minute
MGD = Millions of Gallons per Day
mm = millimeter
NTU = Nephelometric Turbidity Unit
sq ft = square feet
SSI = Subsurface Seawater Intake
yr = year

Appendix E
Subsurface Seawater
Intake Feasibility Screening Tool
Detailed Results
Vertical Wells

Vertical Wells							
Fatal Flaw							
Fatal Flaw	**Feasibility**	**Criteria**	**Value**	**Threshold for infeasibility**	**Input**	**Data Quality**	
Land type at construction site	Potentially feasible	Depth to bedrock (ft)	200	< 25 ft	4	High	
		Cliff and beach width (ft)	No Cliff and 400	Cliff and < 50 ft	2 and 5	High and Medium	
		inlet	Inlet	No inlet	3	High	
Available Beach front	Potentially feasible	Length of beach front needed (ft)	43,425	< 5875 ft	1	N/A	
					6	Medium	
					10	Low	
					12	Low	
Available area	Potentially feasible	Available area needed (Sq Ft)	17,802,000	< 15000 Sq Ft	1	N/A	
					7	Medium	
					11	Low	
					12	Low	

Appendix E
Subsurface Seawater
Intake Feasibility Screening Tool
Detailed Results
Vertical Wells

Vertical Wells										
Signicant Challenges Scoring										
Challenge	**Challenge Score**	**Weight**	**Criteria**	**Value**	**Threshold**			**Input**	**Data Quality**	**Comments**
					Not Challenging	**Moderately Challenging**	**Highly Challenging**			
Construction Challenges										
Available area for construction equipment	Not Challenging	1	Available area (Sq Ft)	463,000	> 50,000	10,000 - 50,000	< 10,000	9	Medium	
General complexity of construction	Not Challenging	4	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI
Topography at construction site	Not Challenging	2	Topography	flat	flat	moderately uneven	highly uneven	13	High	
Wave energy at construction site	N/A		Significant wave height (ft)	N/A	N/A	N/A	N/A			
Depth to seabed	N/A		Depth to seabed (ft)	N/A	N/A	N/A	N/A			
Land type at construction site	Not Challenging	4	Presence of cliff	No Cliff	No Cliff	N/A	Cliff	2	High	
			Beach Width (ft)	400	> = 200 ft	N/A	< 200 ft	5	Medium	
			Depth to bedrock (ft)	200	> = 50 ft	N/A	< 50 ft	4	High	
Operation (Intake) Challenges										
Geologic conditions	Moderately Challenging	5	Transmissivity (gpd/ft)	130,000	> 88,000	25,000 - 88,000	< 25,000	16	Medium	
			Leakance (1/d)	0.05	> 0.1	0.01 - 0.1	< 0.01	17	Medium	
Vulnerability to sea level rise	Not Challenging	2	Planned SSI infrastructure located within an area potentially impacted by sea level rise within 40 years	No	No	N/A	Yes	26	Low	
Beach stability	Highly Challenging	3	Beach nourished in the last 10 years	Yes	No AND	Yes OR	Yes AND	22	High	
			Mean sea lea level shoreline change (ft/year)	20	< 15 ft	> = 15 ft	> = 15 ft	23	Medium	
Maintenance	Not Challenging	3	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI
Clogging potential	Highly Challenging	3	Saturation Index		< 0	0 - 1	> 1	31	Low	default is highly challenging
			Turbidity (NTU)		< 10	10 - 25	> 25	28	Low	
Operation (Treatment) Challenges										
Fouling of treatment work	Not Challenging	1	SDI	1	< 2	2 - 5	> 5	29	Low	
Potential for poor feed water quality	Highly Challenging	1	feed water meets at least one of the criteria listed by DDW for extremely impaired source	Yes	No	N/A	Yes	30	Medium	
Potential Inland Interference										
Potential to interfere with groundwater pumping or injection	Highly Challenging	4	Inland groundwater level	above sea level	below sea level	N/A	above sea level	24	High	
Potential to mobilize contaminanted groundwater	Highly Challenging	3	Presence of contaminated groundwater in the vicinity	Yes	No	N/A	Yes	25	High	
Risk/Uncertainty										
Demonstrated success with similar capacity	Moderately Challenging	3	% of design capacity for existing systems	88%	> 100%	50% - 100%	< 50%	1	N/A	
Demonstrated success with similar number of units	Moderately Challenging	1	% of number of units for existing systems	63%	> 100%	50% - 100%	< 50%	1 12	Low	
Pilot test implementation	Not Challenging	5	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI

Appendix E
Subsurface Seawater
Intake Feasibility Screening Tool
Detailed Results
Slant Wells

Slant Wells						
Fatal Flaw						
Fatal Flaw	**Feasibility**	**Criteria**	**Value**	**Threshold for infeasibility**	**Input**	**Data Quality**
Land type at construction site	Potentially feasible	Depth to bedrock (ft)	200	< 100 ft	4	High
		Cliff and beach width (ft)	No Cliff and 400	Cliff and < 50 ft	2 and 5	High and Medium
		inlet	Inlet	No inlet	3	High
Available Beach front	Potentially feasible	Length of beach front needed (ft)	43,425	< 6450 ft	1 6 10 12	N/A Medium Low Low
Available area	Potentially feasible	Available area needed (Sq Ft)	17,802,000	< 60000 ft	1 7 11 12	N/A Medium Low Low

Appendix E
Subsurface Seawater
Intake Feasibility Screening Tool
Detailed Results
Slant Wells

Slant Wells

Signicant Challenges Scoring

Challenge	Challenge Score	Weight	Criteria	Value	Threshold			Input	Data Quality	Comments
					Not Challenging	**Moderately Challenging**	**Highly Challenging**			
Construction Challenges										
Available area for construction equipment	Not Challenging	1	Available area (Sq Ft)	463,000	> 50,000	10,000 - 50,000	< 10,000	9	Medium	
General complexity of construction	Moderately Challenging	4	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI
Topography at construction site	Not Challenging	2	Topography	flat	flat	moderately uneven	highly uneven	13	High	
Wave energy at construction site	N/A		Significant wave height (ft)	N/A	N/A	N/A	N/A			
Depth to seabed	N/A		Depth to seabed (ft)	N/A	N/A	N/A	N/A			
Land type at construction site	Not Challenging	4	Presence of cliff	No Cliff	No Cliff	N/A	Cliff	2	High	
			Beach Width (ft)	400	> = 200 ft	N/A	< 200 ft	5	Medium	
			Depth to bedrock (ft)	200	> = 200 ft	N/A	< 200 ft	4	High	
Operation (Intake) Challenges										
Geologic conditions	Moderately Challenging	5	Transmissivity (gpd/ft)	130,000	> 88,000	25,000 - 88,000	< 25,000	16	Medium	
			Leakance (1/d)	0.05	> 0.1	0.01 - 0.1	< 0.01	17	Medium	
Vulnerability to sea level rise	Not Challenging	2	Planned SSI infrastructure located within an area potentially impacted by sea level rise within 40 years	No	No	N/A	Yes	26	Low	
Beach stability	Highly Challenging	3	Beach nourished in the last 10 years	Yes	No AND	Yes OR	Yes AND	22	High	
			Mean sea lea level shoreline change (ft/year)	20	< 15 ft	> = 15 ft	> = 15 ft	23	Medium	
Maintenance	Highly Challenging	3	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI
Clogging potential	Moderately Challenging	3	Saturation Index		< 0	0 - 1	> 1	31	Low	default is moderately
			Turbidity (NTU)		< 10	10 - 25	> 25	28	Low	
Operation (Treatment) Challenges										
Fouling of treatment work	Not Challenging	1	SDI	1	< 2	2 - 5	> 5	29	Low	
Potential for poor feed water quality	Highly Challenging	1	feed water meets at least one of the criteria listed by DDW for extremely impaired source	Yes	No	N/A	Yes	30	Medium	
Potential Inland Interference										
Potential to interfere with groundwater pumping or injection	Highly Challenging	4	Inland groundwater level	above sea level	below sea level	N/A	above sea level	24	High	
Potential to mobilize contaminanted groundwater	Highly Challenging	3	Presence of contaminated groundwater in the vicinity	Yes	No	N/A	Yes	25	High	
Risk/Uncertainty										
Demonstrated success with similar capacity	Highly Challenging	3	% of design capacity for existing systems	6%	> 100%	50% - 100%	< 50%	1	N/A	
Demonstrated success with similar number of units	Highly Challenging	1	% of number of units for existing systems	10%	> 100%	50% - 100%	< 50%	1 12	Low	
Pilot test implementation	Moderately Challenging	5	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI

Appendix E
Subsurface Seawater
Intake Feasibility Screening Tool
Detailed Results
Radial Collector Wells

Radial Collector Wells

Fatal Flaw

Fatal Flaw	Feasibility	Criteria	Value	Threshold for infeasibility	Input	Data Quality
Land type at construction site	Potentially feasible	Depth to bedrock (ft)	200	< 25 ft	4	High
		Cliff and beach width (ft)	No Cliff and 400	Cliff and < 50 ft	2 and 5	High and Medium
		inlet	Inlet	No inlet	3	High
Available Beach front	Potentially feasible	Length of beach front needed (ft)	43,425	< 3763 ft	1	N/A
					6	Medium
					10	Low
					12	Low
Available area	Potentially feasible	Available area needed (Sq Ft)	17,802,000	< 60000 Sq Ft	1	N/A
					7	Medium
					11	Low
					12	Low

Appendix E
Subsurface Seawater
Intake Feasibility Screening Tool
Detailed Results
Radial Collector Wells

Radial Collector Wells

Signicant Challenges Scoring

Challenge	Challenge Score	Weight	Criteria	Value	Threshold			Input	Data Quality	Comments
					Not Challenging	Moderately Challenging	Highly Challenging			
Construction Challenges										
Available area for construction equipment	Not Challenging	1	Available area (Sq Ft)	463,000	> 50,000	10,000 - 50,000	< 10,000	9	Medium	
General complexity of construction	Moderately Challenging	4	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI
Topography at construction site	Not Challenging	2	Topography	flat	flat	moderately uneven	highly uneven	13	High	
Wave energy at construction site	N/A		Significant wave height (ft)	N/A	N/A	N/A	N/A			
Depth to seabed	N/A		Depth to seabed (ft)	N/A	N/A	N/A	N/A			
Land type at construction site	Not Challenging	4	Presence of cliff	No Cliff	No Cliff	N/A	Cliff	2	High	
			Beach Width (ft)	400	> = 200 ft	N/A	< 200 ft	5	Medium	
			Depth to bedrock (ft)	200	> = 50 ft	N/A	< 50 ft	4	High	
Operation (Intake) Challenges										
Geologic conditions	Highly Challenging	5	Transmissivity (gpd/ft)	20,000	> 88,000	25,000 - 88,000	< 25,000	16	Medium	
			Leakance (1/d)	0.10	> 0.1	0.01 - 0.1	< 0.01	17	Medium	
Vulnerability to sea level rise	Not Challenging	2	Planned SSI infrastructure located within an area potentially impacted by sea level rise within 40 years	No	No	N/A	Yes	26	Low	
Beach stability	Highly Challenging	3	Beach nourished in the last 10 years	Yes	No AND	Yes OR	Yes AND	22	High	
			Mean sea lea level shoreline change (ft/year)	20	< 15 ft	> = 15 ft	> = 15 ft	23	Medium	
Maintenance	Not Challenging	3	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI
Clogging potential	Moderately Challenging	3	Saturation Index		< 0	0 - 1	> 1	31	Low	default is moderately
			Turbidity (NTU)		< 10	10 - 25	> 25	28	Low	
Operation (Treatment) Challenges										
Fouling of treatment work	Not Challenging	1	SDI	1	< 2	2 - 5	> 5	29	Low	
Potential for poor feed water quality	Highly Challenging	1	feed water meets at least one of the criteria listed by DDW for extremely impaired source	Yes	No	N/A	Yes	30	Medium	
Potential Inland Interference										
Potential to interfere with groundwater pumping or injection	Highly Challenging	4	Inland groundwater level	above sea level	below sea level	N/A	above sea level	24	High	
Potential to mobilize contaminanted groundwater	Highly Challenging	3	Presence of contaminated groundwater in the vicinity	Yes	No	N/A	Yes	25	High	
Risk/Uncertainty										
Demonstrated success with similar capacity	Highly Challenging	3	% of design capacity for existing systems	8%	> 100%	50% - 100%	< 50%	1	N/A	
Demonstrated success with similar number of units	Highly Challenging	1	% of number of units for existing systems	0%	> 100%	50% - 100%	< 50%	1 12	Low	
Pilot test implementation	Moderately Challenging	5	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI

Appendix E
Subsurface Seawater
Intake Feasibility Screening Tool
Detailed Results
HDD Wells

HDD Wells

Fatal Flaw

Fatal Flaw	Feasibility	Criteria	Value	Threshold for infeasibility	Input	Data Quality
Land type at construction site	Potentially feasible	Depth to bedrock (ft)	200	< 10 ft	4	High
		Cliff and beach width (ft)	No Cliff and 400	Cliff and < 50 ft	2 and 5	High and Medium
		inlet	Inlet	No inlet	3	High
Available Beach front	Potentially feasible	Length of beach front needed (ft)	43,425	< 1750 ft	1	N/A
					6	Medium
					10	Low
					12	Low
Available area	Potentially feasible	Available area needed (Sq Ft)	125,042,000	< 2000000 Sq Ft	1	N/A
					8	Medium
					11	Low
					12	Low

Appendix E
Subsurface Seawater
Intake Feasibility Screening Tool
Detailed Results
HDD Wells

HDD Wells

Signicant Challenges Scoring

Challenge	Challenge Score	Weight	Criteria	Value	Threshold			Input	Data Quality	Comments
					Not Challenging	Moderately Challenging	Highly Challenging			
Construction Challenges										
Available area for construction equipment	Not Challenging	1	Available area (Sq Ft)	463,000	> 50,000	10,000 - 50,000	< 10,000	9	Medium	
General complexity of construction	Moderately Challenging	4	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI
Topography at construction site	Not Challenging	2	Topography	flat	flat	moderately uneven	highly uneven	13	High	
Wave energy at construction site	N/A		Significant wave height (ft)	N/A	N/A	N/A	N/A			
Depth to seabed	N/A		Depth to seabed (ft)	N/A	N/A	N/A	N/A			
Land type at construction site	Not Challenging	4	Presence of cliff Beach Width (ft) Depth to bedrock (ft)	No Cliff 400 200	No Cliff > = 200 ft > = 25 ft	N/A N/A N/A	Cliff < 200 ft < 25 ft	2 5 4	High Medium High	
Operation (Intake) Challenges										
Geologic conditions	Highly Challenging	5	Transmissivity (gpd/ft) Leakance (1/d)	5,000 0.15	> 88,000 > 0.1	25,000 - 88,000 0.01 - 0.1	< 25,000 < 0.01	16 17	Medium Medium	
Vulnerability to sea level rise	Not Challenging	2	Planned SSI infrastructure located within an area potentially impacted by sea level rise within 40 years	No	No	N/A	Yes	26	Low	
Beach stability	Highly Challenging	3	Beach nourished in the last 10 years Mean sea lea level shoreline change (ft/year)	Yes 20	No AND < 15 ft	Yes OR > = 15 ft	Yes AND > = 15 ft	22 23	High Medium	
Maintenance	Highly Challenging	3	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI
Clogging potential	Highly Challenging	3	Saturation Index Turbidity (NTU) Sedimentation rate (mm/yr)	 5 6	< 0 < 10 < 1 mm/yr	0 - 1 10 - 25 1 - 5 mm/yr	> 1 > 25 > 5 mm/yr	31 28 27	Low Medium Medium	default is highly challenging
Operation (Treatment) Challenges										
Fouling of treatment work	Moderately Challenging	1	SDI	3	< 2	2 - 5	> 5	29	Medium	
Potential for poor feed water quality	Highly Challenging	1	feed water meets at least one of the criteria listed by DDW for extremely impaired source	Yes	No	N/A	Yes	30	Medium	
Potential Inland Interference										
Potential to interfere with groundwater pumping or injection	N/A	4	Inland groundwater level	N/A	N/A	N/A	N/A			
Potential to mobilize contaminanted groundwater	N/A	3	Presence of contaminated groundwater in the vicinity	N/A	N/A	N/A	N/A			
Risk/Uncertainty										
Demonstrated success with similar capacity	Highly Challenging	3	% of design capacity for existing systems	35%	> 100%	50% - 100%	< 50%	1	N/A	
Demonstrated success with similar number of units	Not Challenging	1	% of number of units for existing systems	125%	> 100%	50% - 100%	< 50%	1 12	Low	
Pilot test implementation	Moderately Challenging	5	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI

Appendix E
Subsurface Seawater
Intake Feasibility Screening Tool
Detailed Results
Beach Infiltration Gallery

Beach Infiltration Gallery						
Fatal Flaw						
Fatal Flaw	**Feasibility**	**Criteria**	**Value**	**Threshold for infeasibility**	**Input**	**Data Quality**
Land type at construction site	Potentially feasible	Depth to bedrock (ft)	200	< 5 ft	4	High
		Cliff and beach width (ft)	No Cliff and 400	Cliff and < 50 ft	2 and 5	High and Medium
		inlet	Inlet	No inlet	3	High
Available Beach front	Potentially feasible	Length of beach front needed (ft)	43,425	< 1375 ft	1 6 10 12	N/A Medium Low Low
Available area	Potentially feasible	Available area needed (Sq Ft)	125,042,000	< 416667 Sq Ft	1 7 11 12	N/A Medium Low Low

Appendix E
Subsurface Seawater
Intake Feasibility Screening Tool
Detailed Results
Beach Infiltration Gallery

Beach Infiltration Gallery

Signicant Challenges Scoring

Challenge	Challenge Score	Weight	Criteria	Value	Threshold			Input	Data Quality	Comments
					Not Challenging	Moderately Challenging	Highly Challenging			
Construction Challenges										
Available area for construction equipment	Not Challenging	1	Available area (Sq Ft)	463,000	> 50,000	10,000 - 50,000	< 10,000	9	Medium	
General complexity of construction	Moderately Challenging	4	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI
Topography at construction site	Not Challenging	2	Slope	low slope	low	moderate	high	14	High	
Wave energy at construction site	Not Challenging	2	Significant wave height (ft)	2.5	< = 3 ft	N/A	> 3 ft	18	Medium	
Depth to seabed	N/A		Depth to seabed (ft)	N/A	N/A	N/A	N/A			
Land type at construction site	Not Challenging	4	Presence of cliff Beach Width (ft) Depth to bedrock (ft)	No Cliff 400 200	No Cliff > = 200 ft > = 15 ft	N/A N/A N/A	Cliff < 200 ft < 15 ft	2 5 4	High Medium High	
Operation (Intake) Challenges										
Geologic conditions	N/A		Transmissivity (gpd/ft) Leakance (1/d)	N/A N/A	N/A N/A	N/A N/A	N/A N/A			
Vulnerability to sea level rise	Not Challenging		Planned SSI infrastructure located within an area potentially impacted by sea level rise within 40 years	No	No	N/A	Yes	26	Low	
Beach stability	Highly Challenging	3	Beach nourished in the last 10 years Mean sea lea level shoreline change (ft/year)	Yes 20	No AND < 15 ft	Yes OR > = 15 ft	Yes AND > = 15 ft	22 23	High Medium	
Maintenance	Moderately Challenging	3	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI
Clogging potential	Highly Challenging	3	Turbidity (NTU) Sedimentation rate (mm/yr)	5 6	< 10 < 1 mm/yr	10 - 25 1 - 5 mm/yr	> 25 > 5 mm/yr	28 27	Medium Medium	default is not challenging
Operation (Treatment) Challenges										
Fouling of treatment work	Moderately Challenging	1	SDI	3	< 2	2 - 5	> 5	29	Medium	
Potential for poor feed water quality	Highly Challenging	1	feed water meets at least one of the criteria listed by DDW for extremely impaired source	Yes	No	N/A	Yes	30	Medium	
Potential Inland Interference										
Potential to interfere with groundwater pumping or injection	N/A		Inland groundwater level	N/A	N/A	N/A	N/A			
Potential to mobilize contaminanted groundwater	N/A		Presence of contaminated groundwater in the vicinity	N/A	N/A	N/A	N/A			
Risk/Uncertainty										
Demonstrated success with similar capacity	Highly Challenging	3	% of design capacity for existing systems	0%	> 100%	50% - 100%	< 50%	1	N/A	
Demonstrated success with similar number of units	Highly Challenging	1	% of number of units for existing systems	0%	> 100%	50% - 100%	< 50%	1 12	Low	
Pilot test implementation	Moderately Challenging	5	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI

Appendix E
Subsurface Seawater Intake Feasibility Screening Tool
Detailed Results
Seabed Infiltration Gallery

Seabed Infiltration Gallery

Fatal Flaw

Fatal Flaw	**Feasibility**	**Criteria**	**Value**	**Threshold for infeasibility**	**Input**	**Data Quality**
Land type at construction site	Potentially feasible	Depth to bedrock (ft)	200	< 5 ft	4	High
Available Beach front	N/A	Length of beach front needed (ft)	N/A	N/A	1	N/A
					6	Medium
					12	Low
Available area	Potentially feasible	Available area needed (Sq Ft)	125,042,000	< 416667 Sq Ft	1	N/A
					7	Medium
					11	Low
					12	Low

Appendix E
Subsurface Seawater
Intake Feasibility Screening Tool
Detailed Results
Seabed Infiltration Gallery

Seabed Infiltration Gallery

Signicant Challenges Scoring

Challenge	Challenge Score	Weight	Criteria	Value	Threshold			Input	Data Quality	Comments
					Not Challenging	Moderately Challenging	Highly Challenging			
Construction Challenges										
Available area for construction equipment	Not Challenging	1	Available area (Sq Ft)	463,000	> 50,000	10,000 - 50,000	< 10,000	9	Medium	
General complexity of construction	Highly Challenging	4	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI
Topography at construction site	Not Challenging	2	Slope	low slope	low	moderate	high	14	High	
Wave energy at construction site	Not Challenging	2	Significant wave height (ft)	2.5	< = 3 ft	N/A	> 3 ft	18	Medium	
Depth to seabed	Moderately Challenging	2	Depth to seabed (ft)	20	< 15 ft	15 - 50 ft	> 50 ft	15	Medium	
Land type at construction site	Not Challenging	4	Depth to bedrock (ft)	200	> = 15 ft	N/A	< 15 ft	4	High	
Operation (Intake) Challenges										
Geologic conditions	N/A		Transmissivity (gpd/ft)	N/A	N/A	N/A	N/A			
			Leakance (1/d)	N/A	N/A	N/A	N/A			
Vulnerability to sea level rise	N/A		Planned SSI infrastructure located within an area potentially impacted by sea level rise within 40 years	N/A	N/A	N/A	N/A			
Scouring	Not Challenging	3	Water depth at depth of closure (ft) Distance from the shore at depth of closure (ft)	5 500	< 10 ft < 1,000 ft	10 - 20 ft OR 1,000 - 2,000 ft	> 20 ft OR > 2,000 ft	20 21	Low Low	
Maintenance	Highly Challenging	3	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI
Clogging potential	Highly Challenging	3	Turbidity (NTU) Sedimentation rate (mm/yr)	5 6	< 10 < 1 mm/yr	10 - 25 1 - 5 mm/yr	> 25 > 5 mm/yr	28 27	Medium Medium	default is not challenging
Operation (Treatment) Challenges										
Fouling of treatment work	Moderately Challenging	1	SDI	3	< 2	2 - 5	> 5	29	Medium	
Potential for poor feed water quality	Highly Challenging	1	feed water meets at least one of the criteria listed by DDW for extremely impaired source	Yes	No	N/A	Yes	30	Medium	
Potential Inland Interference										
Potential to interfere with groundwater pumping or injection	N/A		Inland groundwater level	N/A	N/A	N/A	N/A			
Potential to mobilize contaminanted groundwater	N/A		Presence of contaminated groundwater in the vicinity	N/A	N/A	N/A	N/A			
Risk/Uncertainty										
Demonstrated success with similar capacity	Moderately Challenging	3	% of design capacity for existing systems	56%	> 100%	50% - 100%	< 50%	1	N/A	
Demonstrated success with similar number of units	Moderately Challenging	1	% of number of units for existing systems	69%	> 100%	50% - 100%	< 50%	1 12	Low	
Pilot test implementation	Highly Challenging	5	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI

Appendix E
Subsurface Seawater
Intake Feasibility Screening Tool
Detailed Results
Deep Infiltration Gallery

Deep Inifltration Gallery

Fatal Flaw

Fatal Flaw	**Feasibility**	**Criteria**	**Value**	**Threshold for infeasibility**	**Input**	**Data Quality**	
Land type at construction site	Potentially feasible	Depth to bedrock (ft)	200	< 5 ft	4	High	
		Cliff and beach width (ft)	No Cliff and 400	Cliff and < 50 ft	2 and 5	High and Medium	
Available Beach front	N/A	Length of beach front needed (ft)	N/A	N/A	1 6 12	N/A Medium Low	
Available area	Potentially feasible	Available area needed (Sq Ft)	125,042,000	< 46296 Sq Ft	1 7 12	N/A Medium Low	

Appendix E
Subsurface Seawater
Intake Feasibility Screening Tool
Detailed Results
Deep Infiltration Gallery

Challenge	Challenge Score	Weight	Criteria	Value	Threshold			Input	Data Quality	Comments
Deep Inifltration Gallery										
Signicant Challenges Scoring										
					Not Challenging	Moderately Challenging	Highly Challenging			
Construction Challenges										
Available area for construction equipment	Not Challenging	1	Available area (Sq Ft)	463,000	> 50,000	10,000 - 50,000	< 10,000	9	Medium	
General complexity of construction	Highly Challenging	4	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI
Topography at construction site	N/A		Slope	N/A	N/A	N/A	N/A			
Wave energy at construction site	N/A		Significant wave height (ft)	N/A	N/A	N/A	N/A			
Depth to seabed	N/A		Depth to seabed (ft)	N/A	N/A	N/A	N/A			
Land type at construction site	Not Challenging	4	Presence of cliff	No Cliff	No Cliff	N/A	Cliff	2	High	
			Beach Width (ft)	400	> = 200 ft	N/A	< 200 ft	5	Medium	
			Depth to bedrock (ft)	200	> = 25 ft	N/A	< 25 ft	4	High	
Operation (Intake) Challenges										
Geologic conditions	Highly Challenging	5	Transmissivity (gpd/ft)	12,000	> 88,000	25,000 - 88,000	< 25,000	16	Medium	
			Leakance (1/d)	0.06	> 0.1	0.01 - 0.1	< 0.01	17	Medium	
Vulnerability to sea level rise	N/A		Planned SSI infrastructure located within an area potentially impacted by sea level rise within 40 years	N/A	N/A	N/A	N/A			
Beach stability/Scouring	N/A		Beach nourished in the last 10 years	N/A	N/A	N/A	N/A			
			Mean sea lea level shoreline change (ft/year)	N/A	N/A	N/A	N/A			
Maintenance	Highly Challenging	3	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI
Clogging potential	Not Challenging	3	Saturation Index		< 0	0 - 1	> 1	31	Low	default is not challenging
			Turbidity (NTU)	5	< 10	10 - 25	> 25	28	Low	
Operation (Treatment) Challenges										
Fouling of treatment work	Moderately Challenging	1	SDI	3	< 2	2 - 5	> 5	29	Medium	
Potential for poor feed water quality	Highly Challenging	1	feed water meets at least one of the criteria listed by DDW for extremely impaired source	Yes	No	N/A	Yes	30	Medium	
Potential Inland Interference										
Potential to interfere with groundwater pumping or injection	N/A		Inland groundwater level	N/A	N/A	N/A	N/A			
Potential to mobilize contaminanted groundwater	N/A		Presence of contaminated groundwater in the vicinity	N/A	N/A	N/A	N/A			
Risk/Uncertainty										
Demonstrated success with similar capacity	Highly Challenging	3	% of design capacity for existing systems	35%	> 100%	50% - 100%	< 50%	1	N/A	
Demonstrated success with similar number of units	Highly Challenging	1	% of number of units for existing systems	0%	> 100%	50% - 100%	< 50%	1 12	Low	
Pilot test implementation	Highly Challenging	5	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI

APPENDIX F

Review of Existing Data and Proposed Site-Specific Investigations to Assess Feasibility of Horizontal Well Intakes

Geosyntec
consultants

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Memorandum

Date: 30 July 2015

To: Diane Gatza, West Basin Water District

From: Gordon Thrupp, PhD, PG, CHG and Al Preston, PhD, PE.
Geosyntec Consultants

Subject: Review of Existing Data and Proposed Site-Specific Investigations to Assess Feasibility of Horizontal Well Intakes, West Basin Water District El Segundo Desalination Project

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This memo presents a review of existing data and proposes site-specific field investigations and testing of the shallow sediments near the coastal margin in the vicinity of the NRG power plant to help evaluate the feasibility of horizontal directionally drilled (HDD) wells as subsurface intakes to provide 50 to 60 million gallons per day (mgd) of feedwater for a desalination (desal) facility at El Segundo. Geosyntec Consultants, Inc. (Geosyntec) has prepared this memorandum for West Basin Water District (WBWD).

HDD WELL DESIGN ELEMENTS

HDD wells can be installed beneath the seafloor from the shoreline. During the drilling of the pilot boring the drill head can be directed to the desired stratum or location. Groups of HDD wells can fan out at shallow depths beneath the seafloor from a common inland location.

Commonly, the pilot borings exit the seafloor and the casing and filter pipe is pulled back into the boring from offshore. Pulling the casing back into the boring facilitates installation of larger diameter filter pipe and casing than can be installed without exiting the seafloor. When casing and filter pipe are pulled back from offshore, typically the HDD well is completed with an access port in the sea floor, which can be an advantage for inspection and maintenance of the HDD wells. HDD wells installed without the pull-back method are typically relatively small in diameter and generally limited to lengths 1000 feet to 2000 feet.

A preliminary conceptual design for a group of HDD wells at the NRG facility[1], shows a group of 13 HDD wells (also called drains) extending approximately 2000 ft offshore, with the intake pipes (filter pipes) 0.5 m (~20 in) in diameter and lengths ranging from approximately 1400 to

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[1] 14 Jul 2015 email from P. Finley (Michael Baker International) to D. Gatza (WBWD)

1800 ft. The preliminary conceptual design shows a total length of approximately 22,200 feet for the filter intake portion of the HDD wells, which would be 20 to 40 feet below the seafloor. The preliminary design assumed 3374 gpm as an average intake rate for each of the 13 HDD wells.

The production capacity from an HDD well is dependent on the permeability of the overlying sediments comprising the seafloor. HDD wells potentially can have high yields if drilled beneath a highly permeable seabed. However, if the depth interval within which the HDD wells are completed is not well connected vertically to the overlying sea, the yields of HDD wells may be relatively low (e.g. Missimer et al., 2013). Testing and analysis should be performed to characterize the hydraulic properties of the subsurface, most importantly between the depth of the proposed HDD intakes and the seafloor. Potential methods of testing and analysis include soil borings, laboratory grain-size and permeability analysis, CPT borings and pore pressure dissipation testing, specific capacity tests, aquifer tests, geophysical surveys, and groundwater modeling.

SHALLOW SUBSURFACE CHARACTERISTICS

Available information on the characteristics of the shallow surface near the coastal margin in the vicinity of the proposed desal facility at El Segundo is summarized below and **Figure 1** shows the locations of borings, monitoring wells and sediment samples:

- Numerous borings and monitoring wells at the NRG and Chevron Refinery Facilities (e.g. CA RWQCB Geotracker website);
- 2 offshore borings ~1500 ft offshore to depths of ~40 feet below the seafloor (Dames and Moore, 1954 in Appendix G, El Segundo Power, 2000);
- 6 offshore “probings” 800 to 2500 ft offshore installed in to depths of approximately 10 to 25 feet below the seafloor (Dames and Moore, 1962 in Appendix G, El Segundo Power, 2000);
- 13 shallow seafloor samples 1000 to 6000 ft offshore (Fugro West 2004, 2007 in State Lands EIR for El Segundo Chevron Refinery, 2010); and
- 14 recent beach sand samples collected by Geosyntec July 2015.

Based on our review of these data, the subsurface near the coastal margin in the vicinity of the NRG facility to depths of approximately 100 ft below sea level appears to have a generally consistent stratigraphy which is summarized below:

Elevation of Top	*Elevation of Bottom*	*Description*	*Name*
Sea level and higher	35 to 50 ft bsl	Mainly fine-med sand (SP), locally some gravel and locally coarsening downward	"Old Dune Sand Aquifer"
35 to 50 ft bsl	40 to 60 ft bsl	Clay and Silt (CL & ML)	Manhattan Beach Aquitard
40 to 60 ft bsl	50 to 65 ft bsl	Fine-medium sand to gravelly sand (SP & SW)	Gage Aquifer
50 to 65 ft bsl	65 to 75 ft bsl	Clay and silty clay (CL)	El Segundo Aquitard
65 to 75 ft bsl	Bottom not defined by local borings	Gravelly sand with silt with clayey interbeds (GM with CL)	Silverado Aquifer

Figure 2 provides a schematic stratigraphic column and **Figure 3** is a local cross-section which shows the boring locations on which the stratigraphy is based. The boring logs used for the cross-section and other cross-sections are provided in **Attachment 1.**

Grain-size distribution for five samples of sea floor sand collected between distances of approximately 1000 and 6000 feet offshore along the Chevron Terminal Pipeline just north of the NRG facility show that the sea floor is consistently very fine to fine sand. The locations of the samples are shown on **Figure 1** and the grain-size data are shown by **Figure 4.** Hydraulic conductivities for the offshore sand samples calculated[2] from the grain-size data ranges from approximately 2 to 5 ft/d for a porosity of 0.3.

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[2] Hydraulic conductivities calculated using the Fair and Hatch (1933) and Barr (2001) methods as recommended for beach sand by Rosa et al (2014).

The clayey interval, which begins an elevation of approximately 40 to 50 feet below sea level (ft bsl), is an important factor in evaluating feasibility and conceptual design of HDD wells as intakes for the proposed desal plant at the NRG facility. This clayey interval may correlate with Manhattan Beach Aquitard, which occurs between the Old Dune Sand and the Gage Aquifers. However, some reports (e.g. TriHydro, 2015; Shaw 2007; El Segundo Power, 2000) indicate that Manhattan Beach Aquitard may not be present near coastline portion of the Chevron Refinery and beneath the northern portion of the NRG facility. Alternatively, this clayey interval may correlate with the El Segundo Aquitard, in which case the overlying sand may correlate with both the Old Dune Sand and Gage Aquifers. The El Sequndo Aquitard is reported to range in thickness from 5 to 15 feet with its basal elevation ranging from 35 to 55 ft bsl (Appendix G, El Segundo Power, 2000).

Although the stratigraphic correlation is uncertain, this low permeability clayey interval was encountered in five borings 800 to 1600 feet offshore of the NRG facility at depths of approximately 20 to 25 feet below the seafloor, and based on onshore borings it may be 5 to 10 feet thick. This shallow clayey interval may be a key limitation in the hydraulic connection between the ocean and HDD wells completed beneath it. The vertical hydraulic conductivity of the clayey interval is likely at least 100 to 1000 times lower than the horizontal hydraulic conductivity of the overlying very fine sand, which we estimate is in the order of 1 ft/d[3]. Note also, that the vertical hydraulic conductivity of sand is typically at least 10 times lower than the horizontal hydraulic conductivity due to stratification and textural geometry of the sediment.

As a consequence of much higher horizontal than vertical hydraulic conductivity, and particularly if HDD wells were completed below a clay interval, a significant portion, possibly the majority, of flow to the HDDs would be horizontal from large distances including beneath the NRG and Chevron Refinery where the groundwater is contaminated.

---

[3] The West Coast Basin Barrier Project (WCBBP) groundwater model is an additional source of information about the hydraulic conductivity of the coastal margin subsurface. The value assigned to the upper most layers of WCBBP groundwater model in the vicinity of the NRG facility is in the range of 1 to 10 ft/d (Figure 5, Geoscience, 2009). However, the 2009 model update report does not report the assigned values of vertical hydraulic conductivity in the model.

PROPOSED INVESTIGATIONS AND TESTING

Proposed additional site-specific investigation of the shallow subsurface characteristics including the extent and continuity of the shallow clay layer offshore is discussed below. **Table 1** provides a cost breakdown for each proposed investigation method.

On-Shore CPT and pore pressure dissipation testing

We propose installation of three cone penetrometer testing (CPT) borings to depths of approximately 100 feet at three locations along the coastal margin in the NRG facility. The three proposed CPT boring locations are shown on **Figure 1**. The CPT borings will provide high resolution characterization of the subsurface stratigraphy and pore-pressure dissipation testing will be conducted to measure permeability at approximately 10 ft intervals and at selected depths. The CPT borings will help to determine if that the clayey interval at 40 to 50 ft bsl elevation is present at the northern extent of the NRG facility.

The cost estimate for three CPT borings, which can likely be completed in one day is approximately $15,000. We will schedule the CPT borings as soon as NRG authorizes access.

One or more additional locations approximately 1000 feet and further north may also be helpful to evaluate presence of the clayey interval further to the north along the coastline. One or two additional CPT locations would likely increase cost by approximately $12,000.

Offshore Sub-bottom Profiling Geophysical Survey

We propose an offshore sub-bottom profiling geophysical survey to characterize the shallow offshore stratigraphy and specifically the extent and continuity of the clay interval at 40 to 50 ft bsl elevation, which as discussed above is encountered at depths of approximately 20-ft below the seafloor by borings 1500 ft offshore of the NRG facility. We recommend simultaneous use of (1) an Edge Tech SB-512 sub-bottom profiling system, which is a specialized single channel seismic reflection survey that provides high resolution imaging of the shallow subsurface, and (2) an Applied Acoustics boomer system, which is a multi-channel seismic reflection survey that uses an 8-channel GEOEEL hydrophone array ("streamer") to image deeper offshore stratigraphy and geologic structure (likely to depths greater than 200 ft).

Figure 1 shows the approximate locations for five proposed geophysical survey lines (20,000 feet total), which likely can be run in one day. Note that because the seismic reflection surveys uses an acoustic energy source, a permit is required from the California State Lands Commission (CSLC). To expedite the survey we will contract with a company such as Fugro or EcoSystems Management Associates (Eco-M) that already has the required permits with the CSLC. The estimated cost to for the offshore geophysical surveys, including permitting, processing and reporting of the geophysical surveys, and Geosyntec collaboration and oversight is approximately $77,000 as detailed in Table 1.

Vibracores

To further characterize the shallow subsurface beneath the seafloor and help evaluate the presence and extent of the clay interval at an elevation of approximately 40 to 50 ft bsl, we tentatively propose a minimum of three vibracores to depths of approximately 25 feet. Tentative proposed locations are shown on **Figure 1.** Note however that the actual locations and need for vibracore samples would be based on the findings of the geophysical survey and evaluation of technical feasibility of HDD installations at optimal depths based on the geophysical survey results.

A preliminary cost estimate for one day of vibracore samples (likely 3 locations) is $33,500.

This cost is based on obtaining vibracores to depths of approximately 20 feet; vibracores to depths greater than 20 feet may be more costly. We are exploring options with contractors to cost-effectively reach depths of 25 to 30 feet.

Shallow seafloor sediment sampling

Also as a potential follow-up to the geophysical survey, we tentatively propose collecting samples of seafloor sediment and conducting laboratory grain-size analyses to estimate the hydraulic conductivity. Samples can either be collected using a sampling tool from a boat or by divers.

If the seafloor samples are collected from a boat in conjunction with vibracore sampling the additional cost to collect and analyze shallow samples (1 to 2 ft) from approximately 6 locations, which would take one day, is approximately $13,000.

As a separate mob (not in conjunction with vibracores), the cost to collect and analyze shallow samples (1 to 2 ft) from approximately 6 to 10 locations using a boat, which would take one day, is approximately $27,000.

Another alternative is for divers to collect shallow seafloor samples. The cost for divers to collect sea floor sand samples at 15 locations in depths of water between 10 to 30 feet is approximately $22,000 including laboratory analytical fees. Tentative shallow sea floor sampling locations are shown on **Figure 1.**

On 8 July 2014 Geosyntec collected 14 samples of surficial sand (upper six inches) from the beach adjacent to and extending approximately 500 feet north of the NRG facility. **Figure 1** shows the locations of the sand samples: 7 samples were collected above the approximately mean high tide level and 7 were collected from the seafloor in the surf zone. Based on visual inspection, the sand samples are consistently poorly graded (well sorted) very fine to fine sand.

Laboratory grain-size analyses of composite samples (one from the above the beach above mean high tide and one from the the surf zone) and a permeability test on a composite sample from the surf zone are in progress. The approximate cost for the laboratory analyses is $1000.

The results of the analyses of the surficial sand samples, which will be compared to existing results for offshore sea floor samples, likely provide estimates of maximum hydraulic conductivity for the near shore shallow sea floor sediments.

DISCUSSION AND RECOMMENDATIONS

We recommend two phases of site-specific investigation and testing.

Phase 1 includes the onshore CPT and pore pressure dissipation tests (permeability measurements, and offshore geophysical survey. We recommend doing Phase 1 as soon as possible. Based on discussion and WBWD approval, subcontracting of the offshore geophysical survey is in progress. The survey requires a 3-week public notification period before the work can be done, so the geophysical survey will likely take place in August or early September. The CPT borings at the NRG facility will be scheduled as soon as NRG authorizes access.

Details of Phase 2 including locations of potential vibracores and seafloor samples will be based on findings of the geophysical survey and CPT borings. Initial findings of the geophysical survey will be available during the survey and will be summarized within days of completing the survey, prior to final processing and reporting. We will provide WBWD with an updated recommendations and costs for Phase 2 investigations within one week of completion of the geophysical survey.

As summarized by **Table 1**, the estimated cost to conduct Phase 1 is approximately $95,000 including permitting, contractor costs, contractor reporting, and oversight and project management by the Geosyntec Team. The estimated cost to conduct Phase 2 is approximately

$46,000, however, as discussed above, an updated recommendation for Phase 2 investigation will be based on the Phase 1 results.

We also recommend groundwater modeling to help evaluate the feasibility and preliminary design of HDD collector wells. The modeling would help to estimate the production potential of HDDs and provide quantitative estimates of portions of water that would be derived from the sea and from inland for different possible locations of the HDD wells and a range of hydrogeologic conditions.

Because a low permeability clayey interval approximately 20 feet below the seafloor is likely a significant limitation to production potential from HDD wells at depths of 20 to 40 feet, we recommend consideration of the technical feasibility of installing HDD wells within 20 feet of the seafloor.

REFERENCES

Barr, DW, 2001, Coefficient of permeability determined by measurable parameters, Ground Water, vol 39, pp 356-361.

California State Lands Commission, 2010, Public Draft Environmental Impact Report (EIR) for the Chevron El Segundo Marine Terminal Lease Renewal Project.

El Segundo Power, 2000, Application for Certification, submitted to the California Energy Commission, Appendix G: Geotechnical Report, El Segundo Power Redevelopment Project.

Fair GM and LP Hatch, 1933, Fundamental factors governing the stream-line flow of water through sand, Journal of American Water Works Association, vol 25, pp 1551-1565.

Geoscience Support Services, 2009, 2008 Model Update Report, West Coast Basin Barrier Project, prepared for West Basin Municipal Water District, 27 March 2009.

Missimer, TM, Ghaffour, N, Dehwah, AHA, Rachman, R, Maliva, RG, Amy, G, 2013. “Subsurface intakes for seawater reverse osmosis facilities: Capacity limitation, water quality improvement, and economics.” Desalination, Volume 322, pp. 37–51.

Rosas J, O Lopez, TM Missimer, KM Coulibaly, AHA Dehwah, K Sesler, LR Lujan, D Mantilla, 2014, Determination of hydraulic conductivity from grain-size distribution for different depositional environments, Groundwater, vol 52, pp 399 – 413.

Shaw Environmental, 2007, Revised Draft Remedial Investigation Workplan, El Segundo Power Redevelopment Project, El Segundo Generating Station, 301 Vista Del Mar, El Segundo, California, August 2007

Trihydro, 2015, Liquid hydrocarbon recovery project, Annual report for 2014, Chevron Products Company, El Sequndo Refinery, El Segundo, California, 13 February 2015.

URS, 2013, Summary report for decommissioning of Chevron El Segundo Off-Site Groundwater Observation and Soil Vapor Monitoring Wells Located at LADWP Scattergood Generating Station Site, Playa Del Rey/El Segundo, California, 17 April 2013.

Table 1

Cost Estimates for Proposed and Tentative Site-Specific Field Investigations

Review of Existing Data and Proposed Site-Specific Investigations to Assess Feasibility of Horizontal Well Intakes

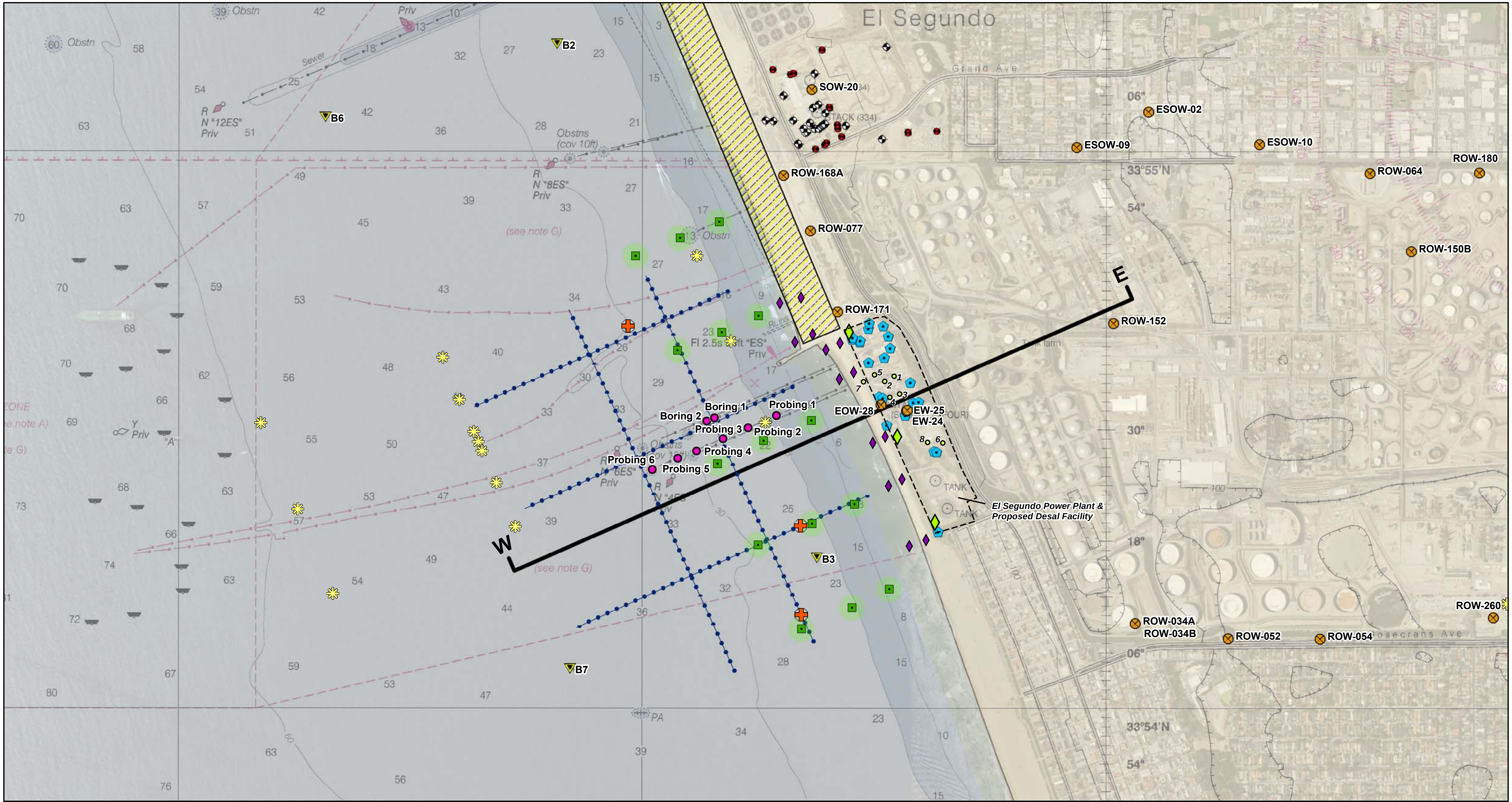
West Basin Water District El Segundo Desalination Project

TASKS	Geosyntec Team Hours	Geosyntec Team Labor and Expenses	Contractor Costs	Total Costs	Comments and Schedule
On shore CPT borings and pore pressure disp testing	43	$6,405	$8,640	$15,045	High priority to characterize coastal margin stratigraphy and measure local permeability and serveral depths. 1 - 2 Days Field Work. Expect completion within 3 weeks of authorization
(3 locations to 100 ft at NRG)					
Offshore Geophysical Survey: simultaneous Subbottom profiling (Chirp) and deeper muti-channel seismic reflection (boomer)	61	$10,743	$66,204	$76,947	Cost includes permitting and marine mammal observer. High priority to characterize offshore stratigraphy and investigate extent of 20-ft clayey interval. 1 - 2 Days Field Work. 3 weeks wait period following public notice. Anticipate completion within 6 weeks of authorization.
1 day, 5 lines (20,000 ft),Requires State Lands Permit					
Offshore Vibracore 3 -4 locations to ~20 ft	45	$7,569	$25,920	$33,489	Details including locations to be finalized after geophysical survey. 1 to 2 Days. No permits needed
Shallow seafloor sediment sampling and PSD analyses					
Analyze Beach and Shallow Surf Zone Sand Samples (7 pairs)	12	$2,101	$1,054	$3,155	Sampling done, analysis in progress
Option 1. Grab Samples from boat (~15 locations) Fugro	25	$4,308	$13,759	$18,068	
Option 2. Sample from boat (~6 locations) Kinnetic with Vibracore	25	$4,308	$8,424	$12,732	Recommended if Vibracore also conducted. 1 day. No permits needed.
Option 2b. Sample from boat (~6 locations) Kinnetic w/o Vibracore	24	$4,096	$22,680	$26,776	
Option 3. Divers sample seafloor sed (**15 shallow cores**)	28	$4,624	$17,042	$21,666	
*** Subcontractor rates include 8% mark-up**					

$95,147 **Phase 1: Onshore CPT and Offshore Geophysical Survey and Beach Samples**

$46,221 **Phase 2: Vibracore and sea floor samples**

Estimated Total **$141,369**



Legend

- ✳ Offshore Seafloor Sediment Sample Location *(State Lands EIR, Chevron El Segundo Refinery, 2010; Fugro West 2004, 2007.)*
- ◆ Beach and Surf-Zone Sand Sample (July 2015)

Tentative Proposed Locations

- 🟩 Shallow Sample (0-2 ft)
- ◆ CPT with Permeability testing (onshore) (~100 ft)
- ✚ Vibracore (~20 ft)
- •–•–• Seismic Reflection Lines

- ▼ B7 Benthic Station Location*
- ○ *8* Dames & Moore Boring (1962)*
- ⊗ ROW-052 Monitoring Well Location**
- ● Probing 6 Boring (1954)/Probing (1962) Location*

- ◆ Scattergood Monitoring Well ***
- ● Decommissioned Scattergood Monitoring Well ***
- ⬟ El Segundo Energy Center Monitoring Well****

- ▨ Western Snowy Plover Critical Habitat
- W ━━ E Cross-Section

N

0 1,000 Feet

Source:
* El Segundo Power, II LLC, 2000. Application for Certification Submitted to the California Energy Commission, El Segundo Power Redevelopment Project. Appendix G.
** Geotracker, Chevron El Segundo Refinery, Site # SL372482441
*** Chevron Decommissioning Wells Report
**** Shaw Environmental, Groundwater Well Map

Existing, Former, and Proposed Offshore Investigation Locations

Subsurface Seafloor Desalination Intake Study
West Basin Municipal Water District

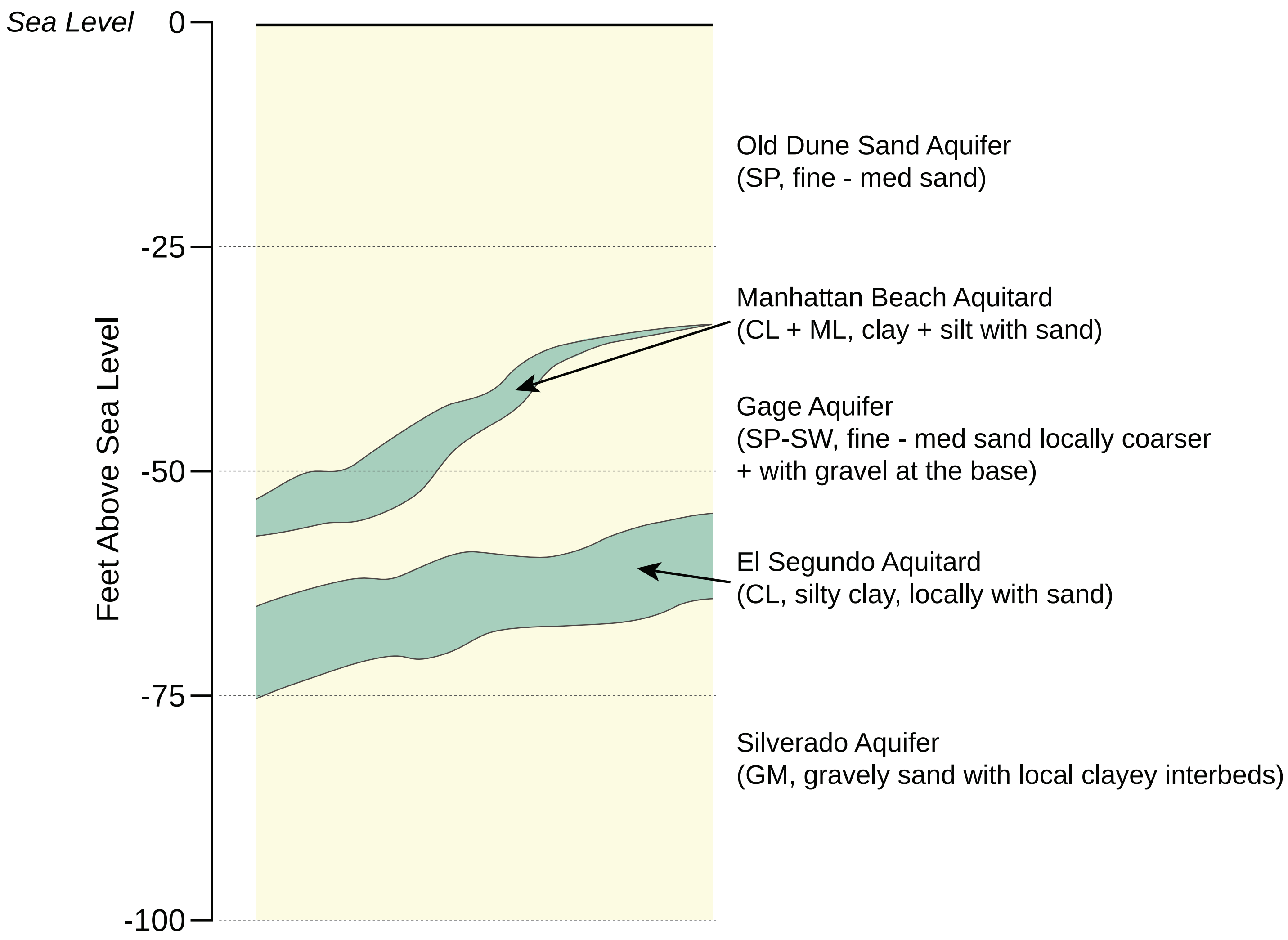
Geosyntec
consultants

LA0324

July 2015

Figure
1

P:\GIS\WestBasinMWD\Project\2015Jul\PropSeaSamps\Fig01_El_Segundo_Proposed_Borings_SeismicLines.mxd 7/16/2015 4:25:00 PM



Legend

🟨 Coarse Grained Material

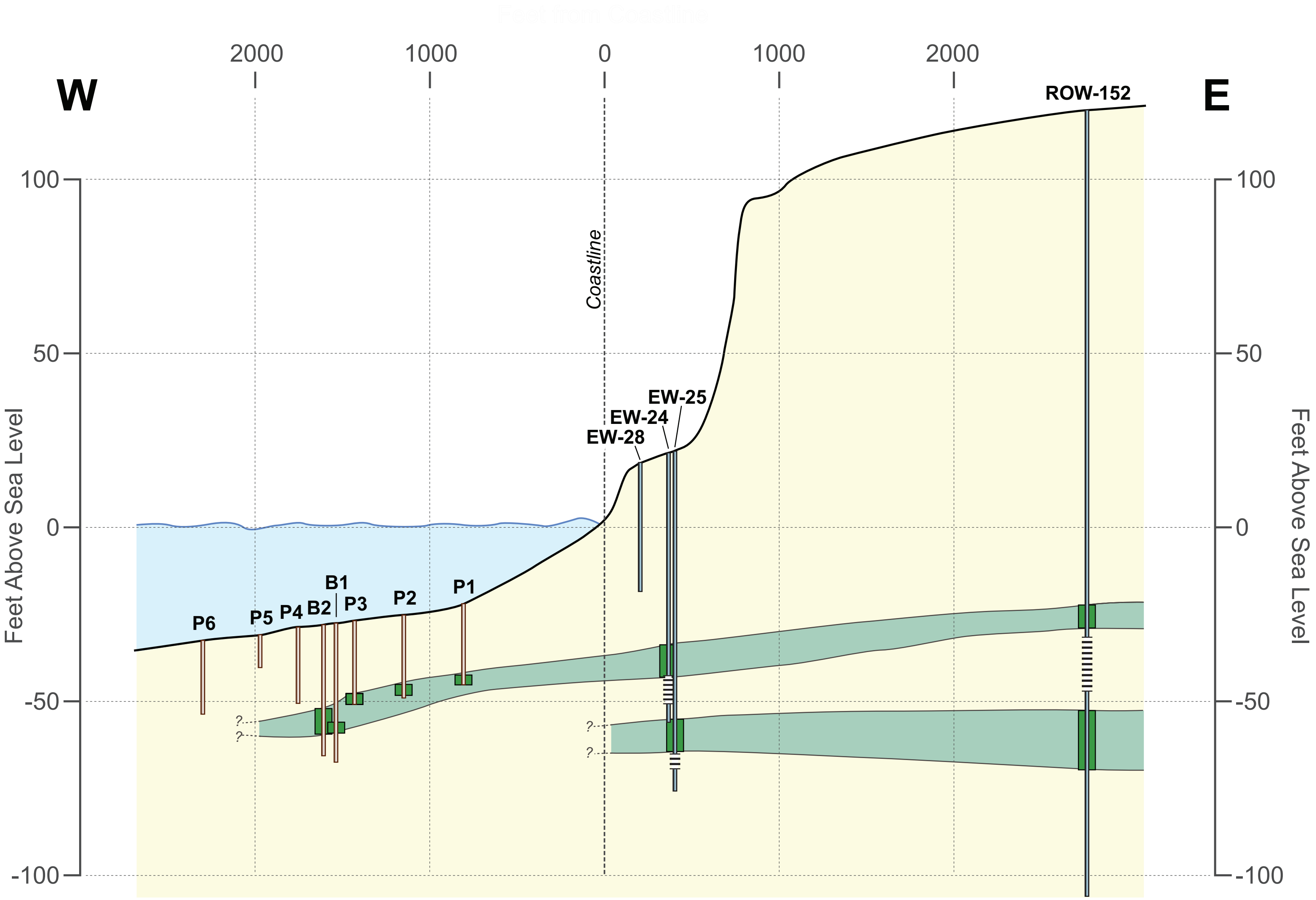
🟩 Fine Grained Material

Schematic Stratigraphic Column
El Segundo Coastal Margin

Subsurface Seawater Intake Study
West Basin Municipal Water District

Geosyntec
consultants

LA0324	October 2015	**Figure 2**



Legend

🟨 Coarse Grained Material

🟩 Fine Grained Material

B2 Soil Boring

Soil Log Indicating Fine Grained Material

EW-24 Extraction Well

Well Screen

Note:
Cross-section location shown on Figure 3.1.

Cross-Section
El Segundo Vicinity

Subsurface Seawater Intake Study
West Basin Municipal Water District

Geosyntec consultants

Figure

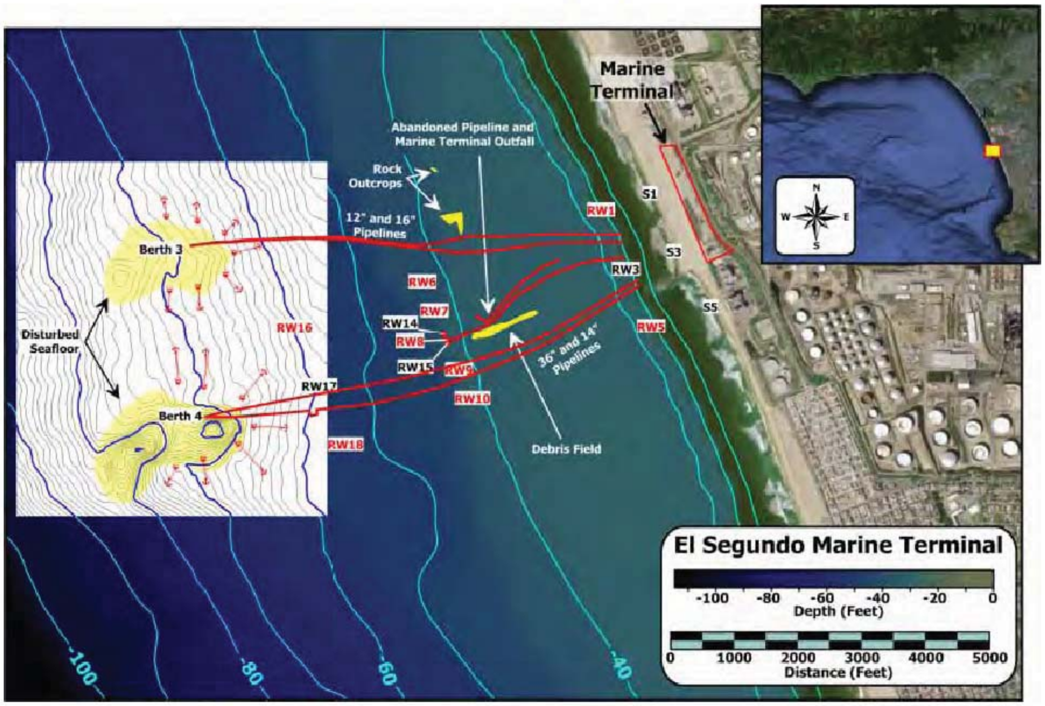
3

LA0324

October 2015

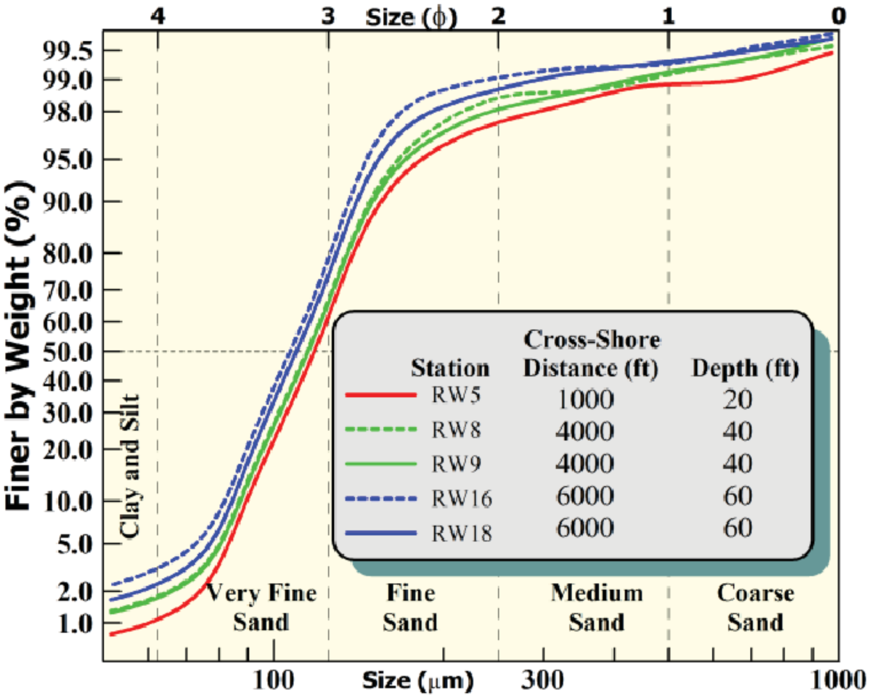
P:\GIS\WestBasinMWD\Project\2015Oct\Fig3_3_Cross-Section.ai

NPDES Monitoring Stations, Seafloor Bathymetry, and Berth Configurations



Source: Fugro West, Inc. 2004, 2007

Grain-Size Distributions along the Marine Terminal Pipeline Corridor



Note: Figure 4.2-6 shows station locations.
Source: Chevron 2007d

Note:
Adapted from State Lands EIR, El Segundo Refinery, 2010.

Sea Floor Sediment Sample Locations and Grain-Size Analyses

Subsurface Seawater Intake Study
West Basin Municipal Water District

Geosyntec
consultants

LA0324

July 2015

Figure

4

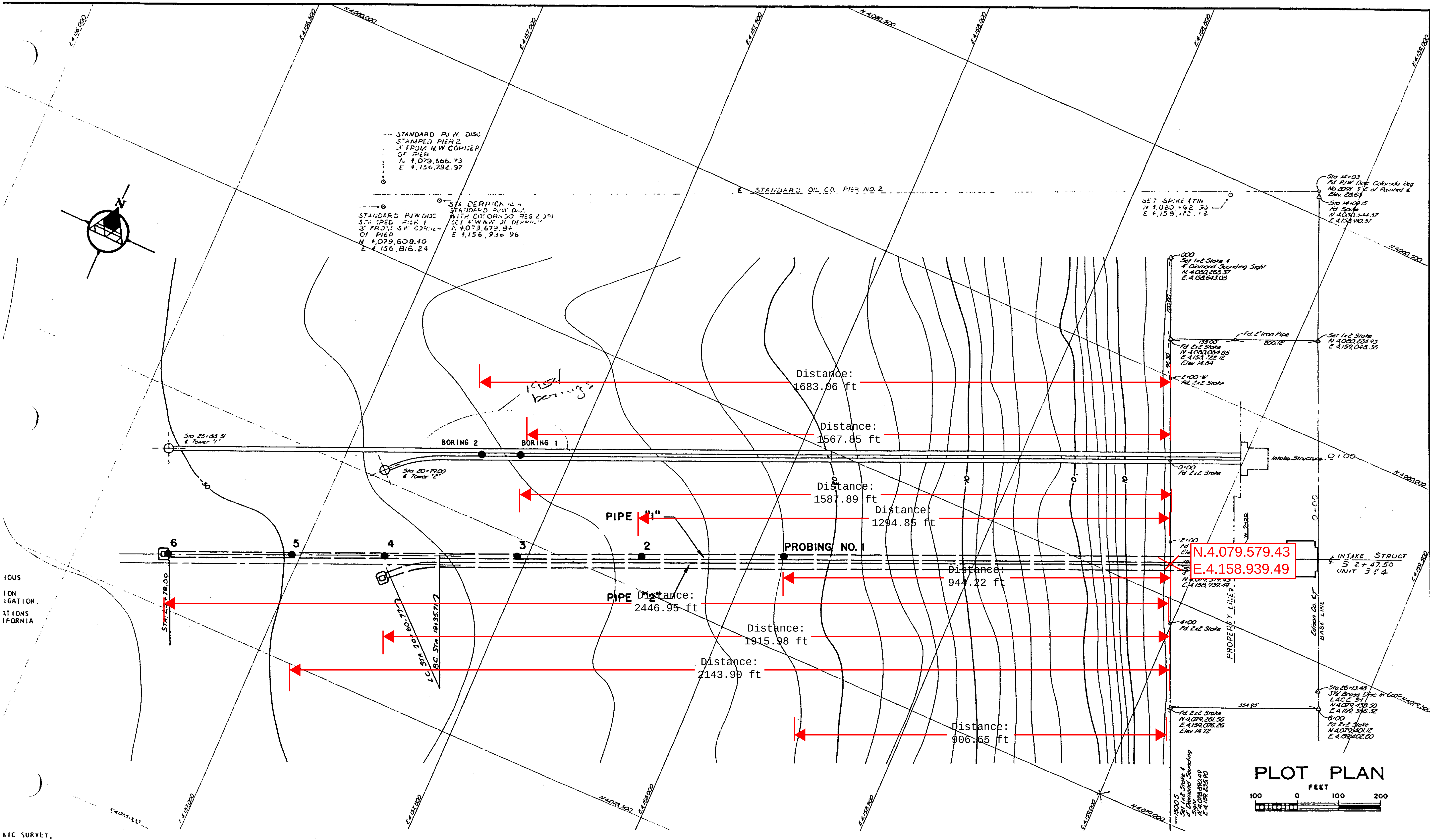
Attachment 1

Map of offshore borings, two onshore boring logs, and cross-sections

Sources:

El Segundo Power, 2000, Application for Certification, submitted to the California Energy Commission, Appendix G: Geotechnical Report, El Segundo Power Redevelopment Project.

California Regional Water Board Geotracker Web Site:
Chevron El Segundo Refinery (SL372482441)
http://geotracker.waterboards.ca.gov/profile_report.asp?global_id=SL372482441



PLOT PLAN

FEET

100 0 100 200

DAMES & MOORE

SOIL MECHANICS ENGINEERS

PLATE I

LOG OF BORING 1&2

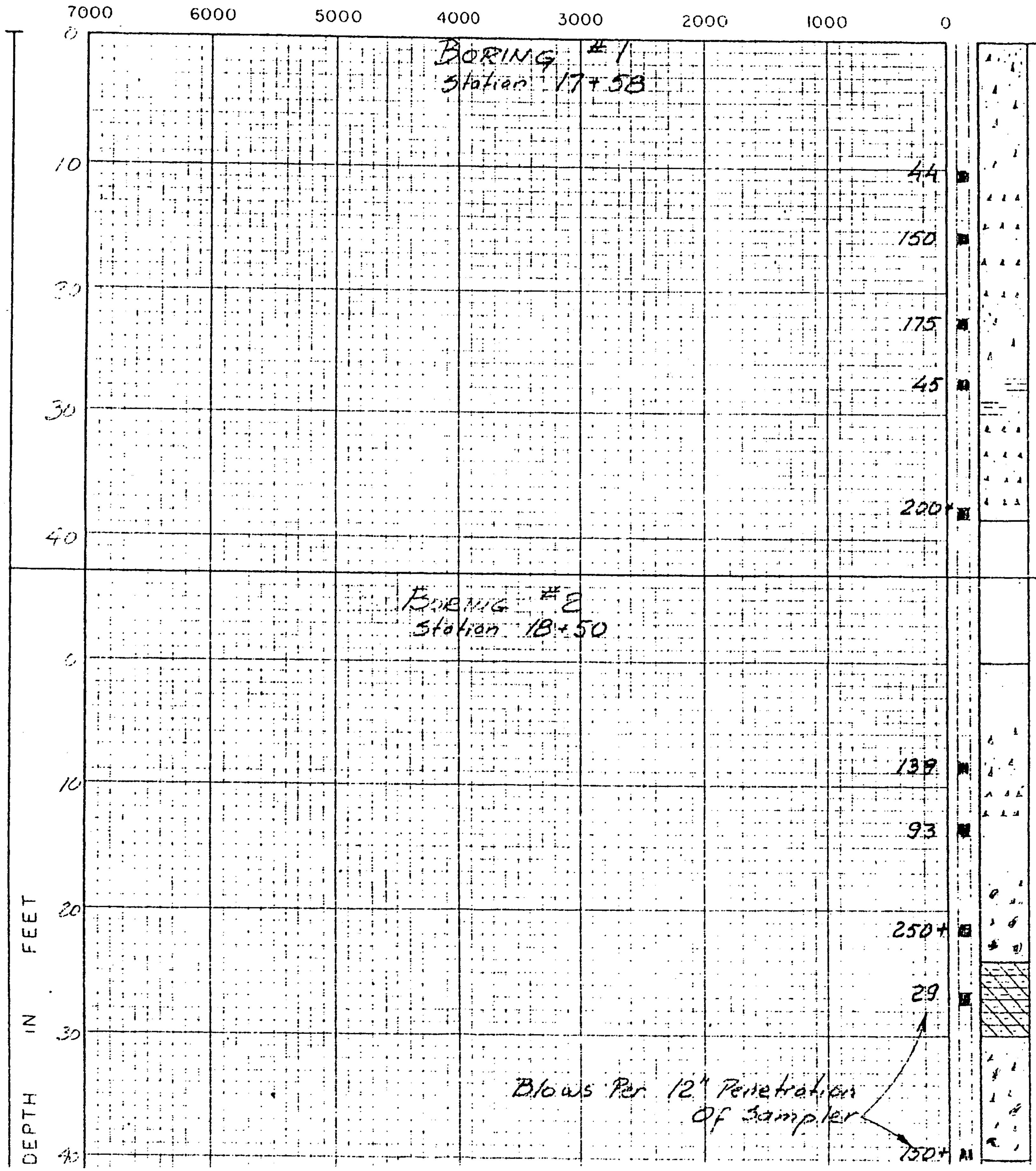
SHEET ____ OF ____ SHEET

PLOTTED BY ______ DATE ______
CHECKED BY ______ DATE ______

JOB NUMBER [illegible]
JOB NAME [illegible]

DATUM)

SHEARING STRENGTH AND FRICTIONAL RESISTANCE IN POUNDS PER SQUARE FOOT



ELEVATION -27'

LIGHT BROWN MEDIUM SAND AND GRAVEL (SHELLS)

GRADING TO LIGHT BROWN MEDIUM SAND WITH LENSES OF GRAVEL

GRADING TO GREY MEDIUM TO COARSE SAND

LENSES OF BLUISH GREY SILTY CLAY

GRADING TO LAMINATIONS OF BROWN MEDIUM SAND AND GRAVEL

ELEV: -24'

BROWN FINE TO MEDIUM SAND

GRADING TO BROWN MEDIUM SAND WITH GRAVEL

(LENSES OF GRAVEL)

GRADING TO COARSE SAND

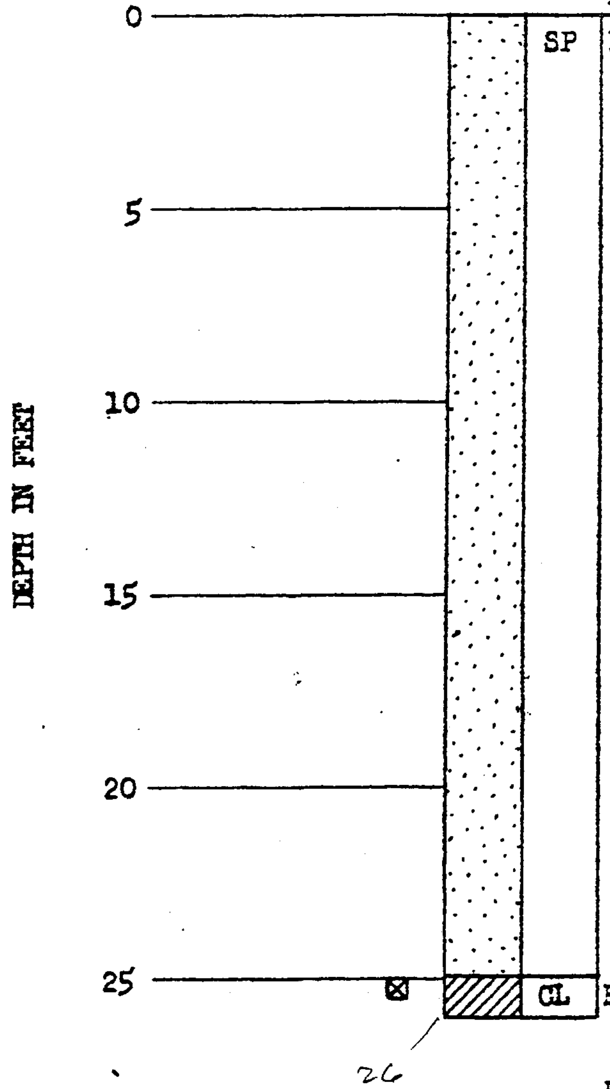
GRAVEL AND COBBLES

MOTTLED BROWN AND GREY SILTY CLAY LOAM

GREY COARSE SAND WITH GRAVEL AND COBBLES

PROBING NO. 1

ELEVATION: -22.2 FEET



BROWN FINE TO MEDIUM SAND WITH SOME GRAVEL

-47.2

JET PIPE COULD NOT PENETRATE BELOW 26'

BROWN SILTY CLAY (FIRM)
COULD NOT PROBE BELOW 26'

BORING COMPLETED - 7/10/62

LOG OF PROBING

KEY:

☒ INDICATES DEPTH OF DISTURBED SAMPLE
☐ INDICATES DEPTH OF SAMPLING ATTEMPT WITH NO RECOVERY

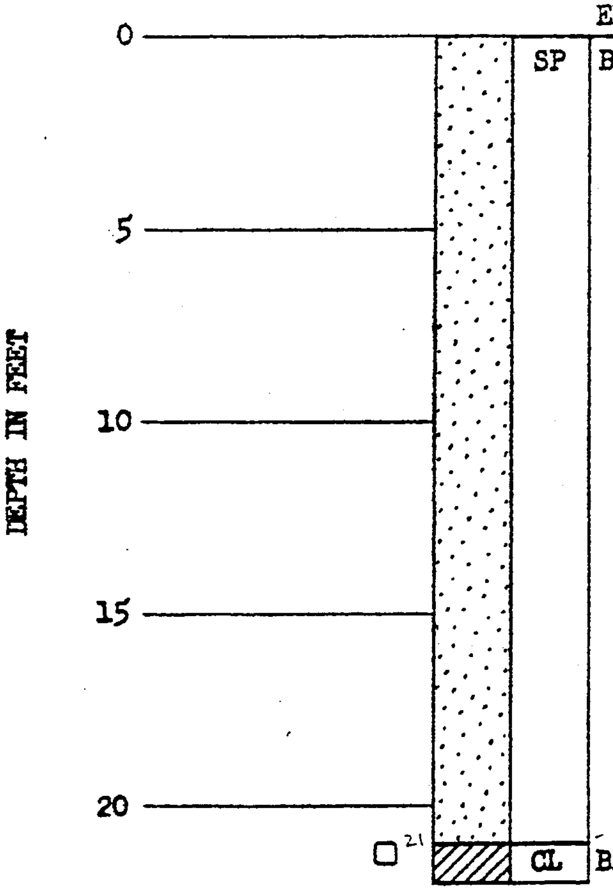
ELEVATIONS REFER TO M.L.L.W. DATUM

DAMES & MOORE
APPLIED EARTH SCIENCES

REVISIONS
BY ______ DATE ______
FILE 377-027 Calif. Edison Co.
BY U.A.M. DATE 1-17-62
CHECKED BY ______

PROBING NO. 2

ELEVATION: -25.7 FEET



BROWN FINE TO MEDIUM SAND WITH SOME GRAVEL

MORE GRAVEL WITH INCREASING DEPTH

LARGE GRAVEL DROPPING TO BOTTOM OF
PROBING AS SAND IS WASHED OUT BY JET

-46.7

BROWN SILTY CLAY (FIRM)
COULD NOT PROBE BELOW 22'

BORING COMPLETED - 7/10/62

LOG OF PROBING

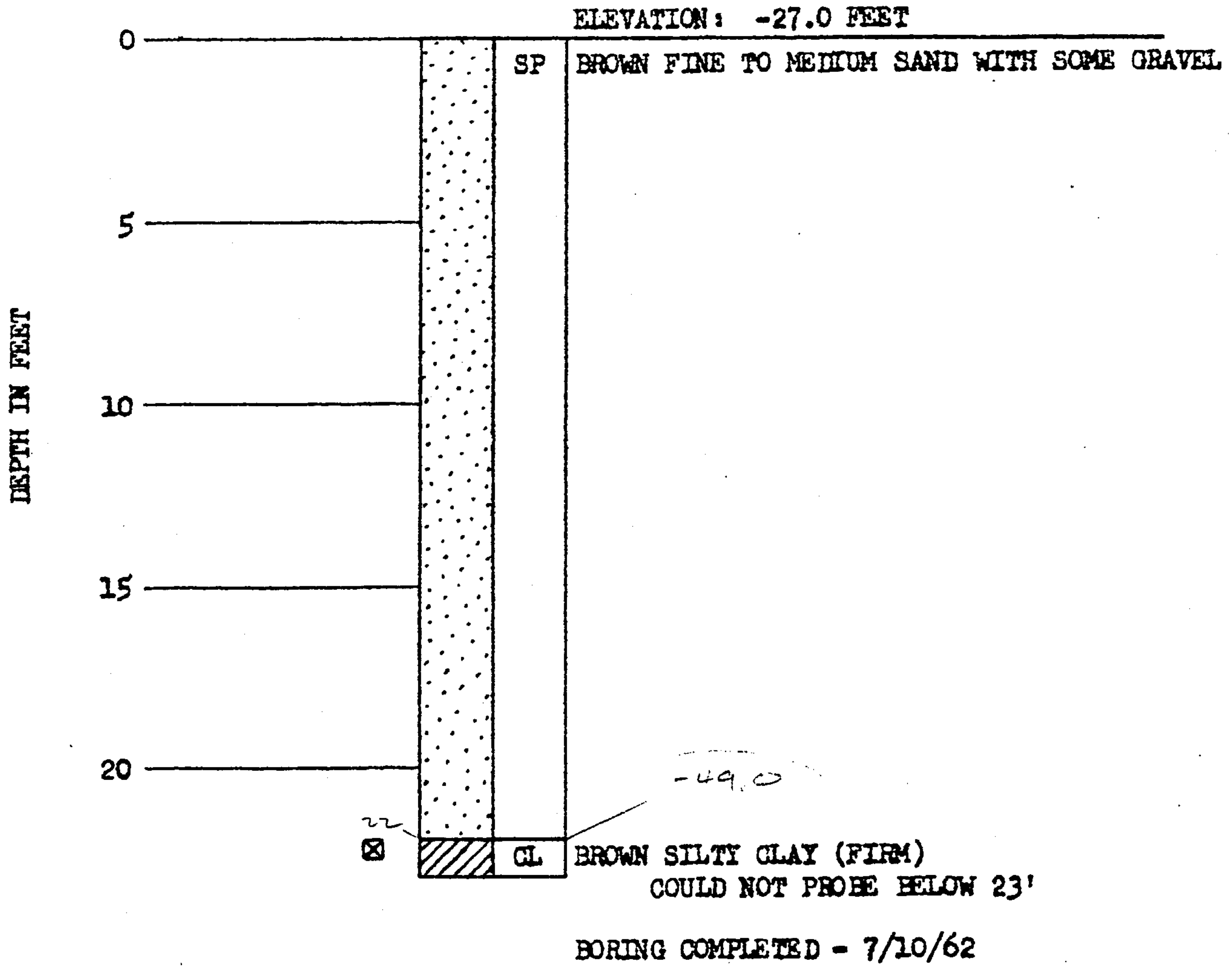
REVISIONS
BY ____ DATE ____

Calif Edison Co.

FILE 377-027

BY D.A.M. DATE 7-17-62
CHECKED BY ____

PROBING NO. 3



BORING COMPLETED - 7/10/62

LOG OF PROBING

REVISIONS BY ______ DATE ______

FILE 377-022 Calif Edison Co.

BY D.A.M. DATE 7-17-62

CHECKED BY ______

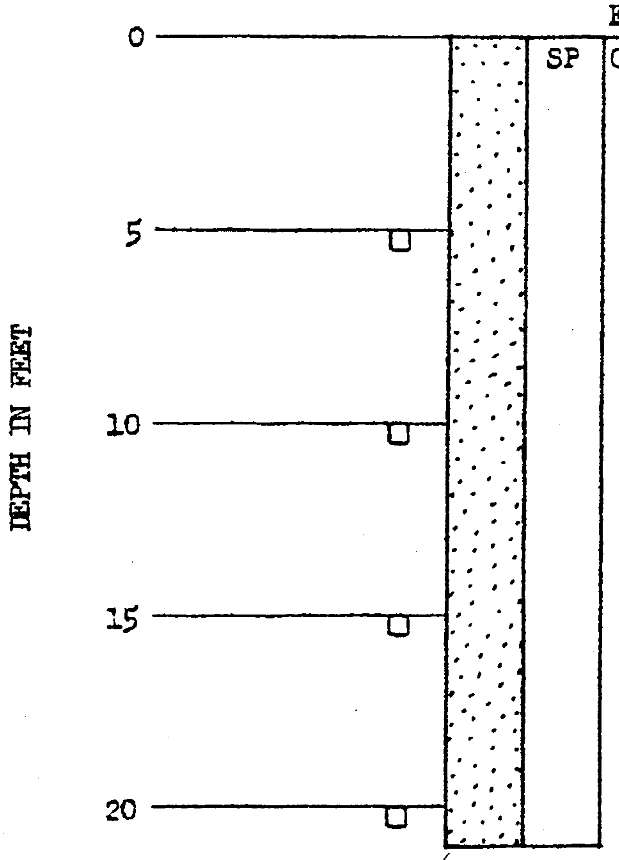
REVISIONS BY ______ DATE ______

FILE 377-027 Calif Edison Co.

BY R.A.M. DATE 7-17-62
CHECKED BY ______

PROBING NO. 4

ELEVATION: -29.2 FEET



GRAY FINE TO MEDIUM SAND

GRADING TO BROWN MEDIUM TO COARSE SAND WITH MUCH GRAVEL

GRAVEL TO AT LEAST 1" ø

LARGE GRAVEL DROPPING TO BOTTOM OF PROBING AS SAND IS WASHED BY JET

COULD NOT PROBE BELOW 21'

BORING COMPLETED - 7/10/62

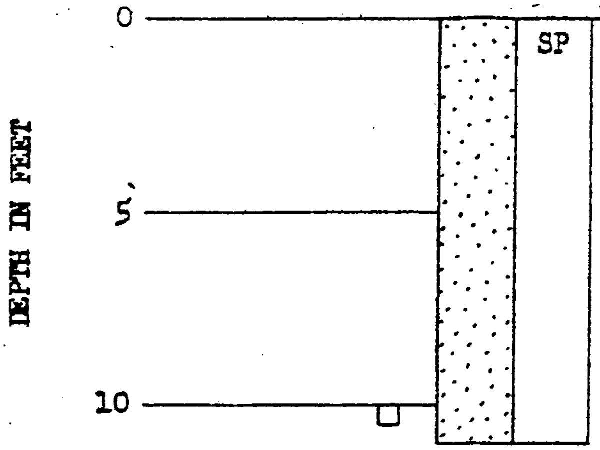
No Clay
to-50.2

LOG OF PROBING

DAMES & MOORE
APPLIED EARTH SCIENCES

PROBING NO. 5

ELEVATION: -29.7 FEET



GRAY FINE TO MEDIUM SAND WITH SOME SMALL SHELLS & GRAVEL

GRADING TO BROWNISH GRAY MEDIUM TO COARSE SAND WITH GRAVEL

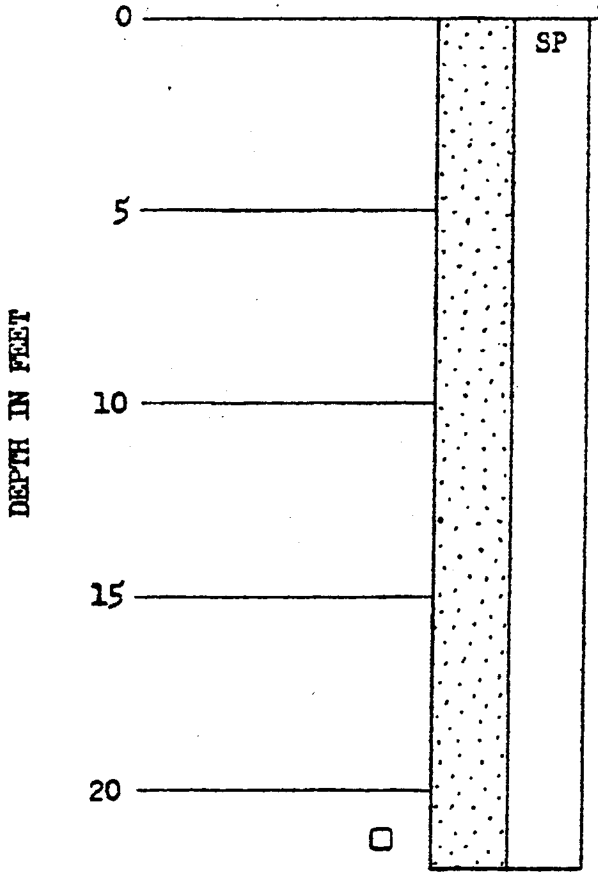
LARGE GRAVEL DROPPING TO BOTTOM OF PROBING AS SAND IS WASHED OUT BY JET

COULD NOT PROBE BELOW 11'

BORING COMPLETED - 7/10/62

PROBING NO. 6

ELEVATION: -32.1 FEET



GRAY FINE TO MEDIUM SAND WITH FEW BROKEN SHELLS

GRADING TO GRAYISH BROWN MEDIUM TO COARSE SAND WITH GRAVEL

LARGE GRAVEL DROPPING TO BOTTOM OF PROBING AS SAND IS WASHED OUT BY JET

GRAVEL CONTENT PROBABLY INCREASING WITH DEPTH

COULD NOT PROBE BELOW 22'

BORING COMPLETED -7/10/62

No Clay to
− 54.1

LOG OF PROBINGS

DAMES & MOORE
APPLIED EARTH SCIENCES

REVISIONS BY ______ DATE ______

FILE 377-027 Calif. Edison Co.

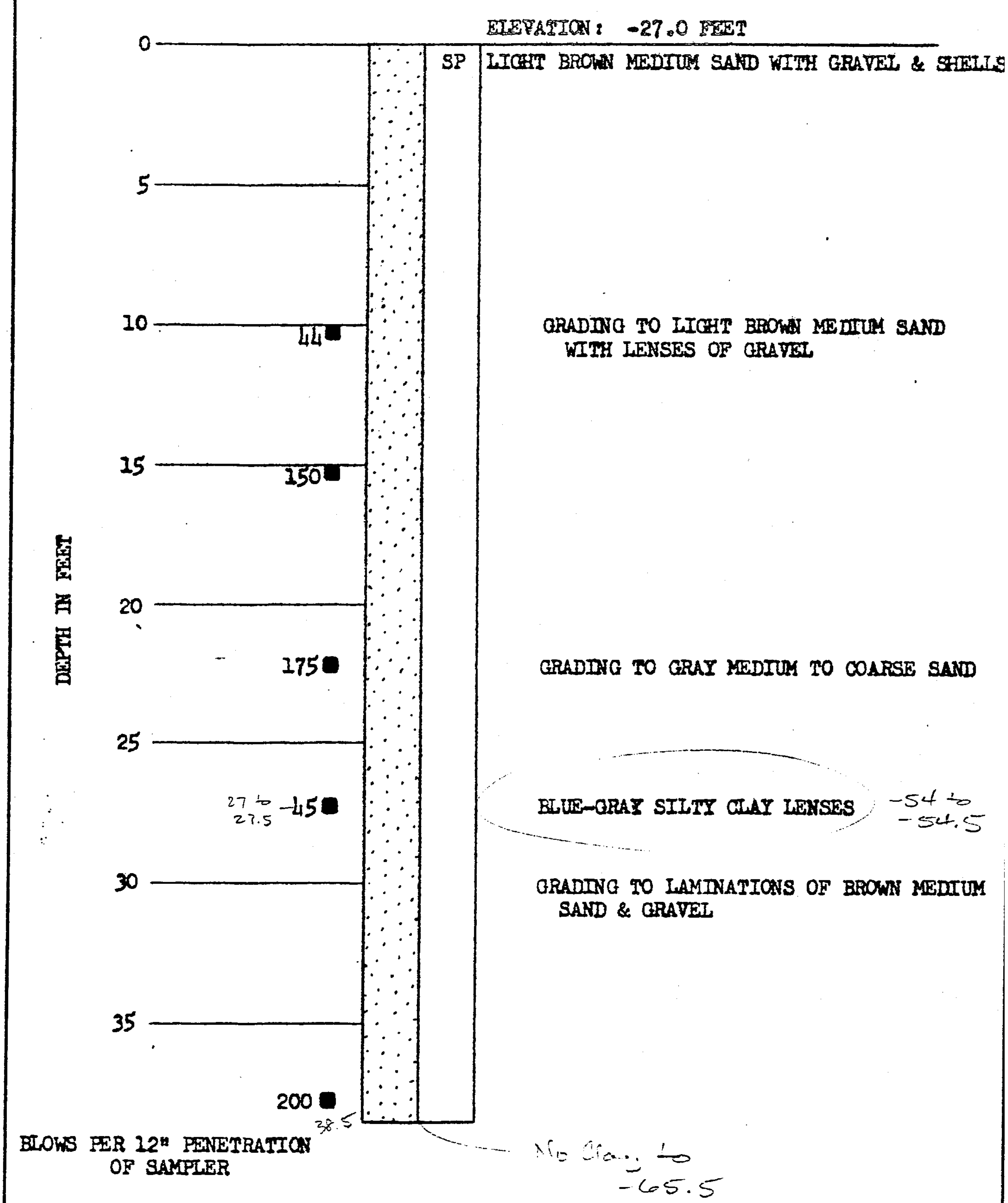
BY D.A.M. DATE 7-17-62
CHECKED BY ______

REVISIONS
BY ______ DATE ______

FILE 2377-027 Calif Edison Co.

BY J.A.M. DATE 1-24-62
CHECKED BY ______

1954 BORING NO. 1

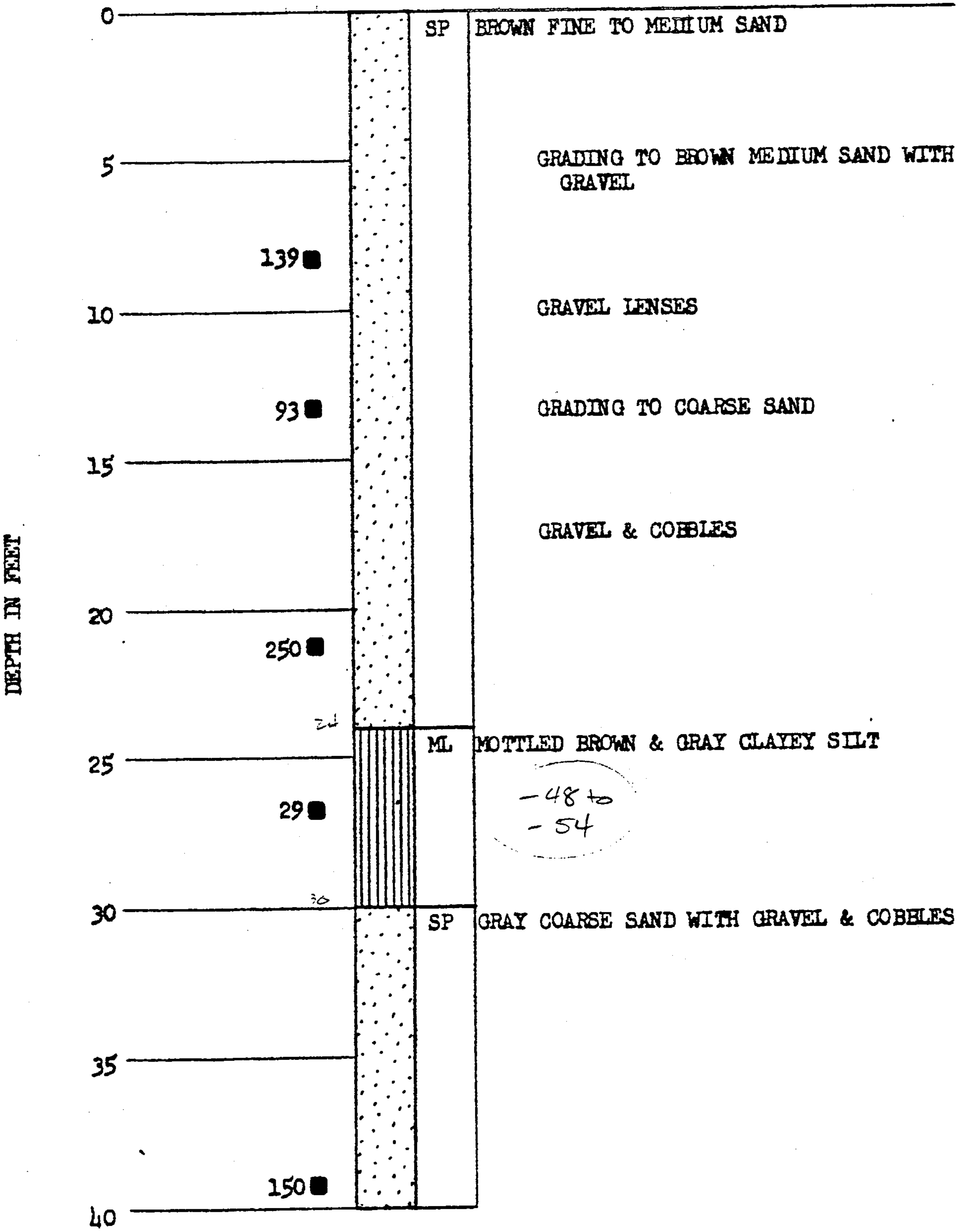


LOG OF BORING

DAMES & MOORE
APPLIED EARTH SCIENCES

1954 BORING NO. 2

ELEVATION: -24.0 FEET



L O G O F B O R I N G

DAMES & MOORE
APPLIED EARTH SCIENCES

REVISIONS BY ______ DATE ______

FILE 0372-027 Calif. Edison Co.

BY D.A.M. DATE 7.24.62 CHECKED BY ______

WELL DRILLING STATUS

DATE: 03/18/86

WELL NUMBER EW-24

CASING & SCREEN TOTAL DEPTH 70'

HI PPM NA AT NA (ft) WITH ——— (TLV,OVA,??)

LIQUID HYDROCARBON (Y/N) NOT ABLE TO DETERMINE

NOTE: Please attach "as built" well diagram.

STATUS: COMPLETE:

0' TO 58'	GROUT (2% BENTONITE)
58' TO 64'	BENTONITE (4 BUCKETS)
64' TO 71'	8 x 16 SAND (9 BAGS)
71' TO 74'	BENTONITE (3 BUCKETS)
0' TO 65'	SCH. 80 PVC BLANK WELL CASING, 4"Ø, 65 feet
65' TO 70'	SCH. 80 PVC SLOTTED WELL SCREEN, .03 SLOTS, 4"Ø, 5 feet.

COMMENTS,PROBLEMS,ETC:

DRILLED MUD ROTARY, VARIFLOW MUD, HELIO CONDITIONER.

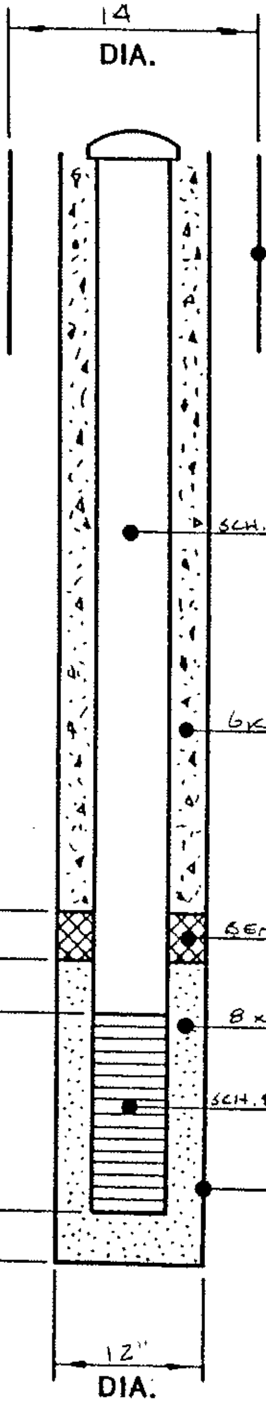
* PLEASE SUBMIT COMPLETED FORM(S) TO C.H.ETTER BY 7:00 AM THE DAY AFTER DRILLING ACTIVITY

che:wellstat

WELL NUMBER : EW 4

DRILLING METHOD : MUD ROTARY

DATE : 03/18/86



22' MLLW SURFACE ELEV.

11' BTM. OF CONDUCTOR (IF APPLICABLE)

STL. CONDUCTOR CASING (IF APPLICABLE)

SCH. 80 PVC BLANK WELL CASING, 4"Ø, 65 FEET

GROUT (2% BENTONITE)

58' TOP OF BENTONITE

64' TOP OF SAND PACK

65' TOP OF SCREEN

BENTONITE PELLETS (4 BUCKETS)

8x16 SAND (9 BAGS)

SCH. 80 PVC SLOTTED WELL SCREEN, .03 SLOTS, 4"Ø, 5 FEET.

WELL BORE

70' BTM. OF SCREEN

71' TOTAL DEPTH

REV	◇					◇				

"IMAGINEERNG A CLEANER WORLD"

RIEDEL ENVIRONMENTAL SERVICES, INC.

Foot of N. Portsmouth Ave. P.O. Box 5007
Portland, Oregon 97208-5007

DR ______ CH. ______
DR APP. ______
ENGR. ______

OPR'G. DEPT.

APPROVE

ENG'R. DEPT.

SCALE NTS DATE ______

W.O. ______

Client: Chevron
Job Location: S.C. Edison
Date Drilled: 03/18/86
Geologist: R. Graff
y Officer: R. Graff
Driller: Bevlik Drilling
:
:

Job ber: B210-EW
Well #: 24
Surface Elevation: 26.14' (MLLW)
Total Depth: 75'
Depth To Fluid:
Drilling Method: Mud Rotary
:
:

% LEL	PPM Draeger	PPM OVA	Sample Depth	Sample Type	Feet	Visual Classification
					1	[SP] Drilled prior to arrival at drill site, no data
					2	obtained. Conductor pipe to 11 feet.
					3	
					4	
					5	
					6	
					7	
					8	
					9	
					10	
					11	Light brown, subrounded, medium sand with a trace
					12	well rounded coarse.
					13	
					14	
					15	
					16	
					17	
					18	
					19	Greyish brown, medium, subangular to subrounded,
					20	sand with shell fragments.
					21	12 - 15% black (basaltic) rock fragments.
					22	HC visible in cuttings.
					23	
					24	
					25	
					26	
					27	
					28	Grading to fine to medium sand.
					29	
					30	
					31	
					32	[SW] [SP] Grading to a fine to coarse sand with a trace
					33	well rounded fine gravel(5-10mm).
					34	
					35	
					36	
					37	
					38	
					39	[SM] Greyish brown, silty, fine sand with a trace medium,
					40	12-18% muscovite.
					41	
					42	

Log Continued on Next Page

Client: Chevron
Job Location: S.C. Edison
Date Drilled: 03/19/86
Geologist: R. Graff
Safety Officer: R. Graff
Driller: Beylik Drilling
:
:

Job ber: 8210-EW
Well #: 24
Surface Elevation: [illegible] (MLLW)
Total Depth: 75'
Depth To Fluid:
Drilling Method: Mud Rotary
:
:

% LEL	PPM Draeger	PPM OVA	Sample Depth	Sample Type	Feet	Visual Classification
					43	
					44	
					45	Grading to a trace rounded coarse.
					46	
					47	
					48	
					49	[SP] Light brown, subangular to subrounded, fine to medium sand with shell fragments.
					50	
					51	
					52	
					53	
					54	[SM] Reddish brown, FeO stained, subangular to subrounded, fine to medium sand grading to a grey, very fine silty sand with interbedded clayey silt layers 5-7mm thick. Transition to Mannhatten Beach Aquiclude.
					55	
					56	
					57	
					58	
					59	[CL] Grey, silty clay with FeO stained stringers. Manhattan Beach Aquiclude.
					60	
					61	
					62	
					63	[SM] [SP] FeO stained, subangular, fine sand grading to a grey, silty, subangular, fine sand.
					64	
					65	[SP] [SM] Grey, angular to subangular, fine to medium sand with interbedded silt-clayey silt lenses grading to a golden 'rust' brown, subangular to subrounded sand with shell fragments.
					66	
					67	
					68	
					69	
					70	
					71	
					72	
					73	[SM] Grey, silty, subangular sand with a trace clay. Transition to El Segundo Aquiclude.
					74	
					75	[CL] Dark grey, silty clay with abundant shell fragments. Total depth - 75

LICATION FOR WELL PERMIT
VIRONMENTAL MANAGEMENT - 2615 S. GRAND UE, LOS ANGELES, CA 90007, ROOM 604
OUNTY OF LOS ANGELES DEPARTMENT OF HEAL RVICES

DATE May 21, 1986

DESCRIPTION

TYPE OF PERMIT (CHECK)

☒ NEW WELL CONSTRUCTION
☐ RECONSTRUCTION OR RENOVATION
☐ DESTRUCTION

TYPE OF WELL

☐ PRIVATE DOMESTIC
☐ PUBLIC DOMESTIC
☐ IRRIGATION
☒ OBSERVATION/MONITORING
☐ CATHODIC
☐ INDUSTRIAI
☐ GRAVEL PA
☐ TEST

TYPE OF CASING
4" Schedule 80 PVC

METHOD OF SEALING OF CASING
Cement Seal (2:1 Sand to Cement)

METHOD OF DESTRUCTION

ADDRESS (NUMBER, STREET AND NEAREST INTERSECTION)

CITY Los Angeles/El Segundo

DIAGRAM (SHOW PROPERTY LINES, STREET, ADDRESS, WELL SITE, SEWERS, AND PRIVATE SEWAGE DISPOSAL SYSTEMS ALONG WITH LABELS AND DIMENSIONS)

Well #	Location	Depth (ft)
SOW-24	Lower level area, N. of Basin "B"	55.0
SOW-25	Lower level area, N. of Basin "B"	75.0
EW-24	East of Edison Acidization Bldg.	70.0
[illegible]-25	East of Edison Acidization Bldg.	90.0

NAME OF WELL DRILLER (PRINT)
Beylik Drilling Company

TRADE NAME

BUSINESS ADDRESS
591 So. Walnut St.,
CITY La Habra, CA 90631

NAME OF WELL OWNER (PRINT)
Chevron U.S.A., Inc.

MAILING ADDRESS
324 W. El Segundo Blvd.

CITY
El Segundo, CA 90245

I hereby agree to comply in every respect with all regulations of the County Preventive/Public Health Services and with all ordinances and laws of the County of Los Angeles and of the State of California pertaining to well construction, reconstruction and destruction. Upon completion of well and within ten days thereafter, I will furnish the County Preventive/Public Health Services with a complete log of the well, giving date drilled, depth of well, all perforations in casing, and any other data deemed necessary by such County Preventive/Public Health Services.

Applicant's Signature

DISPOSITION OF APPLICATION: (For Sanitarians Use Only)

☒ APPROVED
☐ DENIED
☐ APPROVED WITH CONDITIONS

If denied or approved with conditions, report reason or conditions here:

DATE 6-11-86
SANITARIAN

DATE 6-18-86
SECTION CHIEF

When signed by Section Chi

WELL DRILLING STATUS

DATE: 03/20/86

WELL NUMBER GW-25

CASING & SCREEN TOTAL DEPTH 90'

HI PPM NA AT NA (ft) WITH ______ (TLV,OVA,??)

LIQUID HYDROCARBON (Y/N) UNABLE TO DETERM

NOTE: Please attach "as built" well diagram.

STATUS: COMPLETE

0' TO 75'	GROUT (2% BENTONITE)
75' TO 83'	BENTONITE PELLETS (8 BUCKETS)
83' TO 90'	8 X 16 SAND (9 1/2 BAGS)
0' TO 85'	SCH. 80 PVC BLANK WELL CASING, 4"Ø, 85 feet
85' TO 90'	SCH. 80 P/C SLOTTED WELL SCREEN, .03 SLOTS, 4"Ø, 5 feet.

COMMENTS,PROBLEMS,ETC:

DRILLED MUD ROTARY, VARIFLOW MUD, HELD CONDITIONER.

PLEASE SUBMIT COMPLETED FORM(S) TO C.H.ETTER BY 7:00 AM THE DAY AFTER DRILLING ACTIVITY

che:wellstat

WELL NUMBER : E1 -25

DRILLING METHOD : MUD ROTARY

DATE : 03/20/86

25.39' (MLLW) SURFACE ELEV.

11' BTM. OF CONDUCTOR (IF APPLICABLE)

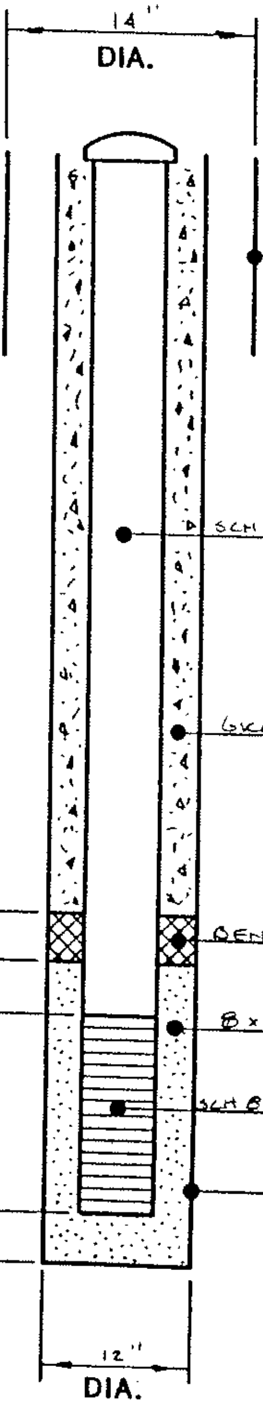
75' TOP OF BENTONITE

83' TOP OF SAND PACK

85' TOP OF SCREEN

90' BTM. OF SCREEN

90' TOTAL DEPTH



STL. CONDUCTOR CASING (IF APPLICABLE)

SCH 80 PVC BLANK WELL CASING, 4"Ø, 85'

GROUT (2% BENTONITE)

BENTONITE PELLETS (8 BUCKETS)

8x16 SAND (9 1/2 BAGS)

SCH 80 PVC SLOTTED WELL SCREEN, .03 SLOTS, 4"Ø, 5 feet

WELL BORE

REV

"IMAGINEERNG A CLEANER WORLD"

RIEDEL ENVIRONMENTAL SERVICES, INC.

Foot of N. Portsmouth Ave. P.O. Box 5007
Portland, Oregon 97208-5007

DR ____ CH. ____

DR APP. ____

ENGR. ____

OPR'G. DEPT.

APPROVED

ENG'R. DEPT.

SCALE NTS DATE ____

W.O. ____

Client: Chevron
Job Location: S.C. Edison
Date Drilled: 03/20/86
Geologist: R. Graff
y Officer: R. Graff
Driller: Beylik Drilling
:
:

Job Number: 8210-EW
Well #: 25
Surface Elevation: 25.39' (MLLW)
Total Depth: 96'
Depth To Fluid:
Drilling Method: Mud rotary
:
:

% LEL	PPM Draeger	PPM OVA	Sample Depth	Sample Type	Feet	Visual Classification
					1	[SP] Potholed, disturbed, greyish brown, moist, sub-angular, medium sand with a trace well rounded coarse, shell fragments. Slight HC odor.
					2	
					3	
					4	
					5	Light brown, moist, subangular, fine to medium sand with shell fragments.
					6	
					7	
					8	
					9	
					10	
					11	Grading to some well rounded coarse.
					12	
					13	
					14	
					15	
					16	Greyish brown, medium, subangular to subrounded, sand with shell fragments. 12-15% black(basaltic?) rock fragments. Slight HC odor, HC visible in cuttings.
					17	
					18	
					19	
					20	
					21	
					22	
					23	
					24	Grading to a fine to medium sand, lower % black rock fragments.
					25	
					26	
					27	
					28	
					29	
					30	[SW] [SP] grading to a fine to coarse with a trace well rounded fine gravel(5-10mm).
					31	
					32	
					33	
					34	
					35	
					36	
					37	
					38	[SM] Greyish brown, silty, subangular, very fine to fine sand with a trace medium, 12-18% muscovite.
					39	
					40	
					41	
					42	

Log Continued on Next Page

Client: Chevron
Job Location: S.C. Edison
Date Drilled: 03/20/86
Geologist: R. Graff
ty Officer: R. Graff
Driller: Beylik Drilling
:
:

Job number: 8210-EW
Well #: 25
Surface Elevation: 25.39'
Total Depth: 96'
Depth To Fluid:
Drilling Method: Mud rotary
:
:

% LEL	PPM Draeger	PPM OVA	Sample Depth	Sample Type	Feet	Visual Classification
					43	Grading to a trace rounded coarse.
					44	
					45	
					46	
					47	Light brown, subangular to subrounded, fine to medium
					48	[SP] sand with shell fragments.
					49	
					50	
					51	
					52	[SM] Reddish brown. FeO stained. subangular to subrounded.
					53	fine to medium sand grading to a grey, silty, very
					54	fine sand interbedded with clayey silt layers
					55	5-7mm thick. Transition to Manhatten Beach Aquiclude.
					56	
					57	
					58	[CL] Grey, silty clay with FeO stained sand stringers,
					59	Manhattan Beach Aquiclude.
					60	
					61	
					62	[SM] [SP] FeO stained, subangular, fine sand grading to a
					63	grey, silty, subangular, fine sand.
					64	[SP] [SM] Grey, angular to subangular, fine to medium
					65	sand with interbedded silt-clayey silt lenses
					66	grading to a golden 'rust' brown, subangular to
					67	subrounded sand with shell fragments.
					68	
					69	
					70	
					71	[SM] Grey, silty, subangular sand with a trace clay.
					72	Transition to the El Segundo Aquiclude.
					73	[CL] Dark grey, silty clay with abundant shell fragments.
					74	El Segundo Aquiclude.
					75	
					76	
					77	
					78	
					79	
					80	Grading to interbedded silty, very fine sand lenses.
					81	
					82	
					83	
					84	[SM] Grey, gravelly, silty, angular to subangular, fine

Log Continued on Next Page

Client: Chevron
Job Location: S.C. Edison
Date Drilled: 03/20/86
Geologist: R. Graff
y Officer: R. Graff
Driller: Beylik Drilling

Job number: 8210-EW
Well #: 25
Surface Elevation: 25.39'
Total Depth: 96'
Depth To Fluid:
Drilling Method: Mud rotary

% LEL	PPM Draeger	PPM OVA	Sample Depth	Sample Type	Feet		Visual Classification
					85		to medium sand with a trace coarse.
					86		
					87		
					88		
					89		
					90		
					91		
					92		
					93		
					94		
					95		
					96		Total depth - 96'

VIRONMENTAL MANAGEMENT – 2615 S. GRAND A UE, LOS ANGELES, CA 90007, ROOM 604
UNTY OF LOS ANGELES DEPARTMENT OF HEAL RVICES

DATE
May 21, 1986

DESCRIPTION

TYPE OF PERMIT (CHECK)
- ☒ NEW WELL CONSTRUCTION
- RECONSTRUCTION OR RENOVATION
- ☐ DESTRUCTION

TYPE OF WELL
- ☐ PRIVATE DOMESTIC
- ☐ PUBLIC DOMESTIC
- ☐ IRRIGATION
- ☒ OBSERVATION/MONITORING
- ☐ CATHODIC
- ☐ INDUSTRIAL
- ☐ GRAVEL PAC
- ☐ TEST

TYPE OF CASING
4" Schedule 80 PVC

METHOD OF SEALING OF CASING
Cement Seal (2:1 Sand to Cement)

METHOD OF DESTRUCTION

ADDRESS (NUMBER, STREET AND NEAREST INTERSECTION)

CITY
Los Angeles/El Segundo

DIAGRAM (SHOW PROPERTY LINES, STREET, ADDRESS, WELL SITE, SEWERS, AND PRIVATE SEWAGE DISPOSAL SYSTEMS ALONG WITH LABELS AND DIMENSIONS)

Well #	Location	Depth (ft)
SOW-24	Lower level area, N. of Basin "B"	55.0
SOW-25	Lower level area, N. of Basin "B"	75.0
EW-24	East of Edison Acidization Bldg.	70.0
[illegible]-25	East of Edison Acidization Bldg.	90.0

NAME OF WELL DRILLER (PRINT)
Beylik Drilling Company

TRADE NAME

BUSINESS ADDRESS / CITY
591 So. Walnut St., La Habra, CA 90631

NAME OF WELL OWNER (PRINT)
Chevron U.S.A., Inc.

MAILING ADDRESS
324 W. El Segundo Blvd.

CITY
El Segundo, CA 90245

I hereby agree to comply in every respect with all regulations of the County Preventive/Public Health Services and with all ordinances and laws of the County of Los Angeles and of the State of California pertaining to well construction, reconstruction and destruction. Upon completion of well and within ten days thereafter, I will furnish the County Preventive/Public Health Services with a complete log of the well, giving date drilled, depth of well, all perforations in casing, and any other data deemed necessary by such County Preventive/Public Health Services.

Applicant's Signature

DISPOSITION OF APPLICATION: (For Sanitarians Use Only)
- ☒ APPROVED
- ☐ DENIED
- ☐ APPROVED WITH CONDITIONS

If denied or approved with conditions, report reason or conditions here:

DATE
6-11-86

SANITARIAN

DATE
6-18-86

SECTION CHIEF

When signed by Section Chief, this application is a permit.

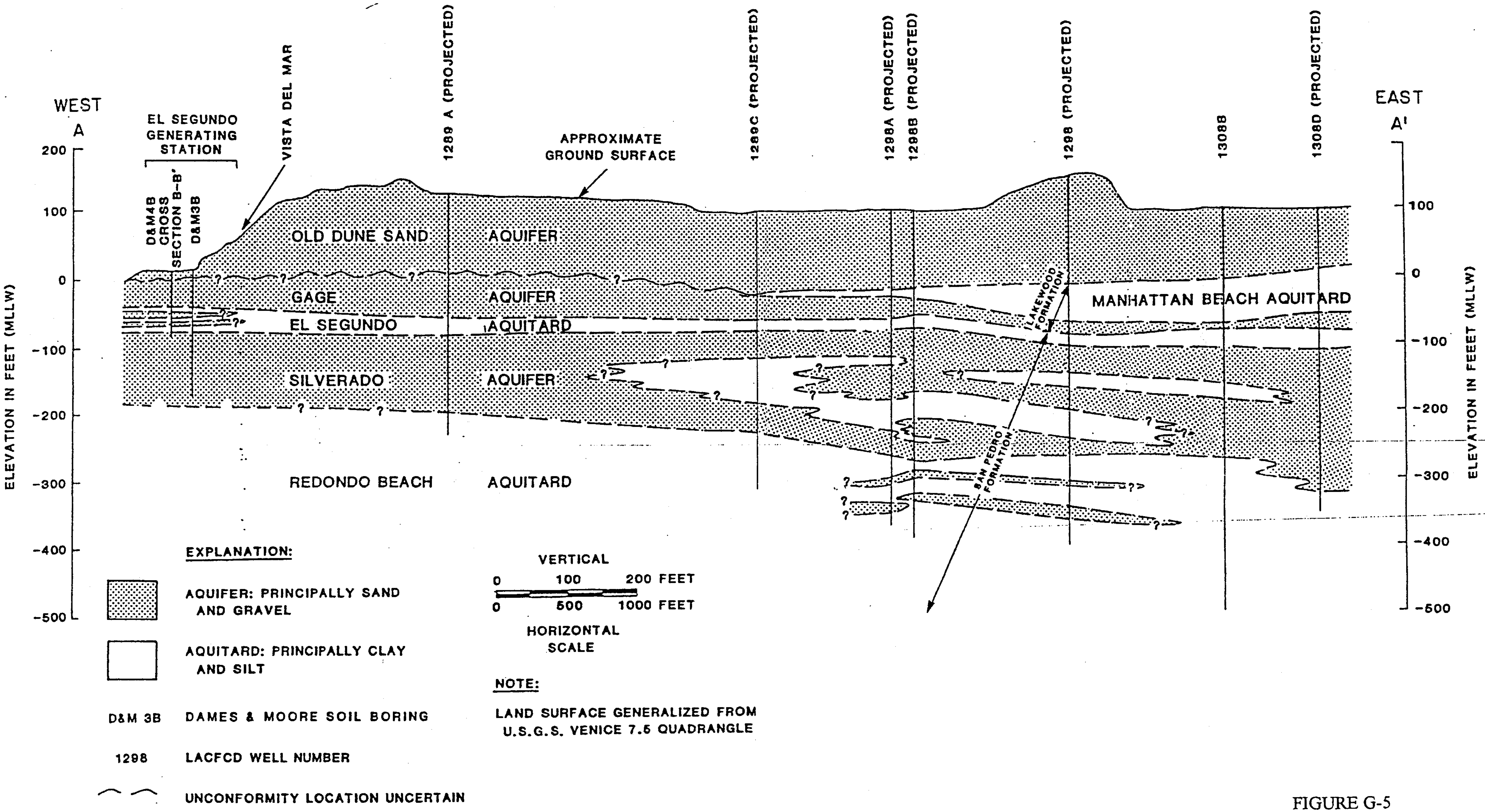
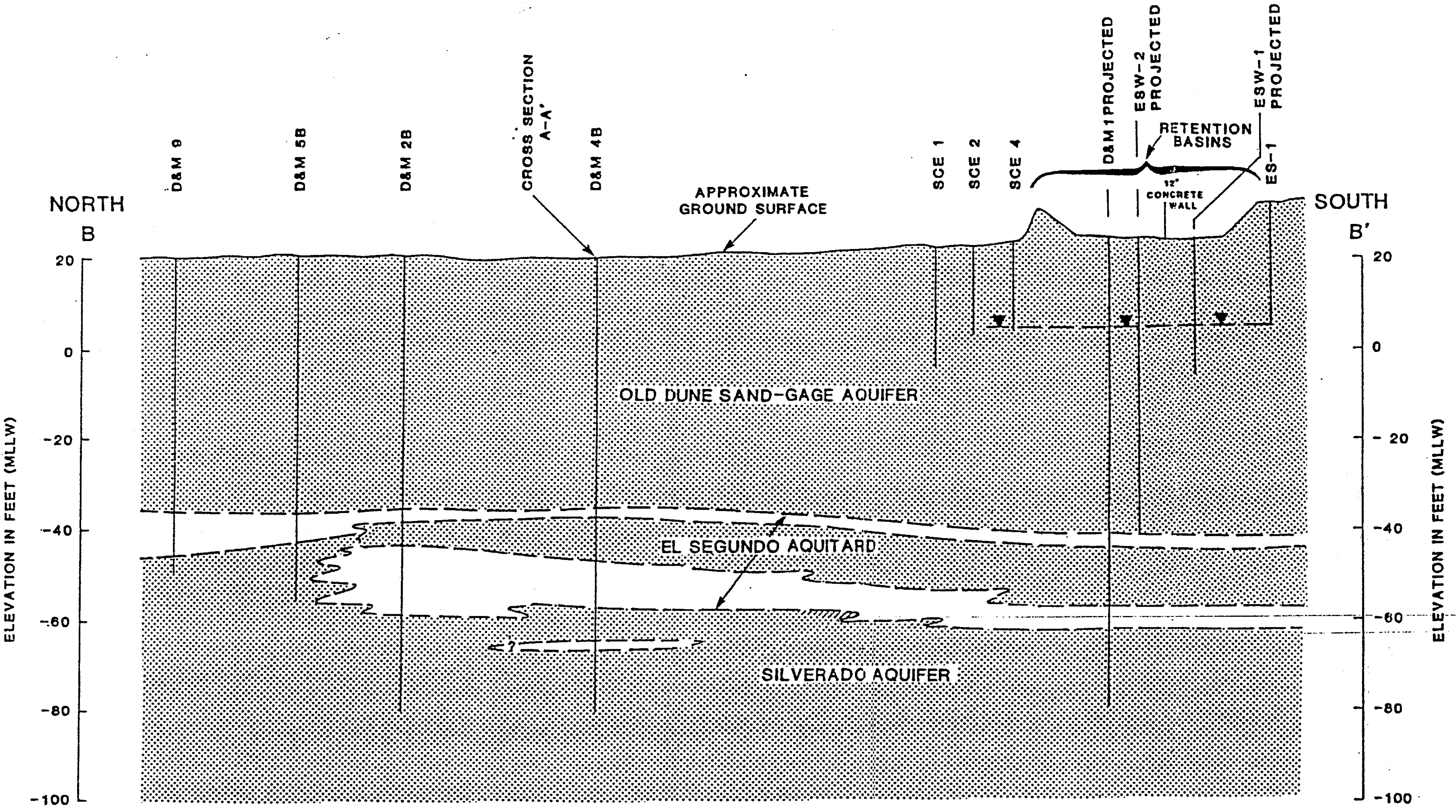


FIGURE G-5
GEOLOGIC CROSS SECTION A-A'
(Reference 7)



EXPLANATION:

▨	OLD DUNE SAND-GAGE AQUIFER: FINE TO COARSE SAND WITH GRAVEL LENSES
☐	EL SEGUNDO AQUITARD: CLAY AND SILTY CLAY WITH INTERLAYERED FINE TO MEDIUM SAND. MINOR SHELLS PRESENT
▨	SILVERADO AQUIFER: FINE TO COARSE SAND AND GRAVEL WITH MINOR SANDY CLAY LENSES
ESW-1	OBSERVATION WELL
ES-1	SOIL BORING
D&M3B	DAMES & MOORE SOIL BORING
SCE 1	SOUTHERN CALIFORNIA EDISON CO. SOIL BORING

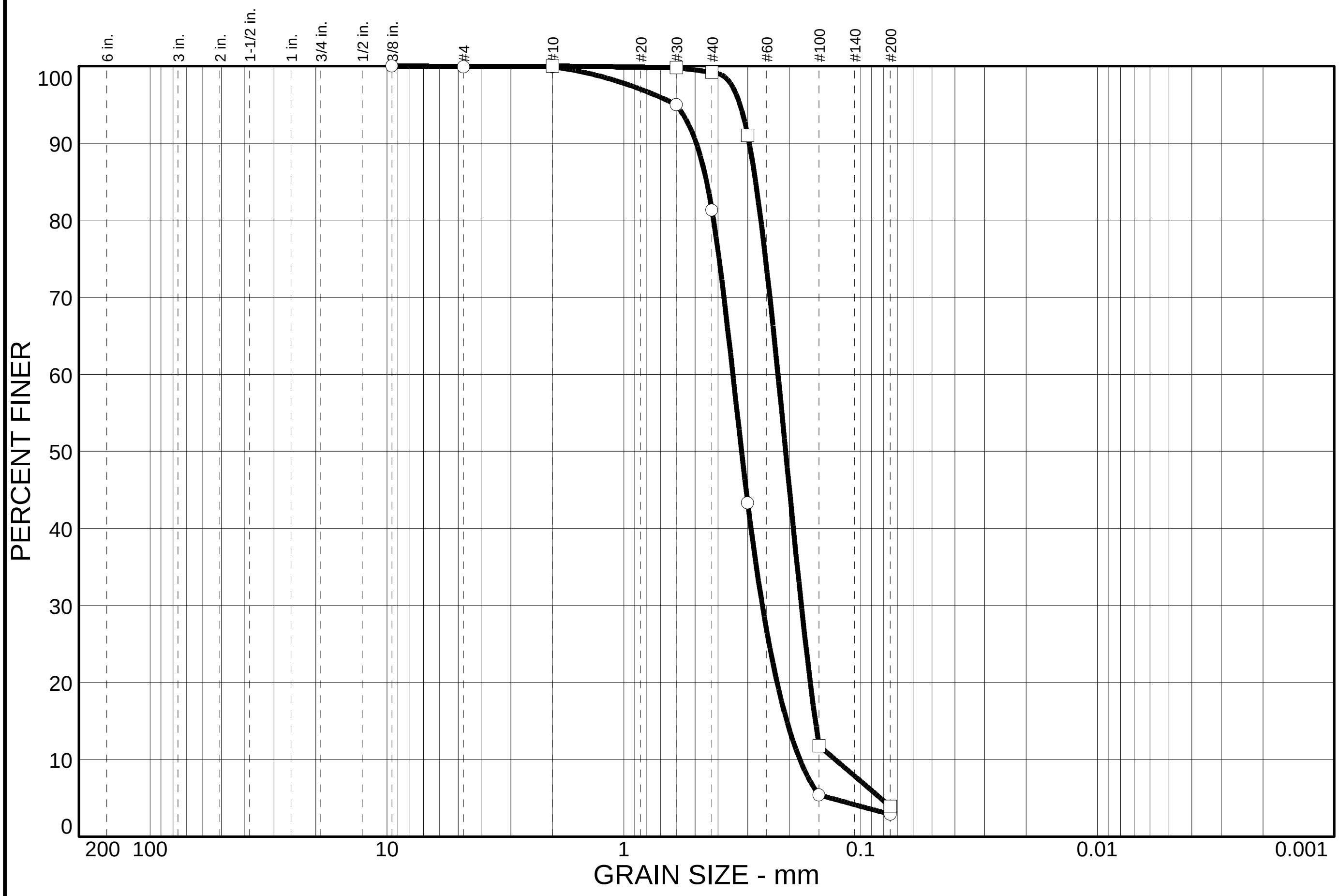
—▼— APPROXIMATE POTENTIOMETRIC SURFACE (SEPT. 1985)

VERTICAL
0 20 40 FEET
0 100 200 FEET
HORIZONTAL
SCALE

FIGURE G-6
GEOLOGIC CROSS SECTION B-B'
(Reference 7)

APPENDIX G
Particle Size Distribution Report

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		0.1	97.0	2.9					
□			96.1	3.9		SP			

SIEVE inches size	PERCENT FINER ○	□	
3/8"	100.0		
	GRAIN SIZE		
D60	0.347	0.224	
D30	0.260	0.178	
D10	0.181	0.128	
	COEFFICIENTS		
Cc	1.08	1.11	
Cu	1.92	1.75	

SIEVE number size	PERCENT FINER ○	□	
#4	99.9		
#10	99.9	100.0	
#30	95.0	99.8	
#40	81.3	99.2	
#50	43.3	91.0	
#100	5.4	11.8	
#200	2.9	3.9	

SOIL DESCRIPTION

○ Olive Poorly Graded SAND

□ Olive Poorly Graded SAND

REMARKS:

○

□

○ Source: BSC-1

□ Source: SZC-1

COOPER TESTING LABORATORY

Client: Geosyntec Consultants

Project: West Basin Coastal Subsurface Intake Feasibility Study

Project No.: 461-300

Figure

COOPER TESTING LABORATORY

Constant Head Permeability Test
ASTM D2434

CTL Job No: 461-300 **Boring:** SZC-1 **Date:** 7/30/2015

Client: Geosyntec Consultants **Sample:** **By:** PJ

Project Name: West Basin Coastal Subsurface Intake Feasibility Study **Depth, ft:**

Project No.:

Soil Description: Olive Poorly Graded SAND

Remolding Data: 6 lifts tamped in with moderate effort

		Constant Head Calculation, K=QL/thA				
Test #	**Elapsed Time t, (sec)**	**Volume Q, (cc)**	**Head Loss h (cm)**	**Water Temp (^{o}C)**	**Hydraulic Gradient**	**Coef. Of Permeability K, (cm/sec)**
1	115	23	2.5	24.6	0.39	0.016
2	85	18	2.5	24.6	0.39	0.016
3	120	33	3.3	24.6	0.52	0.016
4	80	26	3.9	24.6	0.61	0.016
5	160	67	4.9	24.6	0.77	0.017

Average Permeability (cm/sec):	**0.02**
Average Permeability (in/hr):	**23**

Sample Data:		**Initial**		**Final**	
Height, (L)	**in.:**	6.00		5.88	
Diameter,	**in.:**	2.39		2.39	
Area, (A)	**in^2:**	4.49		4.49	
Volume,	**in^3:**	26.92		26.38	
Total Volume.	**cc:**	441		432	
Vol. of Solids,	**cc:**	243		243	
Vol. of Voids,	**cc:**	198		190	
Void Ratio	**e:**	0.82		0.78	
Porosity,	**%:**	45.0		43.9	
Saturation,	**%:**	58.4		100.0	assumed
Sp. Gravity:		2.65	assumed	2.65	assumed
Wet Weight,	**gm:**	758.9		832.7	
Dry Weight	**gm:**	643.1		643.1	
Moisture,	**%:**	18.0		29.5	
Density,	**pcf:**	91.0		92.9	

Remarks: The final moisture content was calculated to force 100% saturation. All final numbers dependant on the moisture content should be considered approximate.

APPENDIX H

West Basin Case Study Hydraulic Conductivity Field Testing Summary and Analysis

Geosyntec consultants

3415 S. Sepulveda Blvd., Suite 500
Los Angeles, CA 90034
PH 310.957.6100
FAX 310.957.6101
www.geosyntec.com

Technical Memorandum

Date: October 8, 2015

To: Al Preston, Gesoyntec

From: Jai Panthail, Rebecca Batchelder, Geosyntec

Subject: West Basin Case Study Hydraulic Conductivity Field Testing Summary and Analysis
Geosyntec Project: LA0324

Attachments
1. Geosyntec Consultants CPT Investigation Field Notes
2. Gregg Drilling and Testing, Inc. CPT Site Investigation Summary
3. Raw CPT and PPDT Data and Hydraulic Conductivity Calculations

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PROJECT BACKGROUND

West Basin Municipal Utility District (West Basin) has contracted with Geosyntec Consultants (Geosyntec) to evaluate the feasibility of using a subsurface seawater intake (SSI) to supply feed water to a proposed desalination plant at 301 Vista Del Mar Blvd El Segundo, CA 90245. An important factor in evaluating the feasibility of using SSIs is the hydraulic conductivity of the sediments at the proposed project site. After reviewing existing data of the area, Geosyntec determined it would be necessary to conduct Cone Penetration Testing (CPT) and Pore Pressure Dissipation Testing (PPDT) at the proposed project site to get more accurate information on the site's hydraulic conductivity.

OBJECTIVE

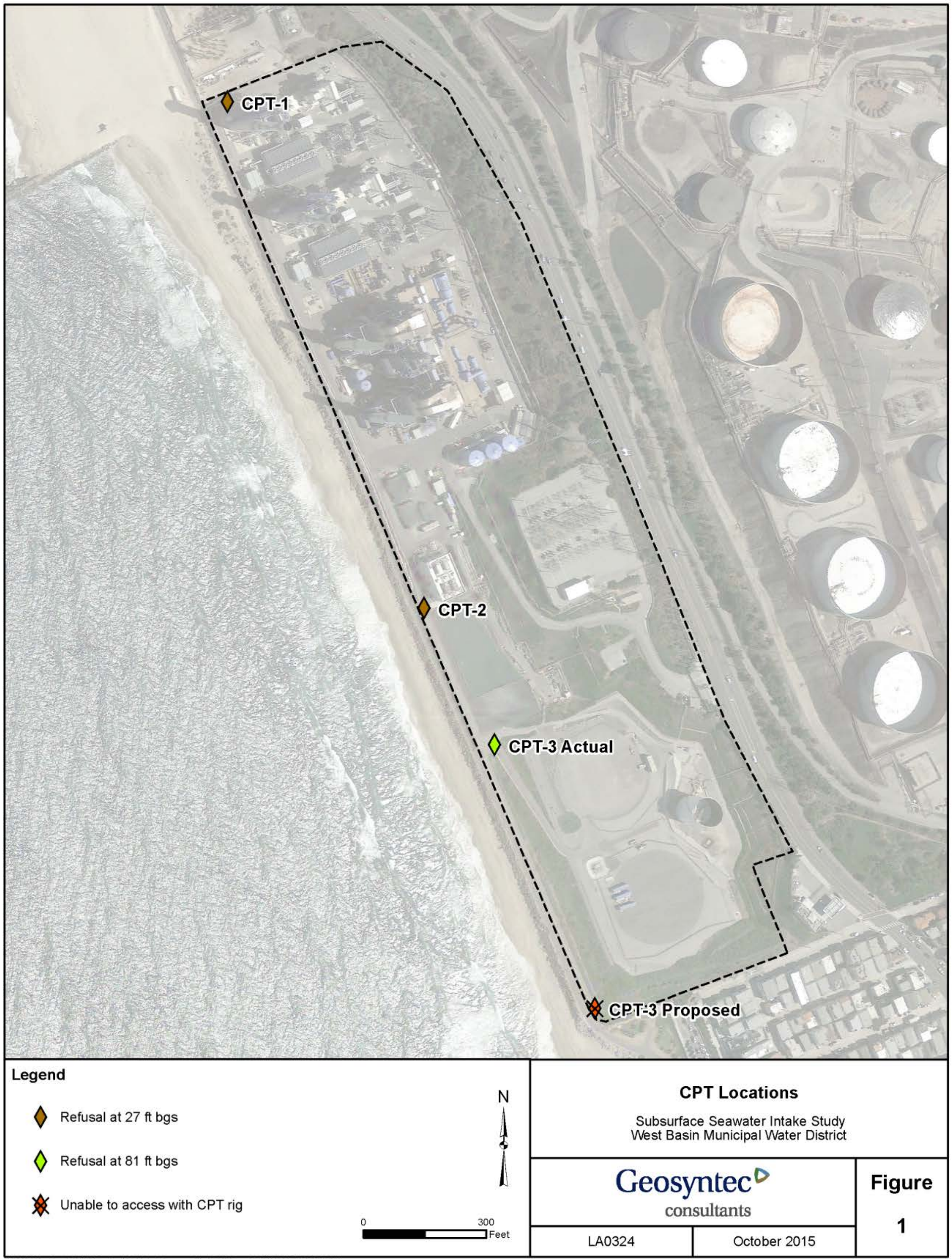
The objective of the fieldwork was to characterize stratigraphy and geotechnical properties of subsurface at El Segundo site to a depth of approximately 100 feet below ground surface (bgs). This technical memorandum present the results of the CPT and PPDT done at the El Segundo site and subsequent analysis of these data to determine the hydraulic conductivity of the sediment. The results of this analysis will be used to assist in evaluating the feasibility of different SSI technology at the proposed desal site.

FIELD TESTING

Field testing, consisting of three CPT borings and PPDT at one of the CPT boring locations, was conducted on August 31, 2015. A map of the CPT testing locations is shown in Figure 1. Drilling was performed by Gregg Drilling and Testing, Inc. (Gregg Drilling). Representatives from West Basin and Gesoyntec were present to oversee the testing. Two of the CPTs (CPT-1 and CPT-2) hit refusal just before 30 feet below ground surface (bgs), and therefore no PPDT was conducted at these locations. The originally proposed CPT-3 location had to be changed due to access issues (see Figure 1). At the revised location, CPT-3 penetrated to a total of 81 feet bgs before hitting refusal. PPDT was conducted at the CPT-3 site every ten feet from 30 to 70 feet bgs, and then two more at 72 and 81.5 feet bgs.

The odor of hydrocarbons was noted during drilling of the first two CPTs just prior to hitting refusal.

Field notes and the preliminary results of the testing prepared by Gregg Drilling are provided in Attachments 1 and 2, respectively.



CPT Locations

Subsurface Seawater Intake Study
West Basin Municipal Water District

Figure

1

P:\GIS\WestBasinMWD\Project\2015Sep\Former_Fig1_CPTs.mxd 10/1/2015 1:37:11 PM

DETERMINATION OF HYDRAULIC CONDUCTIVITY

Hydraulic conductivity values were estimated based on 1) CPT Normalized Soil Behavior Type Index and 2) PPDT results. Both methodologies and their results are presented in the following sections.

Determination of Hydraulic Conductivity from Soil Behavior Type Index

The Soil Behavior Type Index (SBT_nI_c) describes the soil type based on the mechanical characteristics of the soil as determined by the results of the CPT. The SBT_nI_c values of CPT-3 were provided by Gregg Drilling, and are shown in Attachment 2.

A relationship between hydraulic conductivity (k) and the SBT_nI_c has been established by P.K. Robertson and K.L. Cabal (Roberston and Cabal, 2015). This relationship can be summarized in the following equations:

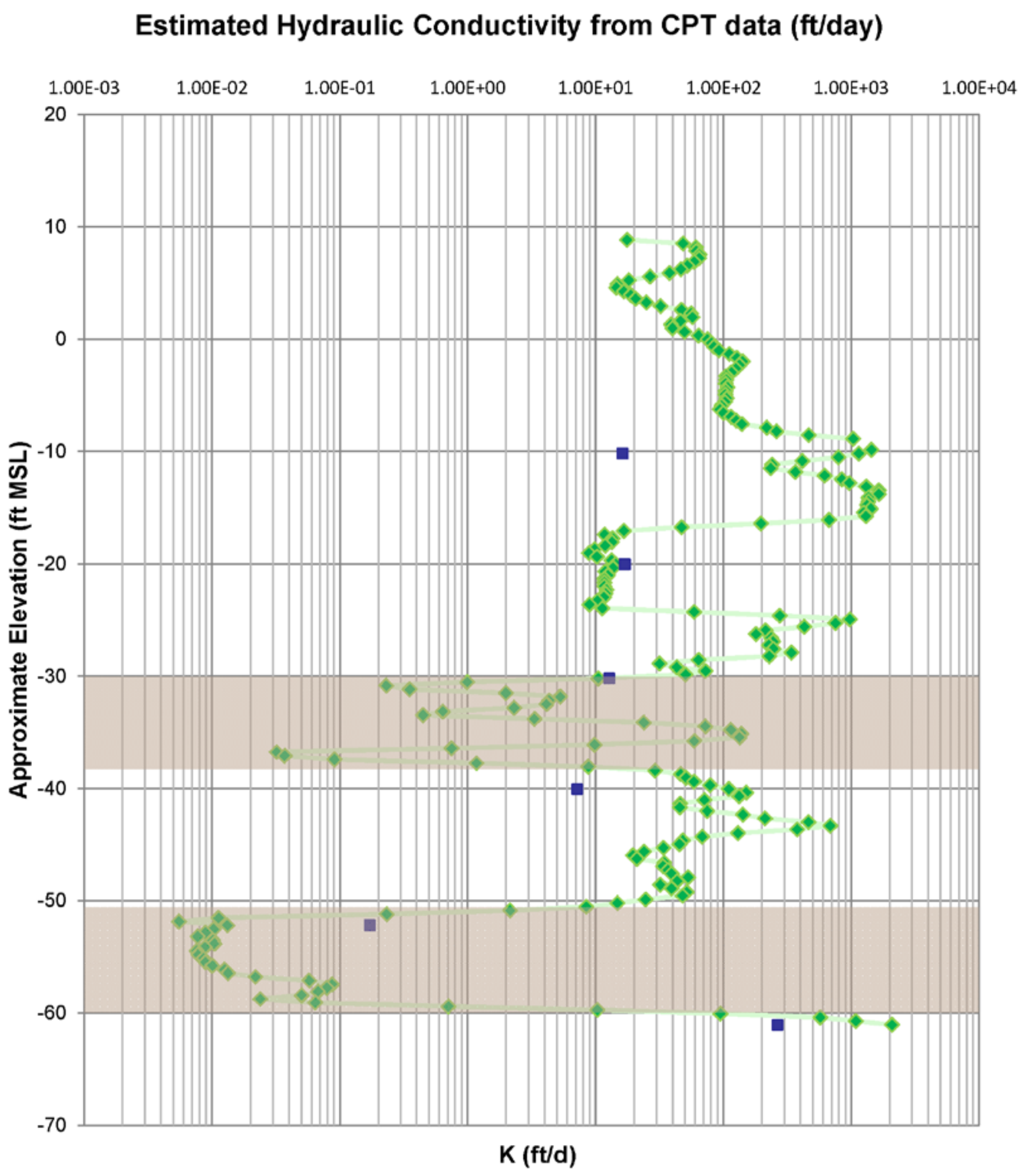
When $1.0 < SBT_nI_c \leq 3.27$ $\quad k = 10^{(0.952-3.04SBTnIc)}$ m/s

When $3.27 < SBT_nI_c \leq 4.0$ $\quad k = 10^{(-4.52 - 1.37SBTnIc)}$ m/s

It should be noted that these equations were developed to provide an approximate estimation of soil hydraulic conductivity, not exact predictions. These equations were applied to the data provided by Gregg Drilling to estimate soil hydraulic conductivity as a function of depth for the CPT-3 location. Results of this analysis are presented in Figure 2, and the raw data and calculations are provided in Attachment 3.

Determination of Hydraulic Conductivity from Results of PPDT

Hydraulic conductivity can also be estimated from parameters measured by the PPDT. Using the methodology proposed by P.K. Robertson and K.L. Cabal (Roberston and Cabal, 2015), hydraulic conductivity was estimated at the seven depths for which PPDT was performed. The results of this method of estimating hydraulic conductivity are also presented in Figure 2. The raw data and calculations for this methodology are provided in Attachment 3.



◆ Estimated using Soil Behavoir Type Index

■ Estimated using PPDT results

▨ Low permeability Interval based on boring logs

Note:
The hydraulic conductivity values calculated from the SBT data are considered more reliable than the pore dissipation test data because with the test at approximately -20 ft MSL, the pore pressure dissipation tests appear to be at depths that straddle high and low permeability intervals. All data and results are provided in appendix D.

Estimated Hydraulic Conductivity (K) from CPT/PPDT Data Subsurface Seawater Intake Study West Basin Municipal Water District	
Geosyntec consultants	Figure 2
LA0324	October 2015

"\\WESTLA-01\Data\Project Folders\LA0324 - West Basin Intake Study\Task 4 Final Reporting\Figures\Figure 3.6 - Estimated K.pptx"

CONCLUSION

Estimates from both methodologies were found to be consistent, and indicated that at the CPT-3 location, two low permeability layers are present between 30 and 40 feet bgs and between 50 and 60 feet bgs.

The odor of hydro carbons noted during field investigations also indicates potential soil contamination which should be investigated further and taken into consideration during evaluation of SSI feasibility.

REFERENCES

Robertson, P.K. and Cabal (Robertson), K.L. (2015) Guide to Cone Penetration Testing for Geotechnical Engineering, 6th Edition. December

ATTACHMENT 1

GEOSYNTEC CONSULTANTS CPT INVESTIGATION FIELD NOTES

Geosyntec
consultants

199 S. Hudson Blvd. Suite 110
Pasadena, California 91101
626-449-0664 (phone) 626-449-0411 (fax)

DAILY FIELD REPORT

PROJECT: West Basin Intake Study

LOCATION: 301 Vista Del Mar PROJECT NO.: ~~SE~~ LAC034 TASK NO.: 03

DESCRIPTION: ~~CTP~~ CPT work DATE: 31 day 8 month 2015 year

CONTRACTOR(S): Spectrum, Gregg Drilling

WEATHER, TEMPERATURE: Hot, 80's °F

- 0500 Left home
- 0555 Arrived onsite
- 0600 All crew members met with NRG safety officer to go through NRG's safety meeting
- 0610 Accidents, Spills, Hazardous waste, (NRG training videos)
Osha: noise protection, air mask, gloves for the required job, safety goggles, speed limit 8 1/2 mph.
-Pay attention to the flashing red light
-only one truck allowed at one time
-wait until flashing lights are off.
-Good house keeping
Call (310) 615-6303
- 0635 Finished safety meeting with NRG
- 0640 Al Preston and Roxana go to Control Room to discuss work to be completed
- 0715 Conducted additional safety meeting with Spectrum & Gregg.
- 0730 mobilized to NW corner to conduct Geophysical screening
- 0830 Began hand augering CPT-1
- 0845 11ft from surface - cleared with hand auger
- 0845 Diane from WBWD arrives onsite
- 0850 CPT-1 is advanced with CPT truck
- 0900 Hand augering started @ CPT-2 location, near center of site

NAME: Roxana Ramirez DATE: 8 / 31 /2015 HOURS: 12.00

Sheet No. 1 of 2

Geosyntec consultants

199 S. Hudson Blvd. Suite 110
Pasadena, California 91101
626-449-0664 (phone) 626-449-0411 (fax)

DAILY FIELD REPORT

PROJECT: West Basin Intake Study

LOCATION: 301 Vista Del Mar PROJECT NO.: LAC0324 TASK NO.: 03

DESCRIPTION: CPT Testing DATE: 31 day 8 month 2015 year

CONTRACTOR(S): Gregg Drilling ; Spectrum Geophysics

WEATHER, TEMPERATURE: Hot 80's °F

- Gravelly sand encountered at ≈ 27.4 ft bgs, new dummy tip added to rod in order to breakthrough gravel
- 0925 Hit refusal at ≈ 27.4 ft, maxed out at 3200 psi pressure for CPT rig
- 0930 CPT-2 located cleaned to ~~10s~~ 10' & 10" bgs.
- 0935 CPT truck mobilizes to CPT-2 location.
- 1000 CPT truck encounters refusal at ≈ 27 ft bgs at Center location (CPT-2)
- location at forth south west ~~on~~ not feasible as CPT truck cannot access potential CPT-3 location due to the distance away from sewer & electrical line
- 1015 Diane from West Basin Water District leaves site
- 1030 met with NRG staff at trailer offices to look through previous boring logs and CPT graphs conducted in 2010, Borings & CPT conducted by Ninyo & Moore
- 1310 Spectrum leaves site after delineating more area at the north.
- 1530 Hit CPT refusal at ≈ 81.3 ft bgs, rods needed to be pulled out.

1600 CPT location backfilled with grout and patched

- 1615 Left site (+ ≈ hour travel time)

NAME: Roxana Ramirez DATE: 8 / 31 /2015 HOURS: 12.00

1310 = Spectrum leaves site

Sheet No. 2 of 2

ATTACHMENT 2

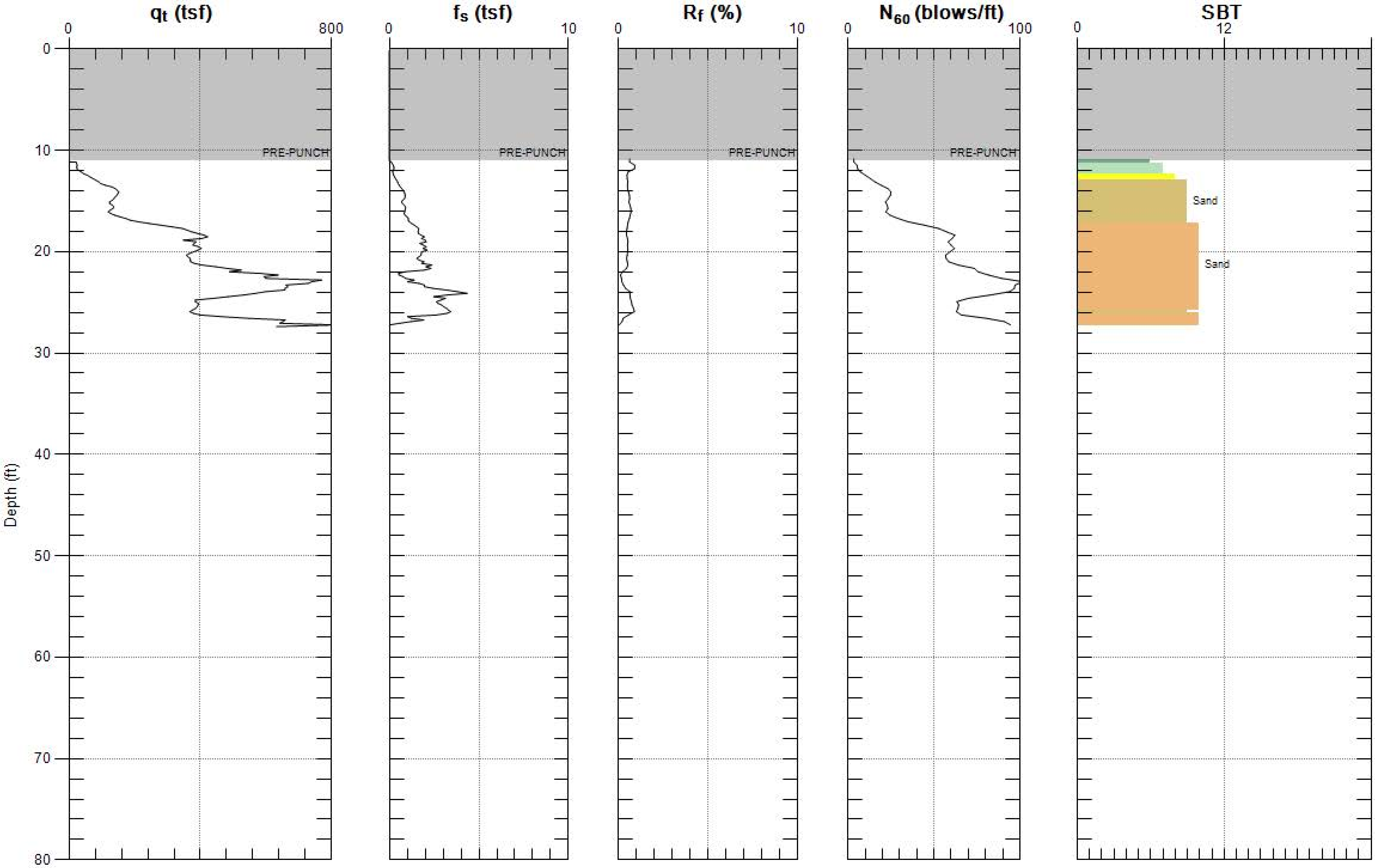
GREGG DRILLING AND TESTING, INC. CPT SITE INVESTIGATION SUMMARY

GREGG

GEOSYNTEC

Site: NRG
Sounding: CPT-1

Engineer: ROXANA
Date: 8/31/2015 08:31



Max. Depth: 27.395 (ft)
Avg. Interval: 0.328 (ft)

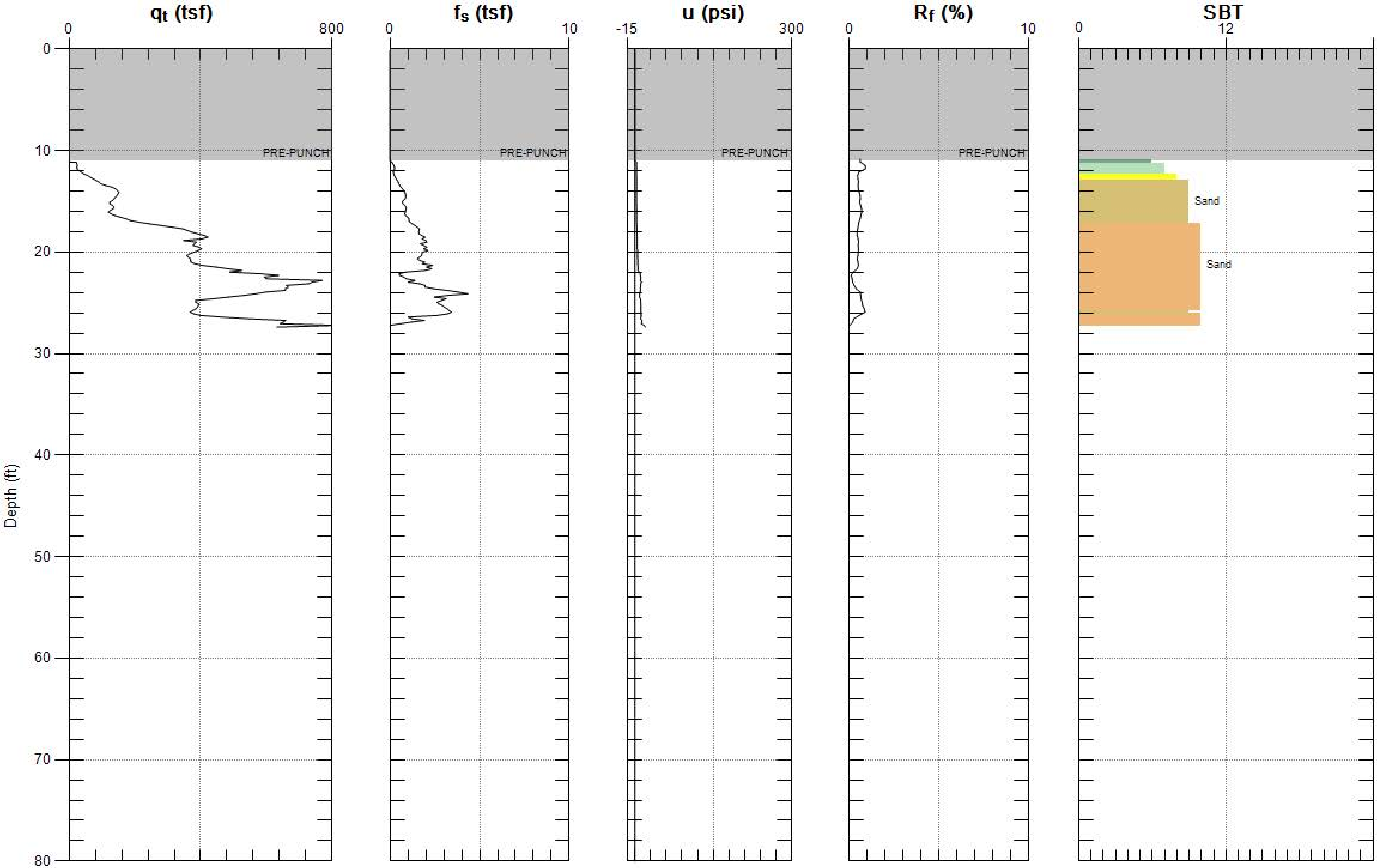
SBT: Soil Behavior Type (Robertson 1990)

GREGG

GEOSYNTEC

Site: NRG
Sounding: CPT-1

Engineer: ROXANA
Date: 8/31/2015 08:31



Max. Depth: 27.395 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

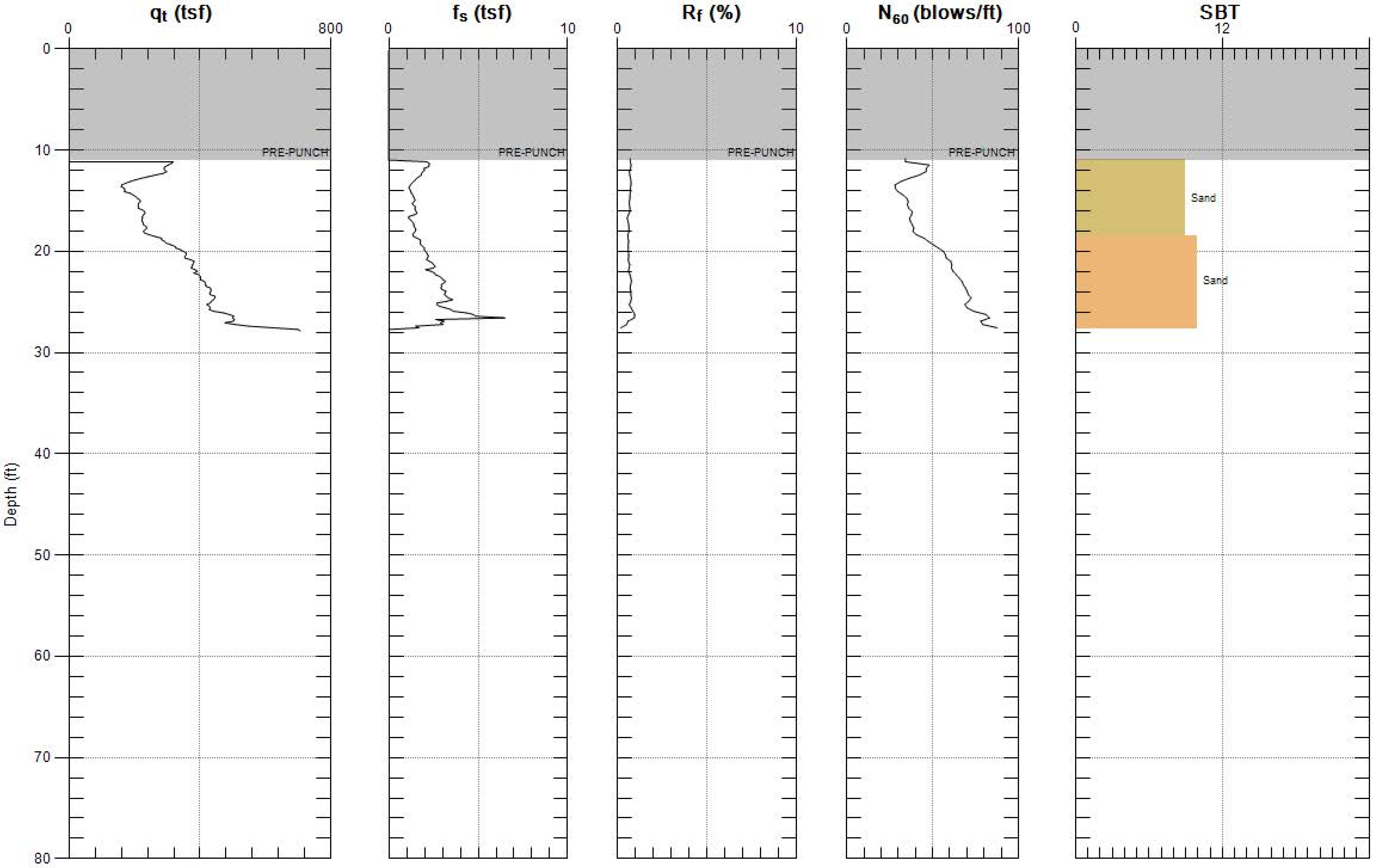
GEOSYNTEC

Site: NRG

Sounding: CPT-2

Engineer: ROXANA

Date: 8/31/2015 09:46



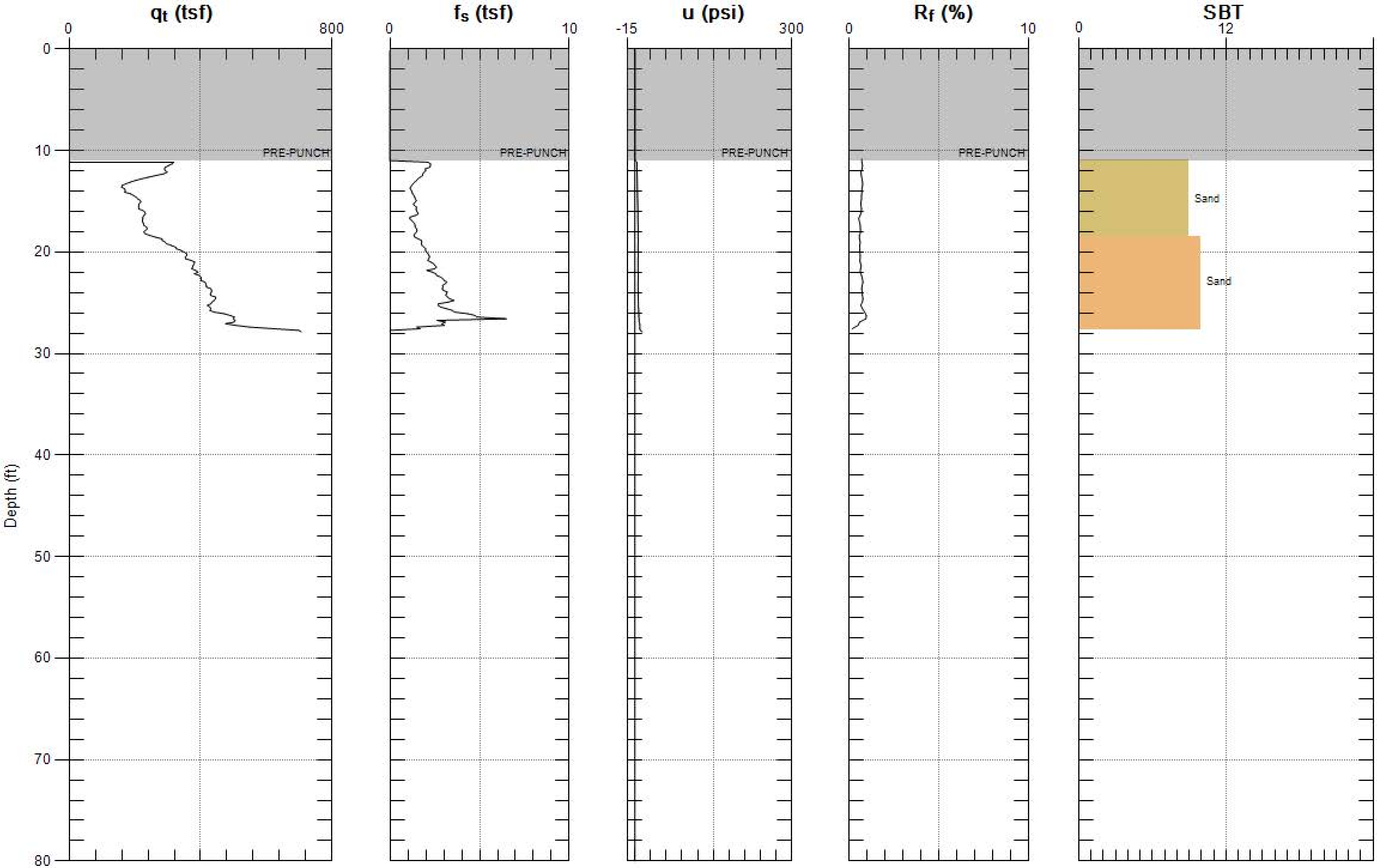
Max. Depth: 27.887 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GREGG **GEOSYNTEC**

Site: NRG
Sounding: CPT-2

Engineer: ROXANA
Date: 8/31/2015 09:46



Max. Depth: 27.887 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

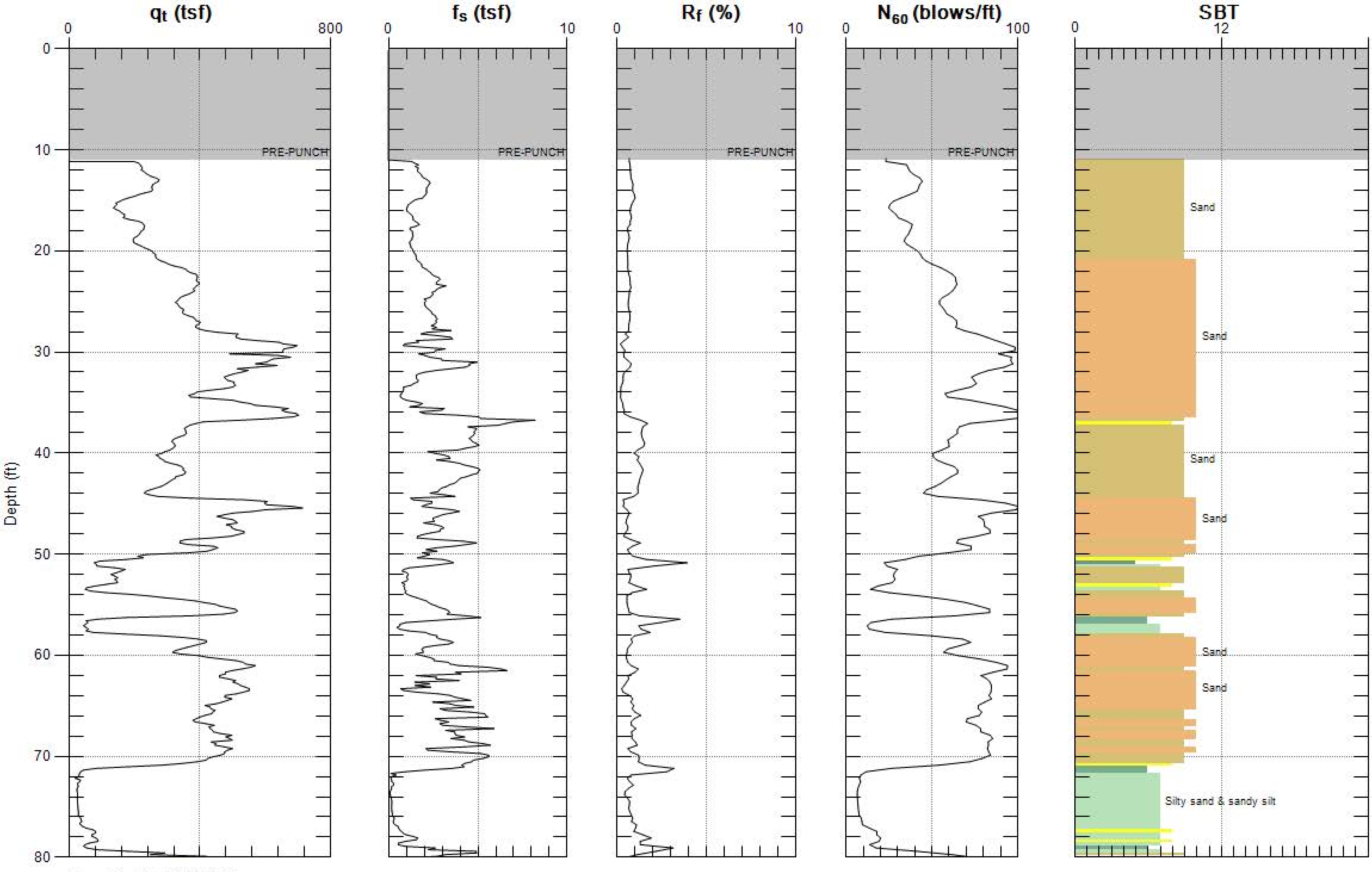
GEOSYNTEC

Site: NRG

Sounding: CPT-3

Engineer: ROXANA

Date: 8/31/2015 11:53



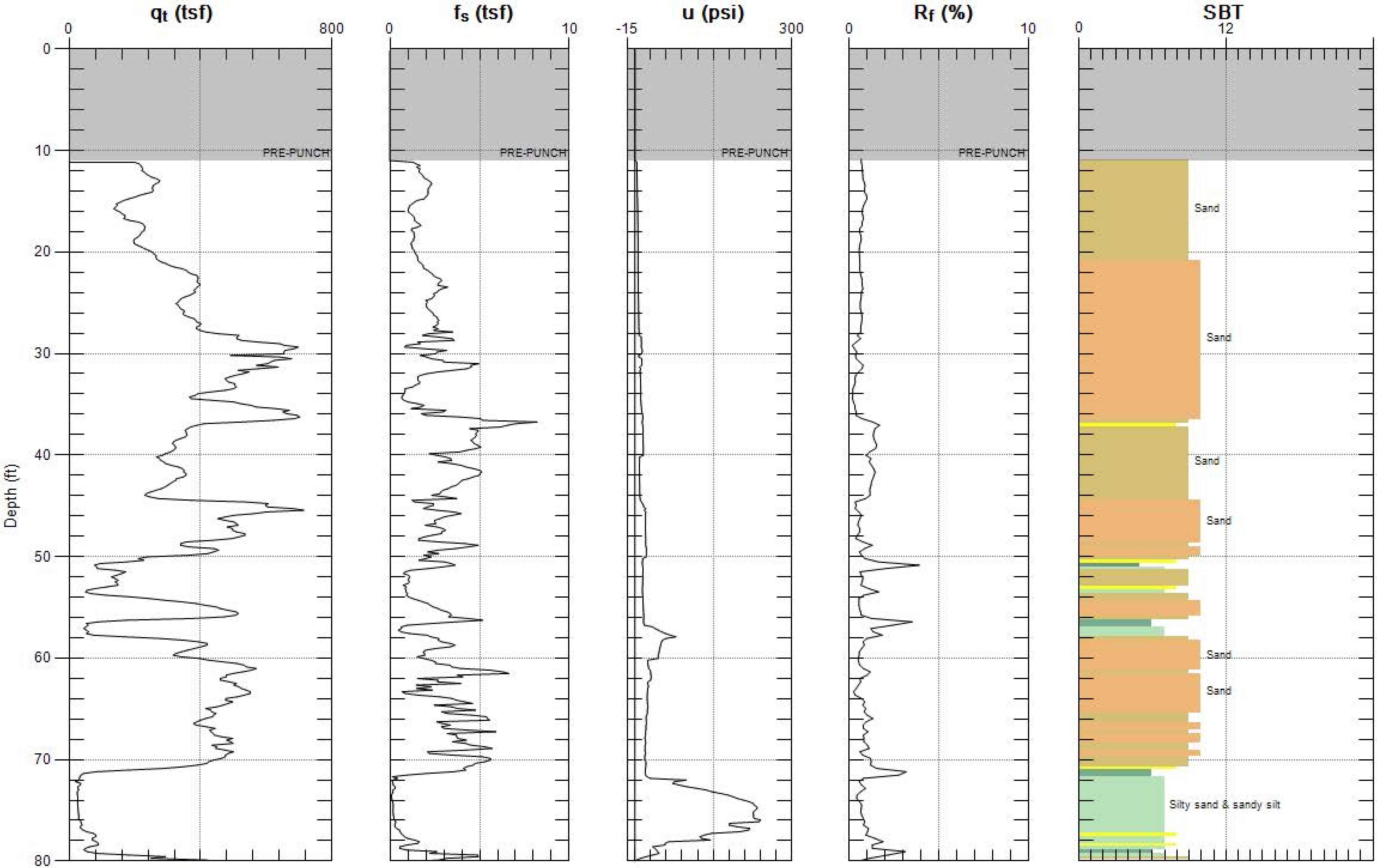
Max. Depth: 81.365 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GREGG **GEOSYNTEC**

Site: NRG
Sounding: CPT-3

Engineer: ROXANA
Date: 8/31/2015 11:53



Max. Depth: 81.365 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

ATTACHMENT 3

RAW CPT AND PPDT DATA AND HYDRAULIC CONDUCTIVITY CALCULATIONS

Estimate of Hydraulic Conductivity Based on SBTnIc

In situ data				Estimated k*	
Depth (ft bgs)	Elev (ft MSL)	SBTn	SBTnIc	Ksbt (ft/s)	Ksbt (ft/d)
0.328	19.672	0	0	0.00E+00	0.00E+00
0.656	19.344	0	0	0.00E+00	0.00E+00
0.984	19.016	0	0	0.00E+00	0.00E+00
1.312	18.688	0	0	0.00E+00	0.00E+00
1.64	18.36	0	0	0.00E+00	0.00E+00
1.969	18.031	0	0	0.00E+00	0.00E+00
2.297	17.703	0	0	0.00E+00	0.00E+00
2.625	17.375	0	0	0.00E+00	0.00E+00
2.953	17.047	0	0	0.00E+00	0.00E+00
3.281	16.719	0	0	0.00E+00	0.00E+00
3.609	16.391	0	0	0.00E+00	0.00E+00
3.937	16.063	0	0	0.00E+00	0.00E+00
4.265	15.735	0	0	0.00E+00	0.00E+00
4.593	15.407	0	0	0.00E+00	0.00E+00
4.921	15.079	0	0	0.00E+00	0.00E+00
5.249	14.751	0	0	0.00E+00	0.00E+00
5.577	14.423	0	0	0.00E+00	0.00E+00
5.906	14.094	0	0	0.00E+00	0.00E+00
6.234	13.766	0	0	0.00E+00	0.00E+00
6.562	13.438	0	0	0.00E+00	0.00E+00
6.89	13.11	0	0	0.00E+00	0.00E+00
7.218	12.782	0	0	0.00E+00	0.00E+00
7.546	12.454	0	0	0.00E+00	0.00E+00
7.874	12.126	0	0	0.00E+00	0.00E+00
8.202	11.798	0	0	0.00E+00	0.00E+00
8.53	11.47	0	0	0.00E+00	0.00E+00
8.858	11.142	0	0	0.00E+00	0.00E+00
9.186	10.814	0	0	0.00E+00	0.00E+00
9.514	10.486	0	0	0.00E+00	0.00E+00
9.843	10.157	0	0	0.00E+00	0.00E+00
10.17	9.829	0	0	0.00E+00	0.00E+00
10.5	9.501	0	0	0.00E+00	0.00E+00
10.83	9.173	0	0	0.00E+00	0.00E+00
11.16	8.845	6	1.57	2.05E-04	1.77E+01
11.48	8.517	6	1.46	5.61E-04	4.85E+01
11.81	8.189	6	1.46	7.06E-04	6.10E+01
12.14	7.861	6	1.47	7.12E-04	6.15E+01
12.47	7.533	6	1.47	7.56E-04	6.53E+01
12.8	7.205	6	1.45	7.51E-04	6.49E+01
13.12	6.877	6	1.49	6.85E-04	5.92E+01
13.45	6.549	6	1.52	6.05E-04	5.23E+01
13.78	6.22	6	1.52	5.40E-04	4.67E+01
14.11	5.892	6	1.55	4.40E-04	3.80E+01
14.44	5.564	6	1.63	3.10E-04	2.68E+01
14.76	5.236	6	1.69	2.11E-04	1.82E+01
15.09	4.908	6	1.71	1.72E-04	1.49E+01
15.42	4.58	6	1.72	1.69E-04	1.46E+01
15.75	4.252	6	1.71	1.93E-04	1.67E+01
16.08	3.924	6	1.67	2.19E-04	1.89E+01
16.4	3.596	6	1.67	2.39E-04	2.06E+01
16.73	3.268	6	1.68	2.90E-04	2.51E+01
17.06	2.94	6	1.6	3.74E-04	3.23E+01
17.39	2.612	6	1.57	5.46E-04	4.72E+01
17.72	2.283	6	1.51	6.49E-04	5.61E+01
18.05	1.955	6	1.53	6.65E-04	5.75E+01
18.37	1.627	6	1.58	5.35E-04	4.62E+01
18.7	1.299	6	1.62	4.52E-04	3.91E+01
19.03	0.971	6	1.61	4.64E-04	4.01E+01
19.36	0.643	6	1.58	5.76E-04	4.98E+01
19.69	0.315	6	1.54	7.43E-04	6.42E+01
20.01	-0.013	6	1.51	8.71E-04	7.53E+01
20.34	-0.341	6	1.51	9.36E-04	8.09E+01

In situ data				Estimated k*	
Depth (ft bgs)	Elev (ft MSL)	SBTn	SBTnIc	Ksbt (ft/s)	Ksbt (ft/d)
20.669	-0.669	6	1.51	9.80E-04	8.47E+01
20.997	-0.997	6	1.5	1.07E-03	9.24E+01
21.325	-1.325	6	1.48	1.29E-03	1.11E+02
21.654	-1.654	6	1.44	1.48E-03	1.28E+02
21.982	-1.982	6	1.44	1.64E-03	1.42E+02
22.31	-2.31	6	1.44	1.55E-03	1.34E+02
22.638	-2.638	6	1.46	1.45E-03	1.25E+02
22.966	-2.966	6	1.47	1.34E-03	1.16E+02
23.294	-3.294	6	1.48	1.22E-03	1.05E+02
23.622	-3.622	6	1.5	1.22E-03	1.05E+02
23.95	-3.95	6	1.47	1.21E-03	1.05E+02
24.278	-4.278	6	1.48	1.25E-03	1.08E+02
24.606	-4.606	6	1.5	1.21E-03	1.05E+02
24.934	-4.934	6	1.49	1.20E-03	1.04E+02
25.262	-5.262	6	1.5	1.23E-03	1.06E+02
25.591	-5.591	6	1.49	1.19E-03	1.03E+02
25.919	-5.919	6	1.51	1.12E-03	9.68E+01
26.247	-6.247	6	1.52	1.09E-03	9.42E+01
26.575	-6.575	6	1.51	1.16E-03	1.00E+02
26.903	-6.903	6	1.49	1.33E-03	1.15E+02
27.231	-7.231	6	1.47	1.46E-03	1.26E+02
27.559	-7.559	6	1.47	1.62E-03	1.40E+02
27.887	-7.887	6	1.45	2.53E-03	2.19E+02
28.215	-8.215	7	1.3	3.02E-03	2.61E+02
28.543	-8.543	7	1.39	5.40E-03	4.67E+02
28.871	-8.871	7	1.21	1.20E-02	1.04E+03
29.199	-9.199	7	0.95	0.00E+00	0.00E+00
29.528	-9.528	7	1.08	0.00E+00	0.00E+00
29.856	-9.856	7	1.2	1.67E-02	1.44E+03
30.184	-10.184	7	1.18	1.33E-02	1.15E+03
30.512	-10.512	7	1.17	9.21E-03	7.96E+02
30.84	-10.84	7	1.33	4.81E-03	4.16E+02
31.168	-11.168	7	1.43	2.79E-03	2.41E+02
31.496	-11.496	7	1.41	2.72E-03	2.35E+02
31.824	-11.824	7	1.34	4.24E-03	3.66E+02
32.152	-12.152	7	1.24	7.19E-03	6.21E+02
32.48	-12.48	7	1.25	9.80E-03	8.47E+02
32.808	-12.808	7	1.25	1.12E-02	9.68E+02
33.136	-13.136	7	1.2	1.52E-02	1.31E+03
33.465	-13.465	7	1.13	1.91E-02	1.65E+03
33.793	-13.793	7	1.18	1.91E-02	1.65E+03
34.121	-14.121	7	1.23	1.58E-02	1.37E+03
34.449	-14.449	7	1.21	1.58E-02	1.37E+03
34.777	-14.777	7	1.17	1.54E-02	1.33E+03
35.105	-15.105	7	1.21	1.65E-02	1.43E+03
35.433	-15.433	7	1.17	1.45E-02	1.25E+03
35.761	-15.761	7	1.21	1.51E-02	1.30E+03
36.089	-16.089	7	1.19	7.79E-03	6.73E+02
36.417	-16.417	6	1.39	2.28E-03	1.97E+02
36.745	-16.745	6	1.68	5.47E-04	4.73E+01
37.073	-17.073	6	1.84	1.93E-04	1.67E+01
37.402	-17.402	6	1.81	1.37E-04	1.18E+01
37.73	-17.73	6	1.8	1.58E-04	1.37E+01
38.058	-18.058	6	1.8	1.56E-04	1.35E+01
38.386	-18.386	6	1.82	1.38E-04	1.19E+01
38.714	-18.714	6	1.86	1.14E-04	9.85E+00
39.042	-19.042	6	1.87	1.03E-04	8.90E+00
39.37	-19.37	6	1.86	1.19E-04	1.03E+01
39.698	-19.698	6	1.79	1.55E-04	1.34E+01
40.026	-20.026	6	1.77	1.67E-04	1.44E+01
40.354	-20.354	6	1.85	1.59E-04	1.37E+01

* calculated using CPeT-IT v.1.6

In situ data				Estimated k*	
Depth (ft bgs)	Elev (ft MSL)	SBTn	SBTnIc	Ksbt (ft/s)	Ksbt (ft/d)
40.68	-20.682	6	1.82	1.38E-04	1.19E+01
41.01	-21.011	6	1.82	1.45E-04	1.25E+01
41.34	-21.339	6	1.83	1.36E-04	1.18E+01
41.67	-21.667	6	1.84	1.36E-04	1.18E+01
42	-21.995	6	1.83	1.36E-04	1.18E+01
42.32	-22.323	6	1.83	1.41E-04	1.22E+01
42.65	-22.651	6	1.83	1.39E-04	1.20E+01
42.98	-22.979	6	1.84	1.35E-04	1.17E+01
43.31	-23.307	6	1.85	1.20E-04	1.04E+01
43.64	-23.635	6	1.88	1.04E-04	8.99E+00
43.96	-23.963	6	1.91	1.31E-04	1.13E+01
44.29	-24.291	6	1.76	6.85E-04	5.92E+01
44.62	-24.619	7	1.31	3.20E-03	2.76E+02
44.95	-24.948	7	1.29	1.13E-02	9.76E+02
45.28	-25.276	7	1.21	8.74E-03	7.55E+02
45.6	-25.604	7	1.38	4.98E-03	4.30E+02
45.93	-25.932	6	1.51	2.48E-03	2.14E+02
46.26	-26.26	6	1.5	2.09E-03	1.81E+02
46.59	-26.588	7	1.44	2.74E-03	2.37E+02
46.92	-26.916	7	1.42	2.84E-03	2.45E+02
47.24	-27.244	7	1.49	2.63E-03	2.27E+02
47.57	-27.572	7	1.47	2.85E-03	2.46E+02
47.9	-27.9	7	1.39	3.95E-03	3.41E+02
48.23	-28.228	7	1.36	2.65E-03	2.29E+02
48.56	-28.556	6	1.65	7.43E-04	6.42E+01
48.89	-28.885	6	1.84	3.67E-04	3.17E+01
49.21	-29.213	6	1.65	5.00E-04	4.32E+01
49.54	-29.541	6	1.53	8.42E-04	7.27E+01
49.87	-29.869	6	1.66	5.88E-04	5.08E+01
50.2	-30.197	6	1.88	1.22E-04	1.05E+01
50.53	-30.525	5	2.16	1.15E-05	9.94E-01
50.85	-30.853	5	2.64	2.68E-06	2.32E-01
51.18	-31.181	5	2.38	4.08E-06	3.53E-01
51.51	-31.509	6	1.92	2.31E-05	2.00E+00
51.84	-31.837	6	1.98	6.15E-05	5.31E+00
52.17	-32.165	6	2.03	5.02E-05	4.34E+00
52.49	-32.493	6	1.99	4.79E-05	4.14E+00
52.82	-32.822	6	2	2.68E-05	2.32E+00
53.15	-33.15	5	2.31	7.41E-06	6.40E-01
53.48	-33.478	5	2.56	5.20E-06	4.49E-01
53.81	-33.806	6	2.1	3.86E-05	3.34E+00
54.13	-34.134	6	1.75	2.77E-04	2.39E+01
54.46	-34.462	6	1.63	8.38E-04	7.24E+01
54.79	-34.79	6	1.56	1.33E-03	1.15E+02
55.12	-35.118	6	1.53	1.60E-03	1.38E+02
55.45	-35.446	6	1.53	1.55E-03	1.34E+02
55.77	-35.774	6	1.56	6.86E-04	5.93E+01
56.1	-36.102	6	1.87	1.14E-04	9.85E+00
56.43	-36.43	5	2.56	8.70E-06	7.52E-01
56.76	-36.759	4	2.7	3.72E-07	3.21E-02
57.09	-37.087	4	2.56	4.29E-07	3.71E-02
57.42	-37.415	5	2.55	1.05E-06	9.07E-02
57.74	-37.743	5	2.4	1.36E-05	1.18E+00
58.07	-38.071	6	1.88	1.02E-04	8.81E+00
58.4	-38.399	6	1.69	3.39E-04	2.93E+01
58.73	-38.727	6	1.69	5.39E-04	4.66E+01
59.06	-39.055	6	1.67	5.93E-04	5.12E+01
59.38	-39.383	6	1.65	6.83E-04	5.90E+01
59.71	-39.711	6	1.67	9.15E-04	7.91E+01
60.04	-40.039	6	1.58	1.28E-03	1.11E+02
60.37	-40.367	6	1.53	1.75E-03	1.51E+02
60.7	-40.696	6	1.52	1.54E-03	1.33E+02

In situ data				Estimated k*	
Depth (ft bgs)	Elev (ft MSL)	SBTn	SBTnIc	Ksbt (ft/s)	Ksbt (ft/d)
61.024	-41.024	6	1.59	8.23E-04	7.11E+01
61.352	-41.352	6	1.73	5.32E-04	4.60E+01
61.68	-41.68	6	1.71	5.29E-04	4.57E+01
62.008	-42.008	6	1.57	8.65E-04	7.47E+01
62.336	-42.336	6	1.58	1.65E-03	1.43E+02
62.664	-42.664	6	1.5	2.45E-03	2.12E+02
62.992	-42.992	7	1.42	5.37E-03	4.64E+02
63.32	-43.32	7	1.3	7.96E-03	6.88E+02
63.648	-43.648	7	1.38	4.38E-03	3.78E+02
63.976	-43.976	6	1.6	1.51E-03	1.30E+02
64.304	-44.304	6	1.67	7.93E-04	6.85E+01
64.633	-44.633	6	1.65	5.59E-04	4.83E+01
64.961	-44.961	6	1.74	5.26E-04	4.54E+01
65.289	-45.289	6	1.7	3.94E-04	3.40E+01
65.617	-45.617	6	1.75	2.78E-04	2.40E+01
65.945	-45.945	6	1.86	2.28E-04	1.97E+01
66.273	-46.273	6	1.78	2.44E-04	2.11E+01
66.601	-46.601	6	1.72	4.00E-04	3.46E+01
66.929	-46.929	6	1.7	3.92E-04	3.39E+01
67.257	-47.257	6	1.78	4.28E-04	3.70E+01
67.585	-47.585	6	1.69	4.57E-04	3.95E+01
67.913	-47.913	6	1.68	6.15E-04	5.31E+01
68.241	-48.241	6	1.67	5.05E-04	4.36E+01
68.57	-48.57	6	1.76	3.72E-04	3.21E+01
68.898	-48.898	6	1.79	4.56E-04	3.94E+01
69.226	-49.226	6	1.58	6.00E-04	5.18E+01
69.554	-49.554	6	1.66	5.56E-04	4.80E+01
69.882	-49.882	6	1.81	2.86E-04	2.47E+01
70.21	-50.21	6	1.84	1.72E-04	1.49E+01
70.538	-50.538	6	1.87	9.83E-05	8.49E+00
70.866	-50.866	6	2.06	2.49E-05	2.15E+00
71.194	-51.194	5	2.6	2.70E-06	2.33E-01
71.522	-51.522	4	2.96	1.31E-07	1.13E-02
71.85	-51.85	4	2.75	6.43E-08	5.56E-03
72.178	-52.178	4	2.75	1.53E-07	1.32E-02
72.507	-52.507	4	2.74	1.20E-07	1.04E-02
72.835	-52.835	4	2.86	1.03E-07	8.90E-03
73.163	-53.163	4	2.82	8.97E-08	7.75E-03
73.491	-53.491	4	2.78	1.18E-07	1.02E-02
73.819	-53.819	4	2.75	1.21E-07	1.05E-02
74.147	-54.147	4	2.82	1.02E-07	8.81E-03
74.475	-54.475	4	2.84	8.81E-08	7.61E-03
74.803	-54.803	4	2.82	9.04E-08	7.81E-03
75.131	-55.131	4	2.8	1.00E-07	8.64E-03
75.459	-55.459	4	2.8	1.03E-07	8.90E-03
75.787	-55.787	4	2.81	1.17E-07	1.01E-02
76.115	-56.115	4	2.75	1.45E-07	1.25E-02
76.444	-56.444	4	2.71	1.55E-07	1.34E-02
76.772	-56.772	4	2.77	2.54E-07	2.19E-02
77.1	-57.1	5	2.57	6.70E-07	5.79E-02
77.428	-57.428	5	2.41	1.01E-06	8.73E-02
77.756	-57.756	5	2.54	9.16E-07	7.91E-02
78.084	-58.084	5	2.57	7.83E-07	6.77E-02
78.412	-58.412	4	2.48	5.84E-07	5.05E-02
78.74	-58.74	4	2.66	2.77E-07	2.39E-02
79.068	-59.068	4	2.81	7.46E-07	6.45E-02
79.396	-59.396	5	2.31	8.21E-06	7.09E-01
79.724	-59.724	6	1.94	1.20E-04	1.04E+01
80.052	-60.052	6	1.54	1.10E-03	9.50E+01
80.381	-60.381	7	1.42	6.64E-03	5.74E+02
80.709	-60.709	7	1.33	1.26E-02	1.09E+03
81.037	-61.037	7	1.28	2.42E-02	2.09E+03

* calculated using CPeT-IT v.1.6

Estimate of Hydraulic Conductivity Based on PPDT Data

Theoretical time factors		Pene-trometer radius	Pene-trometer radius	Specific weight of water	Specific weight of water	Water table depth
T_{90}	T_{50}	r_o	r_o	γ_w	γ_w	
(unitless)	(unitless)	(cm)	(ft)	(lb/ft^3)	(ton/ft^3)	(ft)
0.850	0.197	1.09	0.036	62.43	0.03	20.00

LEGEND
Constant
Calculated
Test data

Test Depth	Corrected Cone Resistence, qt	Total Over-burden Stress, σv	Soil Behavior Type Index, SBTnIc	α_M[1]	Constrain-ed Modulus, M[2]	Pore pressure at t_{100}[3]	Pore pressure at t_0	Pore pressure at t_{50}[4]	Time for 50% dissipa-tion, t_{50}	Coeffi-cient of Consoli-dation, c[5]	Hydraulic Conductivity, k[6]	
(ft bgs)	(tsf)	(tsf)	(unitless)	(unitless)	(tsf)	(PSI)	(PSI)	(PSI)	(sec)	(ft^2/sec)	(ft/sec)	**(ft/day)**
30.02	594	1.889	1.10	3.62	2146.86	4.3	18	11.2	80	3.16E-06	2.12E-04	**1.83E+01**
40.03	281	2.509	1.73	8.05	2240.34	8.7	21	14.8	82	3.09E-06	2.16E-04	**1.86E+01**
50.03	225	3.148	1.77	8.47	1879.55	13.0	28	20.5	85	2.98E-06	1.75E-04	**1.51E+01**
60.04	387	3.754	1.43	5.50	2107.08	17.4	52	34.7	202	1.25E-06	8.24E-05	**7.12E+00**
70.05	428	4.397	1.72	NA	NA	NA	19*	NA	NA	NA	NA	**NA**
72.01	29	4.513	2.72	14.00	340.72	22.5	160	91.3	1641	1.54E-07	1.64E-06	**1.42E-01**
81.20	564	5.043	1.01	3.23	1807.87	26.5	37	31.9	20	5.46E-05	3.08E-03	**2.66E+02**

* invalid data, not used

1. $\alpha_M = 0.0188 \cdot \left[10^{(0.55 SBT_n I_c + 1.68)}\right]$ $for\ \ SBT_n I_c < 2.2\ (coarse\ grained\ soils)$

   $\alpha_M = 14\ for\ SBT_n I_c > 2.2\ and\ q_t > 14\ tsf\ (fine\ grained\ soils)$

2. $M = \alpha_M (q_t - \sigma_{vo})$
3. $Pore\ pressure\ at\ t_{100} =$ $(test\ depth - water\ table\ depth) \cdot specific\ weight\ of\ water$
4. $Pore\ pressure\ at\ t_{50} = \frac{(t_0 - t_{100})}{2} + t_{100}$
5. $c = \left(\frac{T_{50}}{t_{50}}\right) {r_o}^2$
6. $k = \frac{c \cdot \gamma_w}{M}$

APPENDIX I
Offshore Seismic Reflection Survey

Sea Engineering Memorandum (Jim Barry)

Sea Engineering, Inc.
Makai Research Pier 41-305 Kalanianaole Hwy.
Waimanalo, Hawaii 96795-1820
Ph: (808) 259-7966 Fax: (808) 259-8143
Email: sei@seaengineering.com
Website: www.seaengineering.com

Memorandum

DATE: September 10, 2015

TO: Gordon Thrupp, Al Preston
Geosyntec Consultants

FROM: Jim Barry

SUBJECT: West Basin geophysical survey after-action report

Introduction

Geosyntec Consultants commissioned the Ventura, Ca., office of Fugro Pelagos, Inc., to conduct a geophysical survey offshore of a proposed new water desalination facility on the coast at El Segundo. The purpose of the survey was to delineate geologic features below the sea bottom as the offshore substrate is being considered for subsurface sea water intakes. *In situ* data, including two offshore borings, probes, and cone penetrometer testing indicate the substrate consists of approximately 20 ft of coarse sand underlain by two fine grained layers approximately 10 ft apart (Figure 1). The sub-bottom survey was designed to delineate the presence and extent of these fine-grained features.

Survey Date

The survey was conducted on September 3rd, 2015.

Survey Layout

The survey layout is shown in Figure 2, and consists of five survey lines. Three lines are shore perpendicular, and two line (cross-lines) are shore parallel. The shore perpendicular lines are approximately 3,000 ft in length, and the shore parallel lines are approximately 4,000 ft in length.

Survey Vessel

The survey vessel used was the *Theory*, a 37 ft aluminum, catamaran-hulled boat built specifically for survey purposes. A 1,000-lb A-frame was mounted on the stern. The vessel is owned and operated by Theory Marine, based in Ventura, Ca. Figures 3 and 4 are photographs of the boat.

Survey Personnel

A total of five persons were present on-board during the survey. Personnel and affiliations are:

Tom Stark	Boat Captain, Theory Marine Services, LLC

Mark Williams	Survey Hydrographer, Fugro Pelagos, Inc.
Eric Pallister	Survey Geologist, Geo-Marine Technology, Inc.
Jennifer Klaib	Marine Mammal Observer
James Barry	Observer for Geosyntec Consultants and West Basin Municipal Water District, Sea Engineering, Inc.

Survey Instrumentation

Navigation:	Trimble DGPS (Coast Guard Beacon)
Navigation Software:	Hypack
Sub-Bottom Profiler (1):	EdgeTech XStar 3200 SB-512 Chirp
Sub-Bottom Profiler (2):	Towed Boomer Plate (unknown manufacture)
Bathymetry:	Odom Hydrographic Echotrac CV100

The EdgeTech SB-512 is shown on deck in Figure 5, and the boomer system is shown in Figure 6.

Schedule

All personnel met at the survey vessel *Theory* at the dock at Burton Chace Park (Marina del Rey) at 0700, September 3, 2015. Following is the approximate survey timeline:

0800	Vessel orientation and safety briefing
0830	Echo sounder bar check
0900	Leaving dock
0930	On-site at survey location; reconnaissance for obstructions (buoys, fishing gear) and marine mammals
0955	SB-512 tow fish deployed; testing chirp pulses
1034	Start first line (Line 300)
1202	End of SB-512 surveying; retrieving SB-512
1215 - 1330	Deployment of Boomer system; trouble shooting intermittent electrical problem
1330 - 1500	Surveying with Boomer
1500	Retrieving Boomer system
1510	Heading for harbor
1530	Dockside at Burton Chace Park, Marina del Rey

Weather was calm with overcast skies in the morning, becoming sunny with 5 to 8 kt westerly winds by 1100 and through the remainder of the day.

Survey Notes and Results

Chirp Pulse Testing: the following chirp pulses were tested:

0.7 – 12 kHz, 20 ms (e.g. frequency range of 700 to 1200 Hz, pulse length 20 milliseconds)
0.5 – 4.5 kHz, 50 ms (selected pulse)
0.5 – 7 kHz, 30 ms

The testing was done by comparing adjacent recordings, with the intent to maximize the appearance of the sub-bottom layer approximately 20 ft below the sea bottom. The selected pulse was 0.5 – 4.5 kHz, 50 ms.

Figure 7 is from a screen capture of SB-512 data for Line 100 (shore parallel), and Figure 8 is from a screen capture for Line 400 (shore perpendicular). The images have been edited by drawing lines that partially indicate the geologic horizons and the bottom multiple (note: the bottom multiple is a secondary image, or noise, caused by reflection off the air/water interface). Figure 7 (Line 100) shows two geologic horizons, Horizon 1 and Horizon 2 at about 3 meters (10 ft) and 5 meters (16 ft) below the sea bottom, respectively. Figure 8 (Line 400) indicates that Horizon 2 is a relatively uninterrupted feature, but the geology above and below is somewhat more complicated and discontinuous. These findings are preliminary, and subject to change upon further assessment by other members of the survey team.

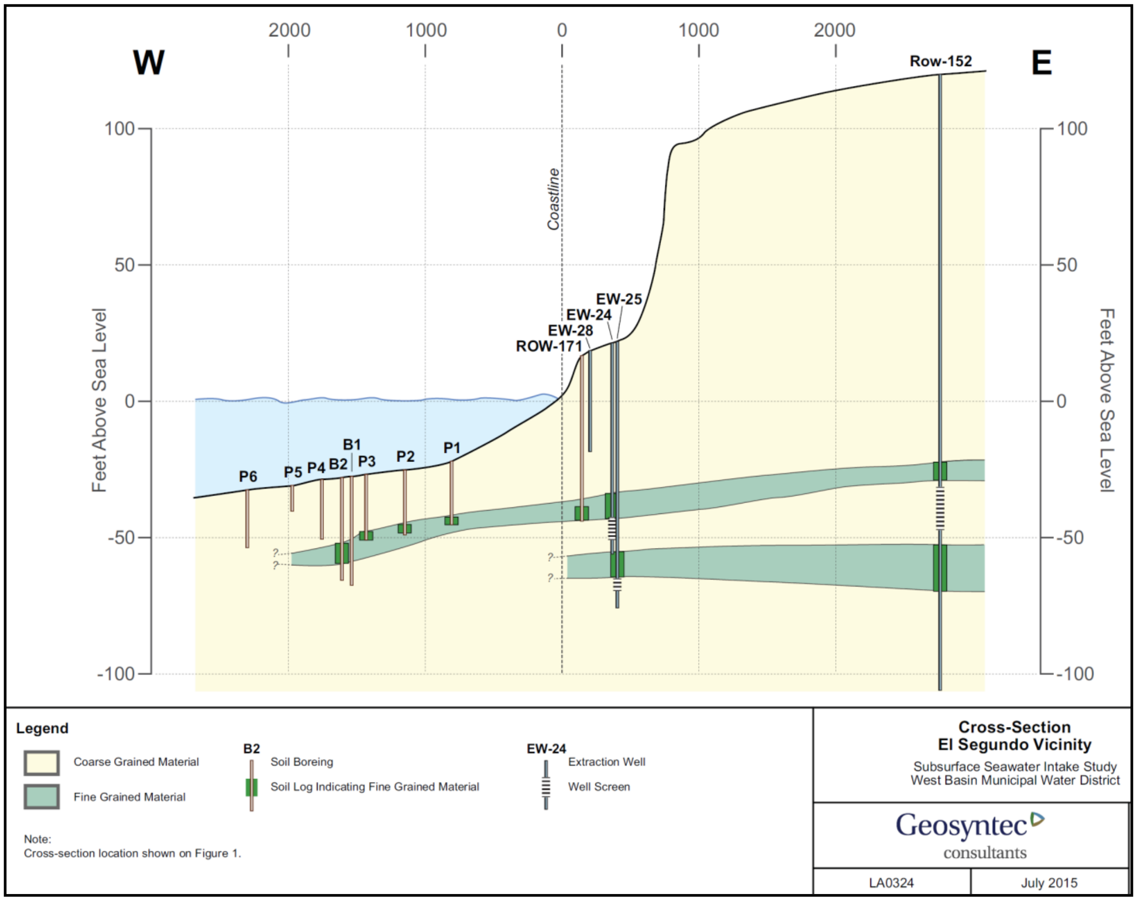


Figure 1. Inferred project site morphology; see Figure 2 for section location

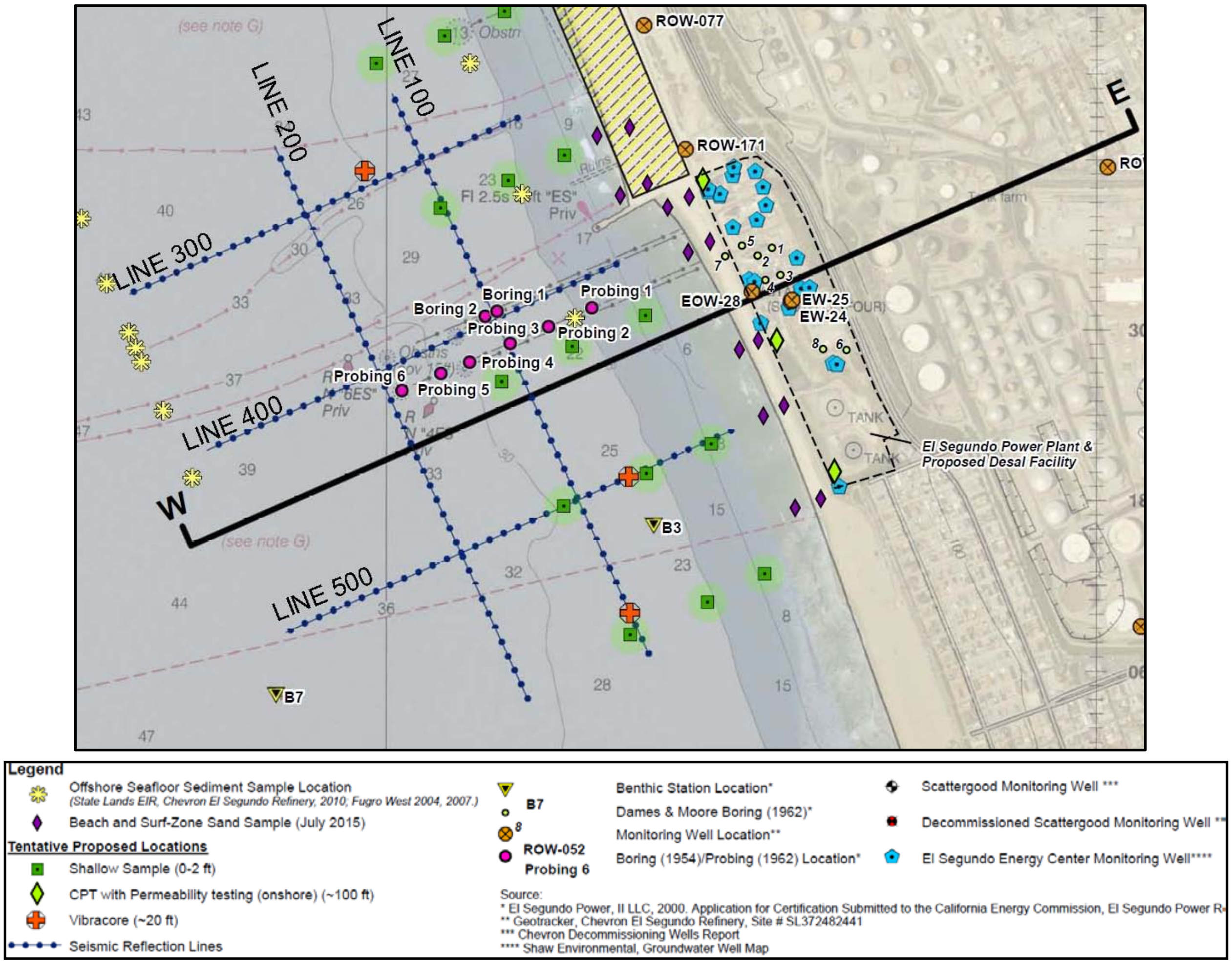


Figure 2. Survey line layout with boring and probe locations

Figure 3. Survey vessel *Theory*

Figure 4. Aft deck with A-frame

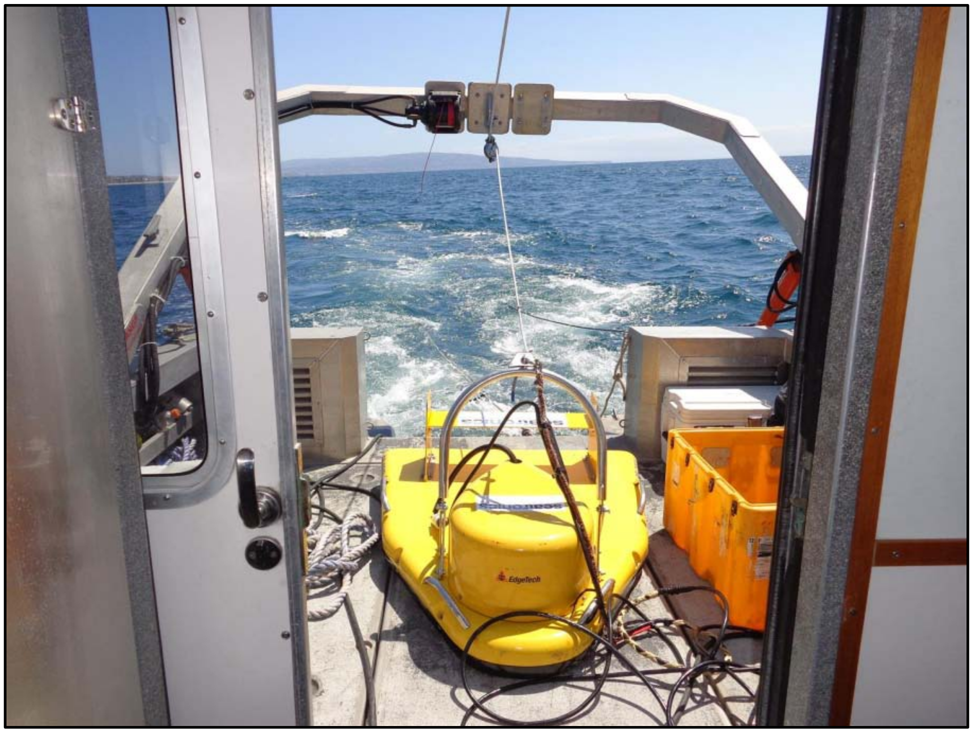


Figure 5. SB-512 on deck

Figure 6. Boomer system (boomer plate is underneath coil of line and cable)

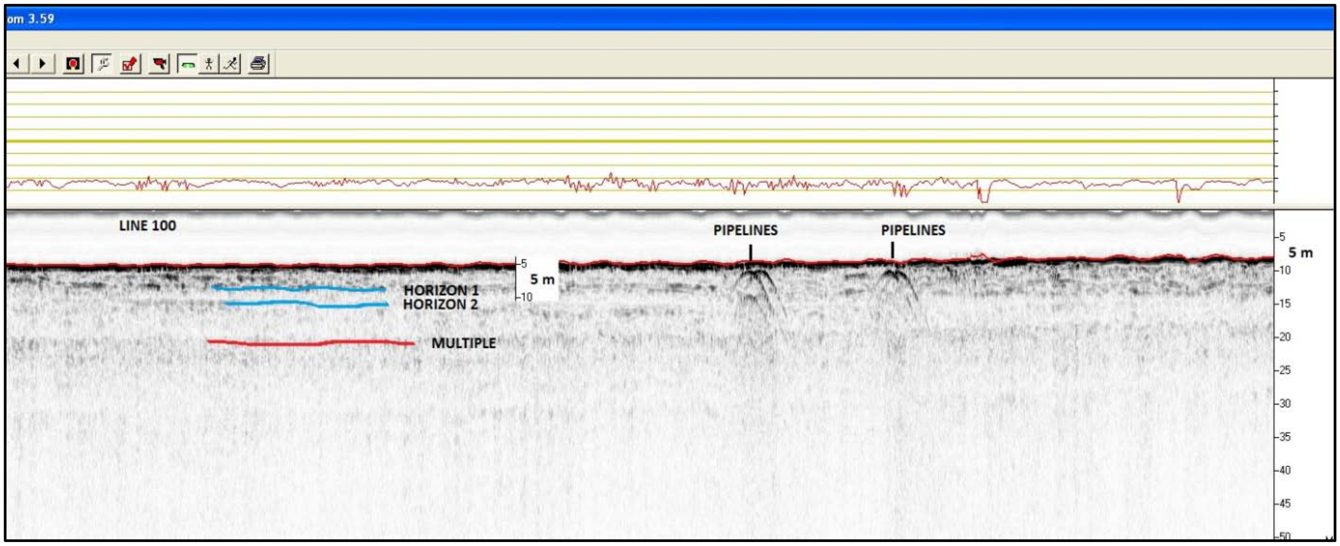


Figure 7. Data example, shore parallel line (Line 100)

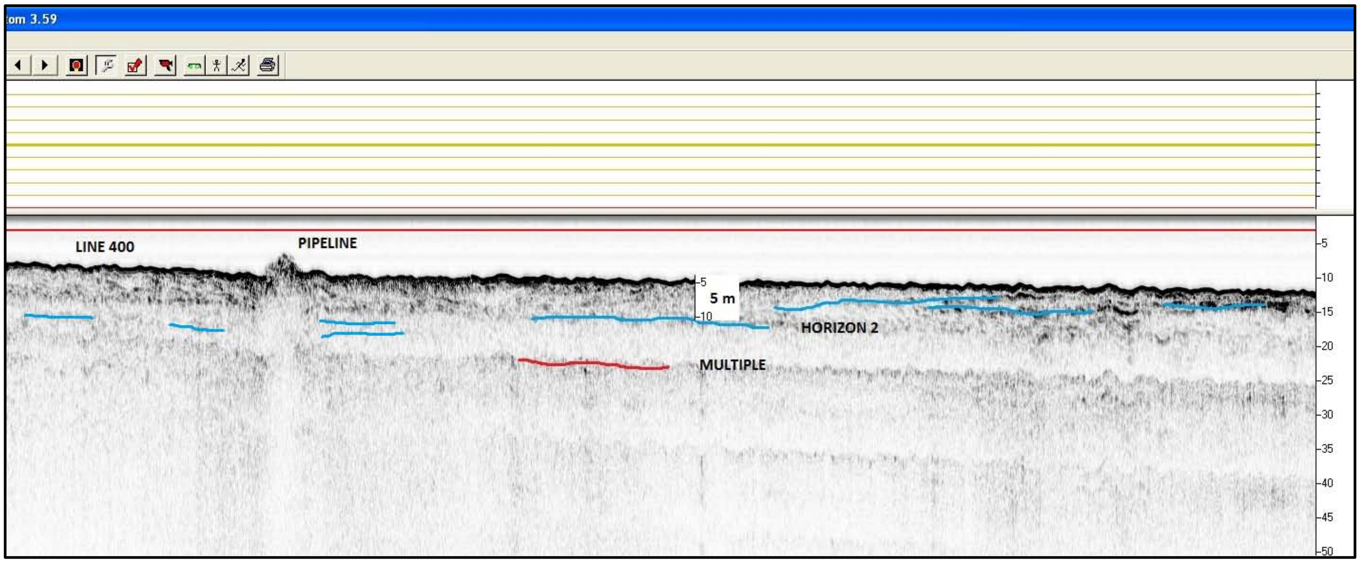


Figure 8. Data example, shore perpendicular line (Line 400)

Subbottom & Multichannel CDP Seismic Survey El Segundo, California Field Operations Report (Fugro)

GEOSYNTEC CONSULTANTS

SUBBOTTOM & MULTICHANNEL CDP SEISMIC SURVEY EL SEGUNDO, CALIFORNIA

FIELD OPERATIONS REPORT

Survey Period: September 3, 2015
Report Number: 23.00007142_R1

Prepared for:	Mr. Gordon Thrupp, PhD, PG, CHG Geosyntec Consultants 595 Market Street, Suite 610 San Francisco, California 94105
Client Reference:	23.00007142

1	Issued as Final	J. Reitman	B. Villegas	C. Pratt	10/7/2015
0	Issued as Draft	J. Reitman	A. Tardif	C. Pratt	9/25/2015
Rev	Description	Prepared	Checked	Approved	Date

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FIGURES

APPENDICES

1. INTRODUCTION AND SCOPE OF WORK

1.1 General

On September 3, 2015, Fugro Pelagos, Inc. (Fugro) acquired a sub-bottom profile (SBP) and multichannel CDP seismic (Boomer) survey to determine the presence and extent of previously identified clay beds in the shallow subsurface, and investigate deeper geologic features to a sub-seabed depth of at least 200 feet, offshore El Segundo Beach.

The survey consisting of Sub-bottom profiler and Boomer data collection was conducted onboard the *M/V Theory* on September 3, 2015. As seen on Plate 1, data were acquired along three (3) lines offset between 1200-1400 feet apart, oriented perpendicular to the shoreline and extending from the offshore limits to as near shore as safely possible. Additionally two (2) lines spaced 930 feet apart were run parallel to the shoreline with first line being approximately 1500 feet from the shoreline.

Previously acquired jet probes and borings indicate that the seabed and shallow sediments consist of sand with gravel and cobbles. This relatively coarse-grained material is notorious for not being conducive to acoustic penetration by high frequency signals such as the SBP. The SBP system used in the field was an Edgetech model SB-512i. To ensure adequate penetration of the upper 200 feet of sediment, a higher energy boomer source was used to supplement the SBP data. The boomer signals were recorded with a 24-channel Geo-Eel streamer.

Fugro delivered the SBP and Boomer data to Geo-Marine Technology (GMT) in early September, 2015. The SBP and Boomer data were loaded into Kingdom Suite (TKS) and RadEx Pro, respectively, for processing and interpretation. This report describes the SBP and Boomer data-processing techniques, and discusses interpretations of the processed data.

All data are referenced to NAD83 California Coordinate System, Zone 5 in U.S. Survey Feet. The vertical datum used for deliverables is MLLW (Mean Lower Low Water) based on NOAA predicted tides.

Because the project included offshore surveys using acoustical methods, and the survey area was within California State Lands Commission (CSLC) jurisdiction, a marine mammal observer was onboard and a copy of the final Marine Wildlife Monitoring Report can be found in Appendix A. In accordance with CSLC regulations, a completed copy of Exhibit H taken from Fugro Geophysical Permit PRC 8391.9 has been completed with acknowledgements and included in Appendix B. Images of the interpreted profiles can be found in Appendix C.

1.2 Units and Conventions

Units used on the survey are as follows:

- Horizontal linear distance units are U.S. Survey Feet.
- Angular units are degrees (°).

Time was recorded and noted in field logs in Pacific Time (UTC -08:00).

1.3 Abbreviations

CSLC	California State Lands Commission
DGPS	Differential Global Positioning System
FM	Formation
GPS	Global Positioning System
HSE	Health, Safety, & Environmental
KHz	Kilohertz
MLLW	Mean Lower Low Water
MSEC	Millisecond
M/V	Marine Vessel
NAD	North American Datum
NOAA	National Oceanic and Atmospheric Administration
QA / QC	Quality Assurance / Quality Control
QHSE	Quality, Health, Safety, & Environmental
SVP	Sound Velocity Profile
TWTT	Two Way Travel Time
UTC	Coordinated Universal Time
WGS84	World Geodetic System of 1984

Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Legend

🟥	Existing Pipeline
⬜	Survey Tracklines with Events
🟩	Survey Lines with Stationing

Notes:

Coordinate Grid: State Plane, NAD 83, CA Zone 5, Feet

N

1 inch = 600 feet

600 300 0 600 Feet

GEOSYNTEC
SURVEY SITE MAP
EL SEGUNDO, CA

Plate 1

N:\Projects\04_2015\23_0000_7142 Geosyntec Seismic\Outputs\2015_09_25_SiteMap\mxd\SiteMap.mxd, 9/22/2015, tardifa

2. METHODS AND RESOLUTION LIMITATIONS

2.1 Positioning and Navigation

A wide area DGPS was used to position the survey vessel. A "wide area" application operates with correction values applied to a stand-alone GPS receiver from base stations located over large distances. DGPS corrections were supplied to the system using the STARFIX II network. This differential network is a worldwide system operated by Fugro. STARFIX II broadcasts differential corrections via a communications satellite downlink to field receivers. The differentially-corrected position from the Trimble receiver was passed to an onboard navigation computer running Hypack navigational software.

2.2 Shallow Geology Mapping

An EdgeTech full-spectrum profiler (Chirp) system was deployed to obtain shallow sub-bottom data for characterization of the sediment layers immediately beneath the seabed. These shallow data provided information on the areal distribution and thickness of the unconsolidated surficial sediments. The EdgeTech FS-SB system included the SB-512i towfish, the Model 3200 topside processor, and EdgeTech's Discover acquisition software. The towfish was deployed and towed from the rear starboard cleat of the *M/V Theory*.

Processing. The raw JSF (Edgetech proprietary data format) files were converted to industry-standard SEG-Y data for further processing. The position of the SBP transducer was recorded for each trace in their respective trace headers in WGS 84 Latitude/Longitude coordinates of arcseconds. These geodetic coordinates were then converted to NAD83 California State Plane System Zone 5 U.S. survey feet, and the converted SEG-Y data were subsequently loaded into Kingdom Suite (TKS), for further processing and interpretation.

Because of the nature of the shallowest sediments in the survey area and the effect of a seabed multiple, SBP penetration and interpretable features are generally limited to the sediments that lie above the 1st seabed multiple or 45 feet beneath the seabed in the very deepest part of the survey area to the southwest. From the SBP data, a horizon based on seismic characteristics was mapped as Horizon A. The depths from the seabed to Horizon A are calculated using an assumed constant sound velocity in sediment of 5,000 feet/second (10 msec = 25’ TWTT). Depths to Horizon A shown on the accompanying profiles are determined from the SBP data; deeper events are determined from the boomer data.

2.3 Deeper Geology Mapping

The seismic reflection system consisted of a single plate "boomer" seismic source, power and tow cable, one power supply, one 24-channel hydrophone streamer, shipboard electronics and recording instruments.

One Applied Acoustics Engineering CSP-D 3000 seismic energy source was used to power the Applied Acoustics AA200 single-plate "boomer" system. The boomer plate is an electro-mechanical transducer made of an insulated metal plate and a rubber diaphragm adjacent to a flat wound electrical coil. A short-duration, high-energy pulse is discharged from the energy source into the coil, and the resulting magnetic field repels the metal plate in the transducer. The plate motion is transferred to the water by the rubber diaphragm, generating a broadband acoustic pulse that does not have strong cavitation or ringing.

Raw data from the streamer was recorded using a Geometrics GeoEel seismic acquisition system. Data were stored on hard disk in SEG-Y format for later post-processing.

Quality Control and Processing. Quality control of the multichannel seismic (boomer) data was conducted during survey operations at the El Segundo site. The boomer yielded data to a recorded time of 0.3 seconds (approximately 740 feet using a sound velocity of 5,000 ft./sec.). Low-frequency noise probably resulting from the nearby surf break was noted in the raw data prior to processing. Limited ringing (typical of boomer sources) is also visible in the raw data. The peak amplitudes ranged in frequency from 85-130 Hz. Figure 2.1 depicts the frequency spectrum plot for a raw field record and a processed stack. Vessel noise (usually higher frequency) was not substantial compared to noise generated by the surf. Bandpass filtering was able to remove most of the low frequency noise.

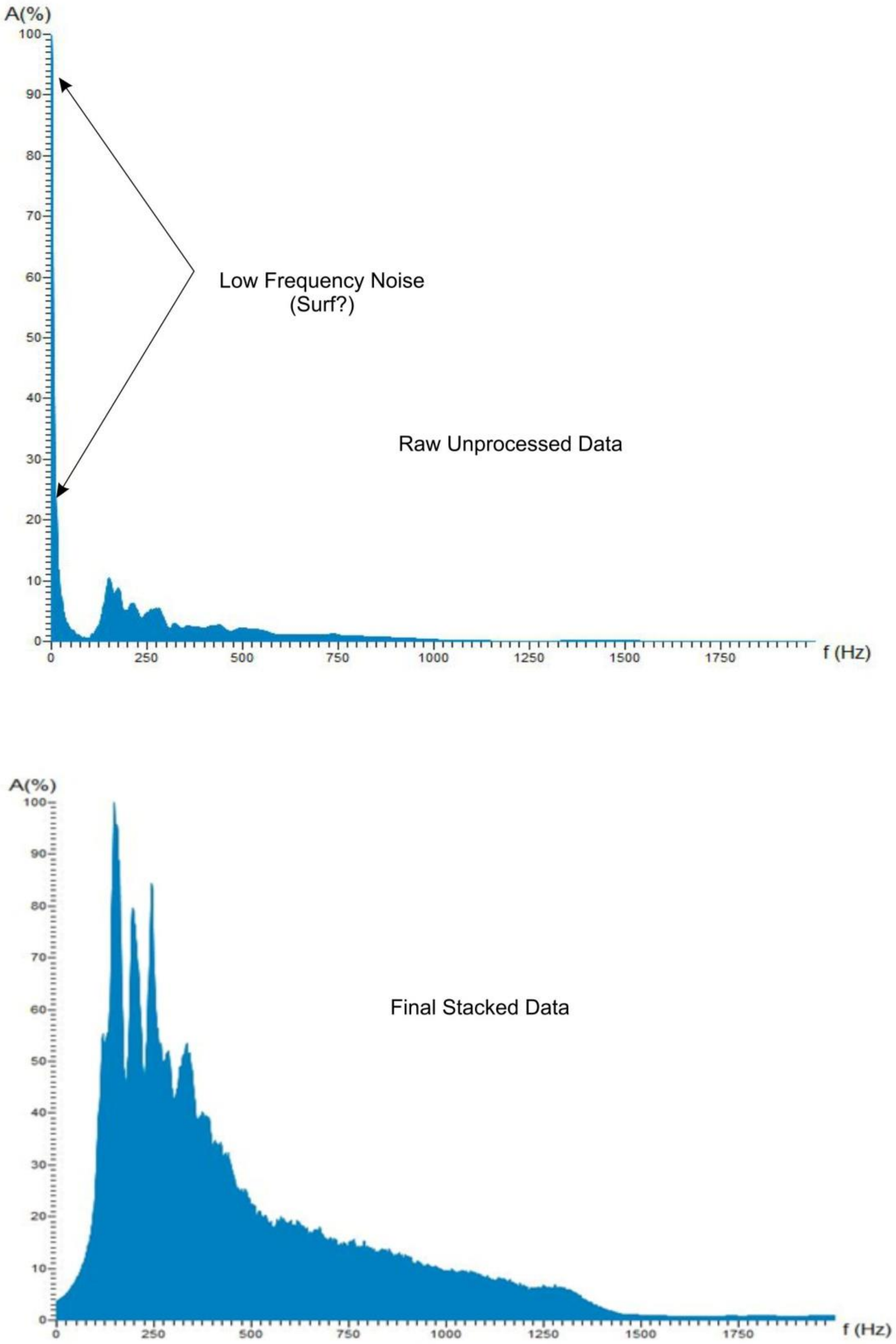


Figure 2-1. Boomer Frequency Spectrums.

Processing steps performed with the Boomer data were as follows:

1. SEG-Y Trace Input
2. Geometry Assignment
3. Dropped Shots Correction
4. Pre-Stack Processing
    1. Amplitude correction for spherical divergence
    2. Predictive Deconvolution
        1. Gate times = 24-300 msec
        2. Prediction Gap = 25 microseconds
        3. Operator Length = 4 msec
        4. White Noise = 0.01%
    3. Bandpass Filter
        1. Ormsby (80-120/1300-1500)
    4. Amplitude correction for trace equalization (Mean mode)
        1. Gate times = 0-250 ms
5. Stack
    1. NMO (mute = 80%)
        1. 2 msec: 1500 mps
        2. 60 msec: 1900 mps
        3. 300 msec: 2100 mps
    2. Ensemble Stack (Mean Mode)
6. Migration/De-Multiple
    1. Zero-Offset De-Multiple
        1. Auto Convolution
        2. Filter Length = 10 samples
        3. White Noise = 0.001%
        4. Adjacent Traces: Number Traces=3; Filter Average Traces=1000
        5. Add processing window (50-300 ms)
        6. Band Transform Window above 50 ms = 100-1200, below 50 ms = 60 - 800 ms
    2. Stolt F-K Migration
        1. Velocity (2.5 km/sec)
        2. Dx (3.125 m)
        3. Max Freq (1200 Hz)
        4. Frequency Declining Interval (3Hz)
        5. Max Dip (10°)
        6. Dip Slope (5°)
        7. Bottom Tapering (5 msec)
    3. SEG-Y Output
    4. Static shift residuals to MLLW vertical datum
        1. Re-Map SOURCE point to Byte offset 17
        2. Re-Map CDP_X and CDP_Y to Offset 73 and 77

The processing flow of the multichannel seismic reflection data follows the basic premise of the wavelet-processing method used in the petroleum exploration industry. Seismic data processing consists of: 1) filtering in time and space, 2) deconvolution to provide a sharper and more consistent seismic wavelet for interpretation, 3) correction of normal move-out (NMO) due to varying subsurface velocity structure, 4) stacking of data traces to increase the signal-to-noise ratio, and 5) post-stack time migration to put the reflecting horizons back into their proper lateral positions.

After the boomer data were processed and exported as processed SEG-Y files from RadEx Pro, the files were loaded in to TKS where horizons could be mapped, compared to the SBP data, and further interpreted.

Although the seismic data were acquired on a 24-channel Geo-Eel streamer and the shot interval was 400 milliseconds, the channels were combined in RadEx Pro to produce enhance the signal to noise ratio. Because the shot interval is approximately 4 feet, the resulting stacked traces are nominally about 20 fold.

Converting times to depths can be difficult without adequate velocity information. Using stacking velocities is not recommended, especially where dipping strata are present. For this survey, a detailed velocity analysis is not a reasonable option due to the short offsets and the absence of streamer positioning. A simple velocity analysis was done on the boomer data to indicate that stacking velocities may increase to about 1900 meters/second at a shallow depth of 60 milliseconds and continue to increase slightly with depth. For consistency, a single sound velocity of 5,000 ft./sec. where 10 msec = 25’ was used to convert all boomer horizons to depths during interpretation. Actual depths may be slightly shallower than the depths shown on the accompanying profiles.

3. RESULTS – DATA INTERPRETATION

The SBP data show a clear horizon at the seafloor and another - termed Horizon A - approximately 10-15 feet below the seabed. Figure 3.1 shows two SBP lines (Line 200 and Line 400) that intersect near the middle of the survey area. Strong, discontinuous and inclined reflectors are visible in the subsurface between the seabed and Horizon A, indicating a reflection character typical for fluvial deposits or discontinuous layers of interbedded bedded sand gravel and cobbles. The 1954 borings and the 1962 probes confirm this interpretation, but their logs provide no obvious correlation with Horizon A. It is clear, however, that this horizon trends through a package of coarse sediment, so it likely records a transition from the layer of interbedded sand gravel and cobbles above to a layer of undifferentiated sand below. This lower layer is comparatively isotropic, except to the east of Line 100 where the sediment below Horizon A has a mottled, acoustically amorphous character indicating that gravel may be intermixed with the sand.

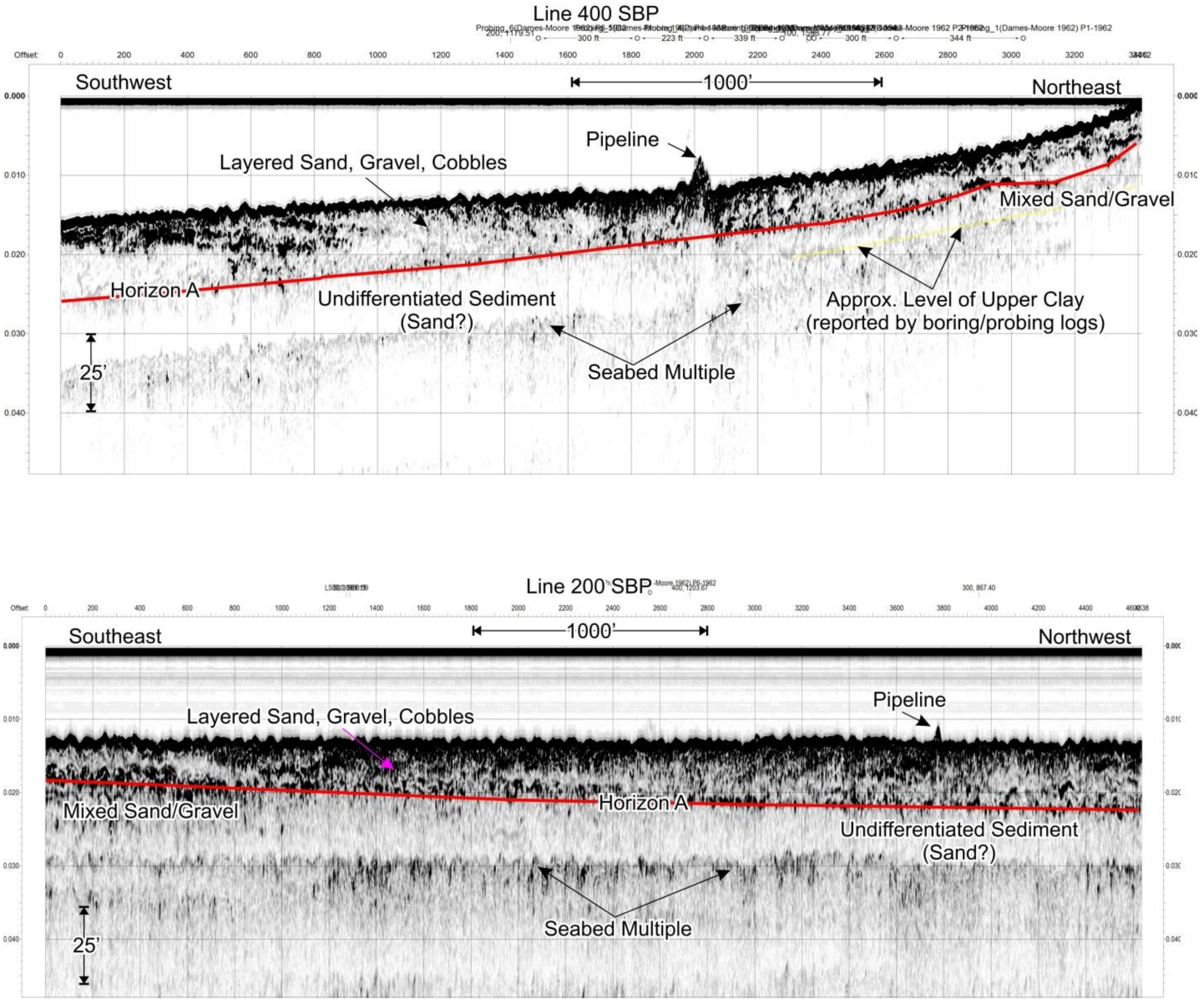


Figure 3-1. Sub-bottom Profiler Lines 200 and 400.

The jet probe logs indicate that an upper clay layer (possible Manhattan Beach Clay) lies shoreward of Line 100 at a sub-seabed depth of 21-27 feet. This upper clay layer is thin - in places only a few inches - and variable and that it disappears or descends below the level of core/probe penetration (ca. 20-22 ft.) to the west of Line 100. The SBP data do not clearly show a reflector that could reasonably be identified as the upper clay; however the boomer data do reveal a relatively strong horizontal reflector that intersects with Horizon A along the general trend of shore-parallel line 200 at about the same level as would be expected for this upper clay. This horizontal reflector shown in both boomer figures (Figure 3.2 and Figure 3.3) where it is labeled Horizon B. This layer may be less than a foot thick which pushes the resolution limits of the boomer system, thus there is no confidence in picking any underlying reflector as the bottom of the clay layer.

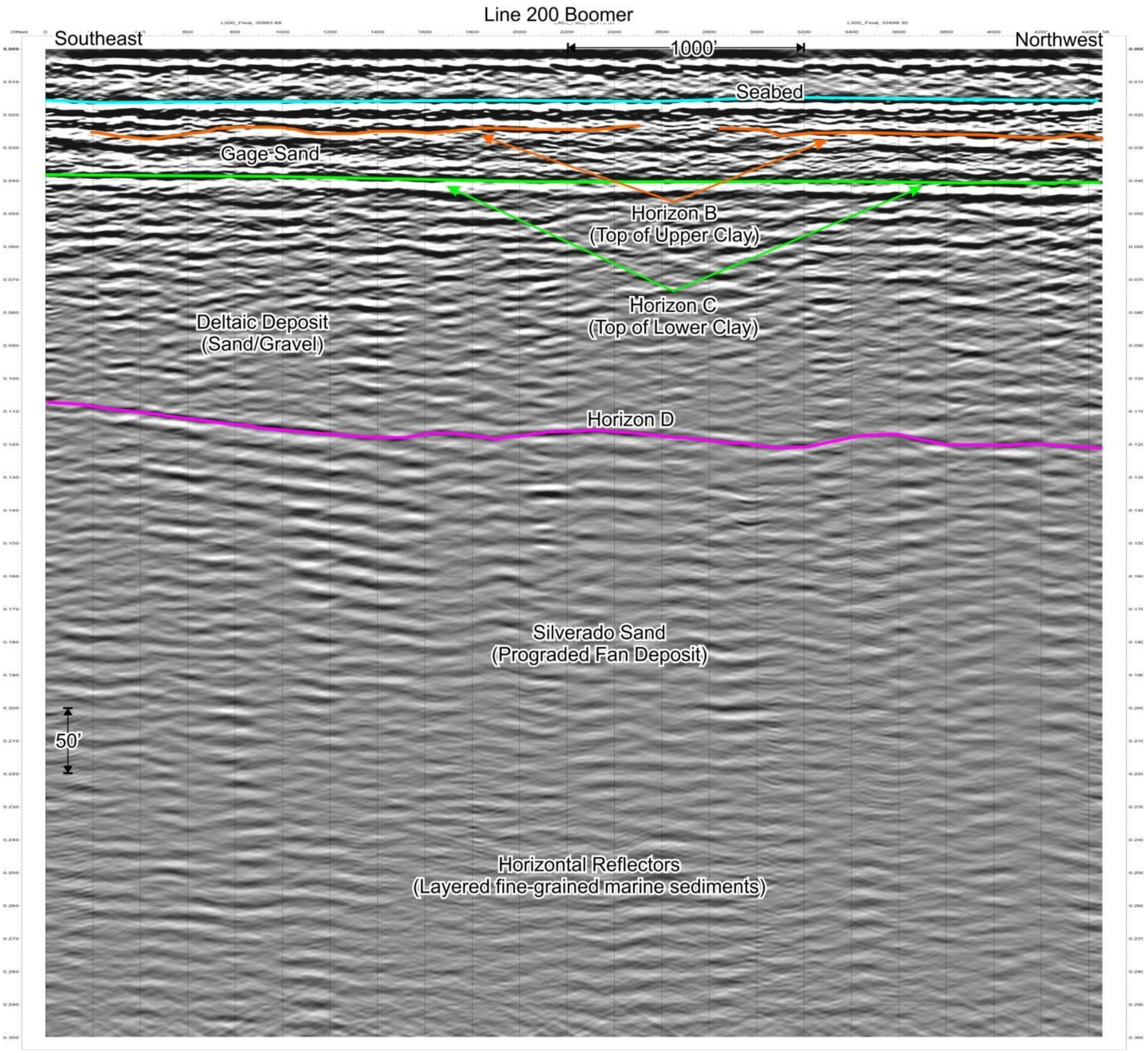


Figure 3-2. Boomer Example: Line 200.

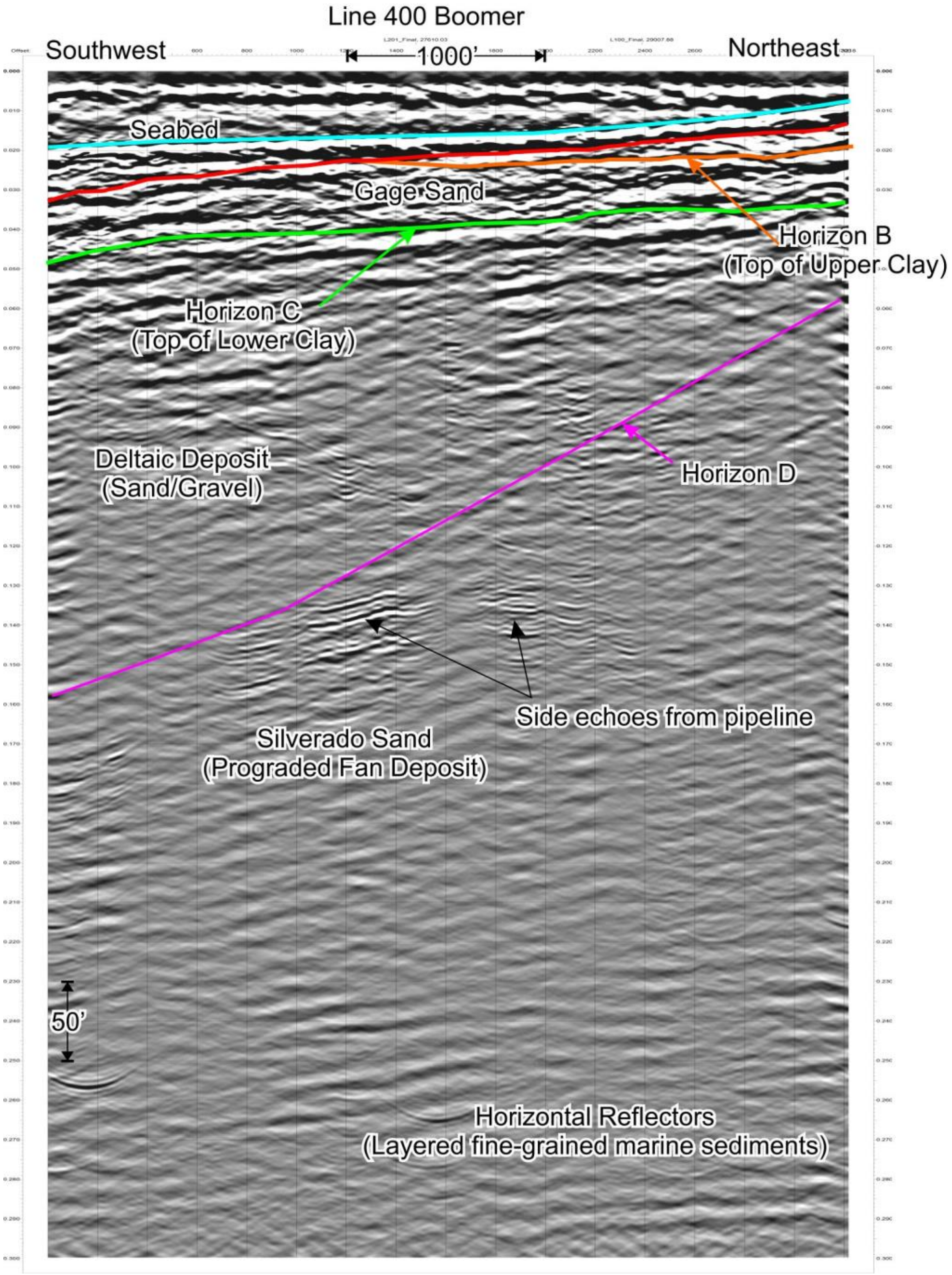


Figure 3-3. Boomer Example: Line 400.

The boomer data reveal a third horizon - Horizon C - at a sub-seabed depth of approximately 50-60 feet and sloping to the southwest. The amplitude and lateral continuity of this horizon indicate an abrupt change in physical conditions, possibly recording a transition from sand and gravel (Gage Sand above) to a lower clay layer (El Segundo Clay?). Another reflector underlies Horizon C by some 4 to 6 milliseconds (10 to 15 feet). Because of resolution limitations of the boomer, it cannot be ascertained if this underlying layer represents the bottom contact of the presumed lower clay layer or not. The accompanying profiles show Horizon C as the top of a green-shaded layer that assumes the bottom contact of the lower clay layer is indeed the underlying strong reflection. Other high-amplitude reflectors are visible between Horizons B and C; although they are too ambiguous and discontinuous to map, they may record lenses or wedges of silty clay within the sandy unit between Horizon B and C. They may also represent gravel lenses within the Gage Sand.

The boomer data reveal a thick sedimentary package extending more than 500 ft. beneath Horizon C. Although at first glance this package appears amorphous, faint yet persistent reflectors (a conspicuous example of which has been mapped as Horizon D) indicate that the strata within this package are dipping to the southwest. This unit may therefore record an ancient progradational fan sequence, such as a regressive beach front or an alluvial apron that was subsequently progressively buried as sea levels rose. The profiles show this unit as the Silverado Sand comprised of deltaic sand/gravel above Horizon D and steeply-dipping fan deposits of sand/gravel below.

4. DISCUSSION

From a regional perspective, the upper-Pleistocene Lakewood Formation (Fm) overlies the lower-Pleistocene San Pedro Fm in the Los Angeles Basin, and is exposed throughout wherever it is not covered by Holocene deposits or civilization. In the vicinity of El Segundo, previous geotechnical investigations of the subsurface have observed and defined several distinct hydrogeologic units within these Formations (Black and Veatch, 2000).

The surface unit exposed on shore, called the Old Dune Sand, is likely younger than and rests unconformably on the Lakewood Fm, but the discontinuous Manhattan Clay and the Gage Sand below represent the Formation's oldest members. The Gage Sand was deposited on a thin and possibly discontinuous silty clay layer called the El Segundo Clay, whose surface marks the upper limit of the San Pedro Fm. The much thicker Silverado Sand underlies the El Segundo Clay, and this sandy unit gives way, at uncertain depth, to the Redondo Beach Clay.

These stratigraphic units may be represented in the survey data as follows. The surficial unit of cross-bedded sand, gravel and cobbles is a Holocene deposit, perhaps correlative with but likely younger than the Old Dune Sand. The cobble and gravel lenses that extend from the seabed down to Horizon A are more noticeable offshore. Closer to shore (shoreward of Line 200), the patchy lenses appear to grade into a unit of acoustically amorphous material interpreted as sand. This sand likely migrates seasonally where a sand bar (offshore bar) migrates towards shore during the summer months and seaward during the winter months. Gravel and possibly cobbles likely underlie the offshore sand bar. This unit was deposited on an erosional boundary marked by Horizon A that truncates the upper beds of the Lakewood Fm, bringing the Holocene sand, gravel, and cobbles in contact with the upper-Pleistocene Gage Sand. The thin and discontinuous silty clay layer (identified as Horizon B) that terminates against Horizon A within this unit may be a vestige of the Manhattan Beach Clay. Alternatively, it may represent an upper extension of the El Segundo Clay, which may interfinger the Gage Sand in the range from approximately 40-90 feet below sea level (MLLW; Black and Veatch, 2000). This upper clay layer may be very thin and does not appear to extend seaward of Line 200. Shoreward of Line 200, this upper clay layer appears to be continuous and horizontal.

Horizon C represents the surface of the El Segundo Clay's main body, and approximately 10 feet to 15 feet below this unit, though the contact is indistinct, is the progradational sequence of the Silverado Sand. This unit apparently meets the Redondo Beach Clay at an elevation of -640 feet.

Horizon D generally defines the level of the steepest of the dipping reflectors. Above and beneath Horizon D the reflector dip-angles gradually flatten. The transition from nearly horizontal (presumably marine) layers near the bottom of the record to steeply-dipping layers may be a conformable sequence of shelf-building during the Pleistocene where sea level may have been falling and a fan prograded across the area. About the level of Horizon D, it appears the progradation slackens possibly in response to rising sea levels or a decrease in sediment input. At some point these fan/deltaic sequence back-stepped (with rising sea level) and the El Segundo Clay was eventually deposited.

APPENDICES

A	**MARINE WILDLIFE MONITORING REPORT**
B	**CSLC MITIGATION MONITORING PROGRAM EXHIBIT H**
C	**PROFILES**

A MARINE WILDLIFE MONITORING REPORT

padre
associates, inc.
ENGINEERS, GEOLOGISTS & ENVIRONMENTAL SCIENTISTS

September 15, 2015
Project No. 1502-3781

Fugro Pelagos, Inc.
4820 McGrath Street, Suite 100
Ventura, CA 93003-7778

Attention: Ms. Cindy Pratt

Subject: Marine Wildlife Monitoring Report: Fugro Pelagos, Inc., Bathymetric and Sub-Bottom Profiling Survey Offshore of El Segundo, California.

Dear Ms. Pratt:

In accordance with the procedures outlined in the California State Lands Commission (CSLC)-issued Geophysical and Geologic Sampling Permit No. 8391.9, Padre Associates, Inc. (Padre) has prepared this report for the Fugro Pelagos, Inc., (Fugro) to address monitoring activities during bathymetric and sub-bottom profiling survey, offshore of El Segundo, California (Figure 1). This report summarizes observations made by Padre's onboard marine wildlife observer during the vessel transit to and from the survey area (Figure 1), and during bathymetric and sub-bottom profiling survey activities conducted on September 3, 2015.

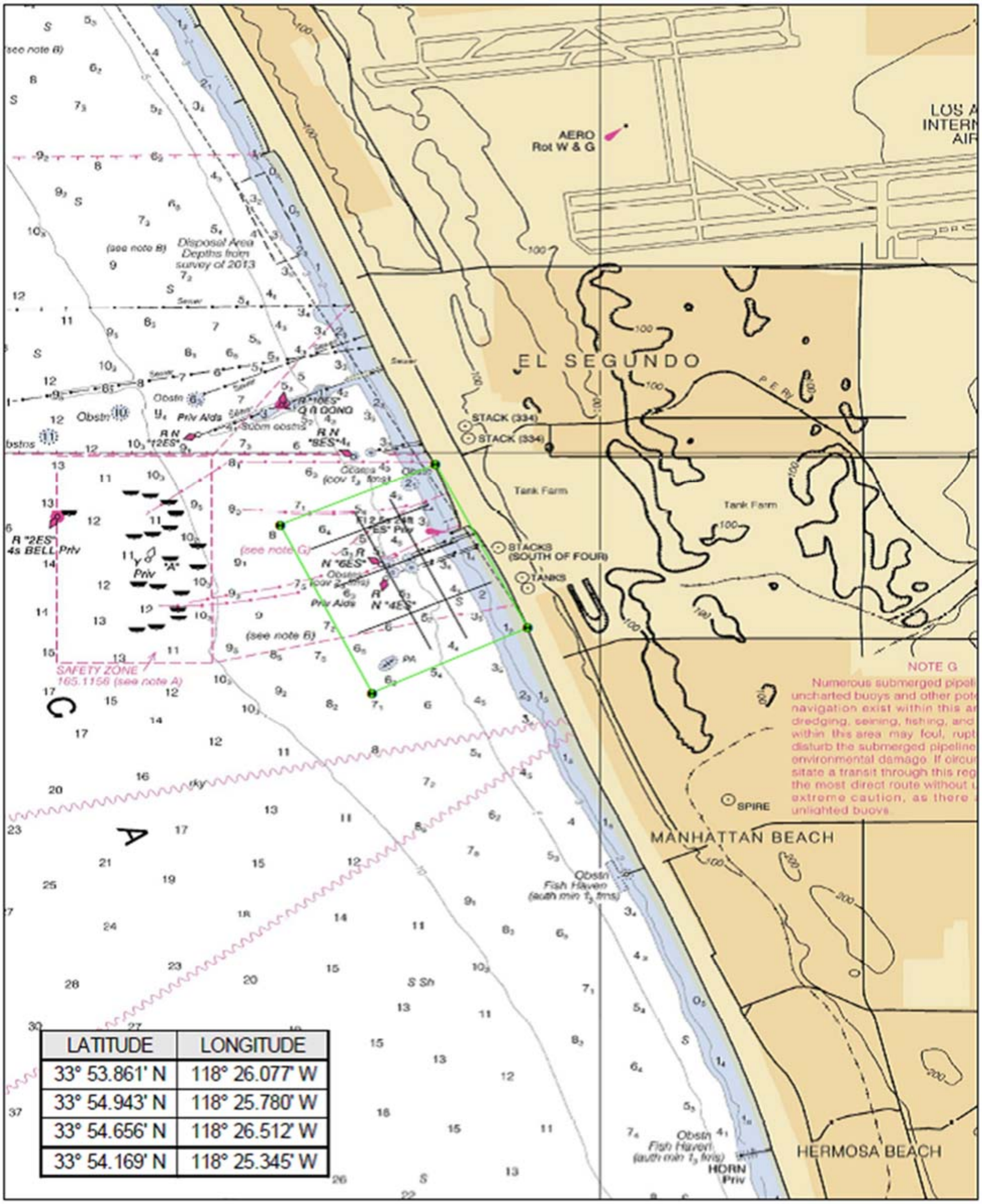
Survey Methods and Equipment

The survey utilized a single beam bathymetry and sub-bottom profiling system to document the seafloor conditions within the survey area. The survey was completed in one day onboard Theory Marine's survey vessel (SV) *Theory*, an 11.2 meter (m) (37 foot [ft]) vessel designed specifically for hydrographic surveying. The survey was conducted within State Waters from water depths of approximately 1.8 m (6 ft) to 15 m (50 ft).

Marine Wildlife Monitoring Methodology

Transit Periods. The survey vessel transited between Marina del Rey Harbor and the survey area. During vessel transit, the National Marine Fisheries Service (NMFS)-approved marine wildlife observer (MWO) was located in the wheelhouse and recorded observations of marine mammals and reptiles (marine wildlife) within an approximately 200 degree arc, centered on the direction of vessel travel.

All vessel transit was completed during daylight hours. Marine wildlife observed while the vessel was transiting were noted on the observer's reporting form (see Attachment: Daily Log) and the vessel operator was informed if marine wildlife was observed in the vessel path and if a collision with the marine wildlife was imminent.



LATITUDE	LONGITUDE
33° 53.861' N	118° 26.077' W
33° 54.943' N	118° 25.780' W
33° 54.656' N	118° 26.512' W
33° 54.169' N	118° 25.345' W

Figure 1. Survey Area

Survey Periods. Once onsite and throughout the operational survey period, the MWO continually observed the area surrounding the location of the single beam and sub-bottom profiler from the stern or within the wheelhouse of the vessel during survey related activities. In addition, the vessel captain was briefed on the marine wildlife that could occur in the project area and was utilized as a secondary MWO to ensure complete coverage of the transit path and survey equipment safety zone.

The observer utilized 7 X 50 reticular binoculars to observe any approaching marine wildlife within the area surrounding the survey equipment. If marine wildlife were observed approaching the vessel or survey equipment, the vessel operator and survey crew were informed and warned of possible alteration or termination of survey activities. Marine wildlife and any action that was required were noted on the observer's reporting form (see Attachment: Daily Log).

Fishing Gear Clearance. A fishing gear clearance was conducted prior to the initiation of survey activities within the survey corridor; the MWO observed and noted if any commercial fishing gear was within the Project area.

Results

Throughout the survey period, a total of 5 hours (hrs) and 15 minutes (mins) of marine wildlife observations were completed. The vessel was in transit for a total of 45 mins, and no marine mammals were observed during the transit period. No negative interaction occurred during vessel transit and no actions were requested from the MWO

The survey operator used a "soft start" technique at the beginning of survey activities to allow any marine mammal that may be in the project area to leave before the sound sources reach full energy. A total of 4 hrs and 30 mins of survey observations were completed and no marine mammals were observed during survey activities.

Prior to initiating bathymetric and geophysical data collection, a fishing gear clearance was completed. A fishing buoy was observed within the survey area. The location and water depth were recorded, the fishing buoy number was not recorded due to fowling on the buoy. The fishing buoy was avoided and no active fishing gear was disturbed during the project activities.

See Attachment: Daily Log for observer notes during survey activities.

Conclusions

A total of 5 hrs and 15 mins of marine wildlife monitoring was completed during the performance of the survey. There were no occasions where it was necessary for the MWO to request implementation of avoidance measures.

Project activities were never delayed or altered due to encroachment by marine wildlife, and no negative effects to marine wildlife were observed. Based on the observations of Padre's MWOs, and the cooperative efforts of the Fugro Project team and vessel crew, no negative survey activity or transit-related effects to the marine wildlife were observed during either of the specified Phases.

If you should have any questions regarding this report, please contact me at (805) 786-2650, ext. 30, or by email at jklaib@padreinc.com.

Sincerely,

PADRE ASSOCIATES, INC.

Jennifer Klaib
Marine Biologist

Attachment: Daily Log

cc: S. Poulter (Padre, Goleta)

padre associates, inc.
ENGINEERS, GEOLOGISTS &
ENVIRONMENTAL SCIENTISTS

Daily Log

To: Fugro Pelagos, Inc.
Attn: Cynthia Pratt

From: Jennifer Klaib

Date: September 3, 2015

Subject: Marine Mammal Monitoring for Bathymetric and Sub-Bottom Profiling Survey Offshore of El Segundo, California.

Time	Activity
0915	Departed Marina del Rey Harbor
0930	Arrived at survey site. Weather: Partly cloudy, wind 0-5 knots (kts), swell 1-3 feet (ft)
0931	Started fishing gear clearance
0940	Completed fishing gear clearance. Found one fishing gear buoy in project area. Buoy is heavily fouled and has been noted on previous surveys in same area. Buoy marked and noted by survey team and will be avoided by survey equipment.
0941	Starting marine mammal clearance
0950	Deploying single beam
0955	Turning equipment on. No marine mammals in safety zone
1200	End of single beam survey. Recovering equipment
1201	Starting marine mammal clearance for Chirp survey
1210	Weather: Sunny, clear, wind 5-10 kts, swell 1-3ft
1225	Starting Chirp ramp-up procedures. No marine mammals in the safety zone.
1245	Completed ramp-up procedures. Equipment at full power. No marine mammals in the safety zone.
1320	All equipment off.
1330	Starting Chirp ramp-up procedures. No marine mammals in the safety zone.
1340	Completed ramp-up procedures. Equipment at full power. No marine mammals in the safety zone.
1500	All equipment off.
1501	Start transit to Marina del Rey Harbor
1526	Arrived at Marina del Rey Harbor

B CSLC MITIGATION MONITORING PROGRAM EXHIBIT H

EXHIBIT H

Mitigation Measure (MM)	Location and Scope of Mitigation	Effectiveness Criteria	Monitoring or Reporting Action	Responsible Party	Timing	Implementation Date(s) and Initials
Air Quality and Greenhouse Gas (GHG) Emissions (MND Section 3.3.3)						
MM AIR-1: Engine Tuning, Engine Certification, and Fuels. The following measures will be required to be implemented by all Permittees under the Offshore Geophysical Permit Program (OGPP), as applicable depending on the county offshore which a survey is being conducted. Pursuant to section 93118.5 of CARB's Airborne Toxic Control Measures, the Tier 2 engine requirement applies only to diesel-fueled vessels.	All Counties: Maintain all construction equipment in proper tune according to manufacturers' specifications; fuel all off-road and portable diesel-powered equipment with California Air Resources Board (CARB)-certified motor vehicle diesel fuel limiting sulfur content to 15 parts per million or less (CARB Diesel).	Daily emissions of criteria pollutants during survey activities are minimized.	Determine engine certification of vessel engines. Review engine emissions data to assess compliance, determine if changes in tuning or fuel are required.	OGPP permit holder and contract vessel operator; California State Lands Commission (CSLC) review of Final Monitoring Report.	Prior to, during, and after survey activities. Submit Final Monitoring Report after completion of survey activities.	8/12/15 csd
	Los Angeles and Orange Counties: Use vessel engines meeting CARB's Tier 2-certified engines or cleaner; the survey shall be operated such that daily NO_x emissions do not exceed 100 pounds based on engine certification emission factors. This can be accomplished with Tier 2 engines if daily fuel use is 585 gallons or less, and with Tier 3 engines if daily fuel use is 935 gallons or less.		Verify that Tier 2 or cleaner engines are being used. Calculate daily NO_x emissions to verify compliance with limitations.			8/12/15 csd
	San Luis Obispo County: Use vessel engines meeting CARB's Tier 2-certified engines or cleaner, accomplished with Tier 2 engines if daily fuel use is 585 gallons or less; all diesel equipment shall not idle for more than 5 minutes; engine use needed to maintain position in the water is not considered idling; diesel idling within 300 meters (1,000 feet) of sensitive receptors is not permitted; use alternatively fueled construction equipment on site where feasible, such as compressed natural gas, liquefied natural gas, propane or biodiesel.		Verify that Tier 2 or cleaner engines are being used. Inform vessel operator(s) of idling limitation. Investigate availability of alternative fuels.			
	Santa Barbara County: Use vessel engines meeting CARB's Tier 2-certified engines or cleaner, accomplished with Tier 2 engines if daily fuel use is 790 gallons or less.		Verify that Tier 2 or cleaner engines are being used. Investigate availability of alternative fuels.			
	Ventura County: Use alternatively fueled construction equipment on site where feasible, such as compressed natural gas, liquefied natural gas, propane or biodiesel.		Investigate availability of alternative fuels.			

EXHIBIT H

Mitigation Measure (MM)	Location and Scope of Mitigation	Effectiveness Criteria	Monitoring or Reporting Action	Responsible Party	Timing	Implementation Date(s) and Initials
MM BIO-1: Marine Mammal and Sea Turtle Presence – Current Information.	All State waters; prior to commencement of survey operations, the geophysical operator shall: (1) contact the National Oceanic and Atmospheric Administration Long Beach office staff and local whale-watching operations and shall acquire information on the current composition and relative abundance of marine wildlife offshore, and (2) convey sightings data to the vessel operator and crew, survey party chief, and onboard Marine Wildlife Monitors (MWMs) prior to departure. This information will aid the MWMs by providing data on the approximate number and types of organisms that may be in the area.	No adverse effects to marine mammals or sea turtles due to survey activities are observed.	Document contact with appropriate sources. Submit Final Monitoring Report after completion of survey activities.	OGPP permit holder; Inquiry to NOAA and local whale watching operators.	Prior to survey.	8/31/15 & 9/3/15 JK
MM BIO-2: Marine Wildlife Monitors (MWMs).	Except as provided in section 7(h) of the General Permit, a minimum of two (2) qualified MWMs who are experienced in marine wildlife observations shall be onboard the survey vessel throughout both transit and data collection activities. The specific monitoring, observation, and data collection responsibilities shall be identified in the Marine Wildlife Contingency Plan required as part of all Offshore Geophysical Permit Program permits. Qualifications of proposed MWMs shall be submitted to the National Oceanic and Atmospheric Administration (NOAA) and CSLC at least twenty-one (21) days in advance of the survey for their approval by the agencies. Survey operations shall not commence until the CSLC approves the MWMs.	Competent and professional monitoring or marine mammals and sea turtles; compliance with established monitoring policies.	Document contact with and approval by appropriate agencies. Submit Final Monitoring Report after completion of survey activities.	OGPP permit holder.	Prior to survey.	9/3/15 JK
MM BIO-3: Safety Zone Monitoring.	Onboard Marine Wildlife Monitors (MWMs) responsible for observations during vessel transit shall be responsible for monitoring during the survey equipment operations. All visual monitoring shall occur from the highest practical vantage point aboard the survey vessel; binoculars shall be used to observe the surrounding area, as appropriate. The MWMs will survey an area (i.e., safety or exclusion zone) based on the equipment used, centered on the sound source (i.e., vessel, towfish), throughout time that the survey equipment is operating. Safety zone radial distances, by equipment type, include:	No adverse effects to marine mammals or sea turtles due to survey activities are observed; compliance with established safety zones.	Compliance with permit requirements (observers); compliance with established safety zones. Submit Final Monitoring Report after completion of survey activities.	OGPP permit holder.	Prior to survey.	9/3/15 JK

<table>
<tr><th>Mitigation Measure (MM)</th><th>Location and Scope of Mitigation</th><th>Effectiveness Criteria</th><th>Monitoring or Reporting Action</th><th>Responsible Party</th><th>Timing</th><th>Implementation Date(s) and Initials</th></tr>
<tr><td></td><td>
<table>
<tr><th>Equipment Type</th><th>Safety Zone (radius, m)</th></tr>
<tr><td>Single Beam Echosounder</td><td>50</td></tr>
<tr><td>Multibeam Echosounder</td><td>500</td></tr>
<tr><td>Side-Scan Sonar</td><td>600</td></tr>
<tr><td>Subbottom Profiler</td><td>100</td></tr>
<tr><td>Boomer System</td><td>100</td></tr>
</table>

If the geophysical survey equipment is operated at or above a frequency of 200 kilohertz (kHz), safety zone monitoring and enforcement is not required; however, if geophysical survey equipment operated at a frequency at or above 200 kHz is used simultaneously with geophysical survey equipment less than 200 kHz, then the safety zone for the equipment less than 200 kHz must be monitored. The onboard MWMs shall have authority to stop operations if a mammal or turtle is observed within the specified safety zone and may be negatively affected by survey activities. The MWMs shall also have authority to recommend continuation (or cessation) of operations during periods of limited visibility (i.e., fog, rain) based on the observed abundance of marine wildlife. Periodic reevaluation of weather conditions and reassessment of the continuation/cessation recommendation shall be completed by the onboard MWMs. During operations, if an animal's actions are observed to be irregular, the monitor shall have authority to recommend that equipment be shut down until the animal moves further away from the sound source. If irregular behavior is observed, the equipment shall be shut-off and will be restarted and ramped-up to full power, as applicable, or will not be started until the animal(s) is/are outside of the safety zone or have not been observed for 15 minutes.

For nearshore survey operations utilizing vessels that lack the personnel capacity to hold two (2) MWMs aboard during survey operations, at least twenty-one (21) days prior to the commencement of survey activities, the Permittee may petition the CSLC to conduct survey operations with one (1) MWM aboard. The CSLC will consider such authorization on a case-by-case basis and
</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

EXHIBIT H

Mitigation Measure (MM)	Location and Scope of Mitigation	Effectiveness Criteria	Monitoring or Reporting Action	Responsible Party	Timing	Implementation Date(s) and Initials
	factors the CSLC will consider will include the timing, type, and location of the survey, the size of the vessel, and the availability of alternate vessels for conducting the proposed survey. CSLC authorizations under this subsection will be limited to individual surveys and under any such authorization; the Permittee shall update the MWCP to reflect how survey operations will occur under the authorization.					
MM BIO-4: Limits on Nighttime OGPP Surveys.	All State waters; nighttime survey operations are prohibited under the OGPP, except as provided below. The CSLC will consider the use of single beam echosounders and passive equipment types at night on a case-by-case basis, taking into consideration the equipment specifications, location, timing, and duration of survey activity.	No adverse effects to marine mammals or sea turtles due to survey activities are observed.	Presurvey request for nighttime operations, including equipment specifications and proposed use schedule. Document equipment use. Submit Final Monitoring Report after completion of survey activities.	OGPP permit holder.	Approval required before survey is initiated. Monitoring Report following completion of survey.	9/3/15 JK
MM BIO-5: Soft Start.	All State waters; the survey operator shall use a "soft start" technique at the beginning of survey activities each day (or following a shut down) to allow any marine mammal that may be in the immediate area to leave before the sound sources reach full energy. Surveys shall not commence at nighttime or when the safety zone cannot be effectively monitored. Operators shall initiate each piece of equipment at the lowest practical sound level, increasing output in such a manner as to increase in steps not exceeding approximately 6 decibels (dB) per 5-minute period. During ramp-up, the Marine Wildlife Monitors (MWMs) shall monitor the safety zone. If marine mammals are sighted within or about to enter the safety zone, a power-down or shut down shall be implemented as though the equipment was operating at full power. Initiation of ramp-up procedures from shut down requires that the MWMs be able to visually observe the full safety zone.	No adverse effects to marine mammals or sea turtles due to survey activities are observed.	Compliance with permit requirements (observers); compliance with safe start procedures. Submit Final Monitoring Report after completion of survey activities.	OGPP permit holder.	Immediately prior to survey.	9/3/15 JK

EXHIBIT H

Mitigation Monitoring Program

Mitigation Measure (MM)	Location and Scope of Mitigation	Effectiveness Criteria	Monitoring or Reporting Action	Responsible Party	Timing	Implementation Date(s) and Initials
MM BIO-6: Practical Limitations on Equipment Use and Adherence to Equipment Manufacturer's Routine Maintenance Schedule.	All State waters; geophysical operators shall follow, to the maximum extent possible, the guidelines of Zykov (2013) as they pertain to the use of subbottom profilers and side-scan sonar, including: • Using the highest frequency band possible for the subbottom profiler; • Using the shortest possible pulse length; and • Lowering the pulse rate (pings per second) as much as feasible. Geophysical operators shall consider the potential applicability of these measures to other equipment types (e.g., boomer). Permit holders will conduct routine inspection and maintenance of acoustic-generating equipment to ensure that low energy geophysical equipment used during permitted survey activities remains in proper working order and within manufacturer's equipment specifications. Verification of the date and occurrence of such equipment inspection and maintenance shall be provided in the required presurvey notification to CSLC.	No adverse effects to marine mammals or sea turtles due to survey activities are observed.	Document initial and during survey equipment settings. Submit Final Monitoring Report after completion of survey activities.	OGPP permit holder.	Immediately prior to and during survey.	
MM BIO-7: Avoidance of Pinniped Haul-Out Sites.	The Marine Wildlife Contingency Plan (MWCP) developed and implemented for each survey shall include identification of haul-out sites within or immediately adjacent to the proposed survey area. For surveys within 300 meters (m) of a haul-out site, the MWCP shall further require that: • The survey vessel shall not approach within 91 m of a haul-out site, consistent with National Marine Fisheries Service (NMFS) guidelines; • Survey activity close to haul-out sites shall be conducted in an expedited manner to minimize the potential for disturbance of pinnipeds on land; and • Marine Wildlife Monitors shall monitor pinniped activity onshore as the vessel approaches, observing and reporting on the number of pinnipeds potentially disturbed (e.g., via head lifting, flushing into the water). The purpose of such reporting is to provide CSLC and California Department of Fish and Wildlife (CDFW) with information regarding potential disturbance associated with OGPP surveys.	No adverse effects to pinnipeds at haul outs are observed.	Document pinniped reactions to vessel presence and equipment use. Submit Final Monitoring Report after completion of survey activities.	OGPP permit holder.	Monitoring Report following completion of survey.	8/12/15 JK

EXHIBIT H

Mitigation Measure (MM)	Location and Scope of Mitigation	Effectiveness Criteria	Monitoring or Reporting Action	Responsible Party	Timing	Implementation Date(s) and Initials
MM BIO-8: Reporting Requirements – Collision.	All State waters; if a collision with marine mammal or reptile occurs, the vessel operator shall document the conditions under which the accident occurred, including the following: • Vessel location (latitude, longitude) when the collision occurred; • Date and time of collision; • Speed and heading of the vessel at the time of collision; • Observation conditions (e.g., wind speed and direction, swell height, visibility in miles or kilometers, and presence of rain or fog) at the time of collision; • Species of marine wildlife contacted (if known); • Whether an observer was monitoring marine wildlife at the time of collision; and, • Name of vessel, vessel owner/operator, and captain officer in charge of the vessel at time of collision. After a collision, the vessel shall stop, if safe to do so; however, the vessel is not obligated to stand by and may proceed after confirming that it will not further damage the animal by doing so. The vessel will then immediately communicate by radio or telephone all details to the vessel's base of operations, and shall immediately report the incident. Consistent with Marine Mammal Protection Act requirements, the vessel's base of operations or, if an onboard telephone is available, the vessel captain him/herself, will then immediately call the National Oceanic and Atmospheric Administration (NOAA) Stranding Coordinator to report the collision and follow any subsequent instructions. From the report, the Stranding Coordinator will coordinate subsequent action, including enlisting the aid of marine mammal rescue organizations, if appropriate. From the vessel's base of operations, a telephone call will be placed to the Stranding Coordinator, NOAA National Marine Fisheries Service (NMFS), Southwest Region, Long Beach, to obtain instructions. Although NOAA has primary responsibility for marine mammals in both State and Federal waters, the California Department of Fish and Wildlife (CDFW) will also be advised that an incident has occurred in State waters affecting a protected species.	No adverse effects to marine mammals or sea turtles due to survey activities are observed.	Submit Final Monitoring Report after completion of survey activities.	OGPP permit holder.	Monitoring Report following completion of survey.	9/3/15 JK

EXHIBIT H

Mitigation Measure (MM)	Location and Scope of Mitigation	Effectiveness Criteria	Monitoring or Reporting Action	Responsible Party	Timing	Implementation Date(s) and Initials
MM BIO-9: Limitations on Survey Operations in Select Marine Protected Areas (MPAs).	All MPAs; prior to commencing survey activities, geophysical operators shall coordinate with the CLSC, California Department of Fish and Wildlife (CDFW), and any other appropriate permitting agency regarding proposed operations within MPAs. The scope and purpose of each survey proposed within a MPA shall be defined by the permit holder, and the applicability of the survey to the allowable MPA activities shall be delineated by the permit holder. If deemed necessary by CDFW, geophysical operators will pursue a scientific collecting permit, or other appropriate authorization, to secure approval to work within a MPA, and shall provide a copy of such authorization to the CSLC as part of the required presurvey notification to CSLC. CSLC, CDFW, and/or other permitting agencies may impose further restrictions on survey activities as conditions of approval.	No adverse effects to MPA resources due to survey activities are observed.	Monitor reactions of wildlife to survey operations; report on shutdown conditions and survey restart. Submit Final Monitoring Report after completion of survey activities.	OGPP permit holder; survey permitted by CDFW.	Prior to survey.	N/A
MM HAZ-1: Oil Spill Contingency Plan (OSCP) Required Information.	Permittees shall develop and submit to CSLC staff for review and approval an OSCP that addresses accidental releases of petroleum and/or non-petroleum products during survey operations. Permittees' OSCPs shall include the following information for each vessel to be involved with the survey: • Specific steps to be taken in the event of a spill, including notification names, phone numbers, and locations of: (1) nearby emergency medical facilities, and (2) wildlife rescue/response organizations (e.g., Oiled Wildlife Care Network); • Description of crew training and equipment testing procedures; and • Description, quantities, and location of spill response equipment onboard the vessel.	Reduction in the potential for an accidental spill. Proper and timely response and notification of responsible parties in the event of a spill.	Documentation of proper spill training. Notification of responsible parties in the event of a spill.	OGPP permit holder and contract vessel operator.	Prior to survey.	8/12/15 CLP
MM HAZ-2: Vessel fueling restrictions.	Vessel fueling shall only occur at an approved docking facility. No cross vessel fueling shall be allowed.	Reduction in the potential for an accidental spill.	Documentation of fueling activities.	Contract vessel operator.	Following survey.	8/12/15 CLP
MM HAZ-3: OSCP equipment and supplies.	Onboard spill response equipment and supplies shall be sufficient to contain and recover the worst-case scenario spill of petroleum products as outlined in the OSCP.	Proper and timely response in the event of a spill.	Notification to CSLC of onboard spill response equipment/supplies inventory, verify	Contract vessel operator.	Prior to survey.	8/12/15 CLP

EXHIBIT H

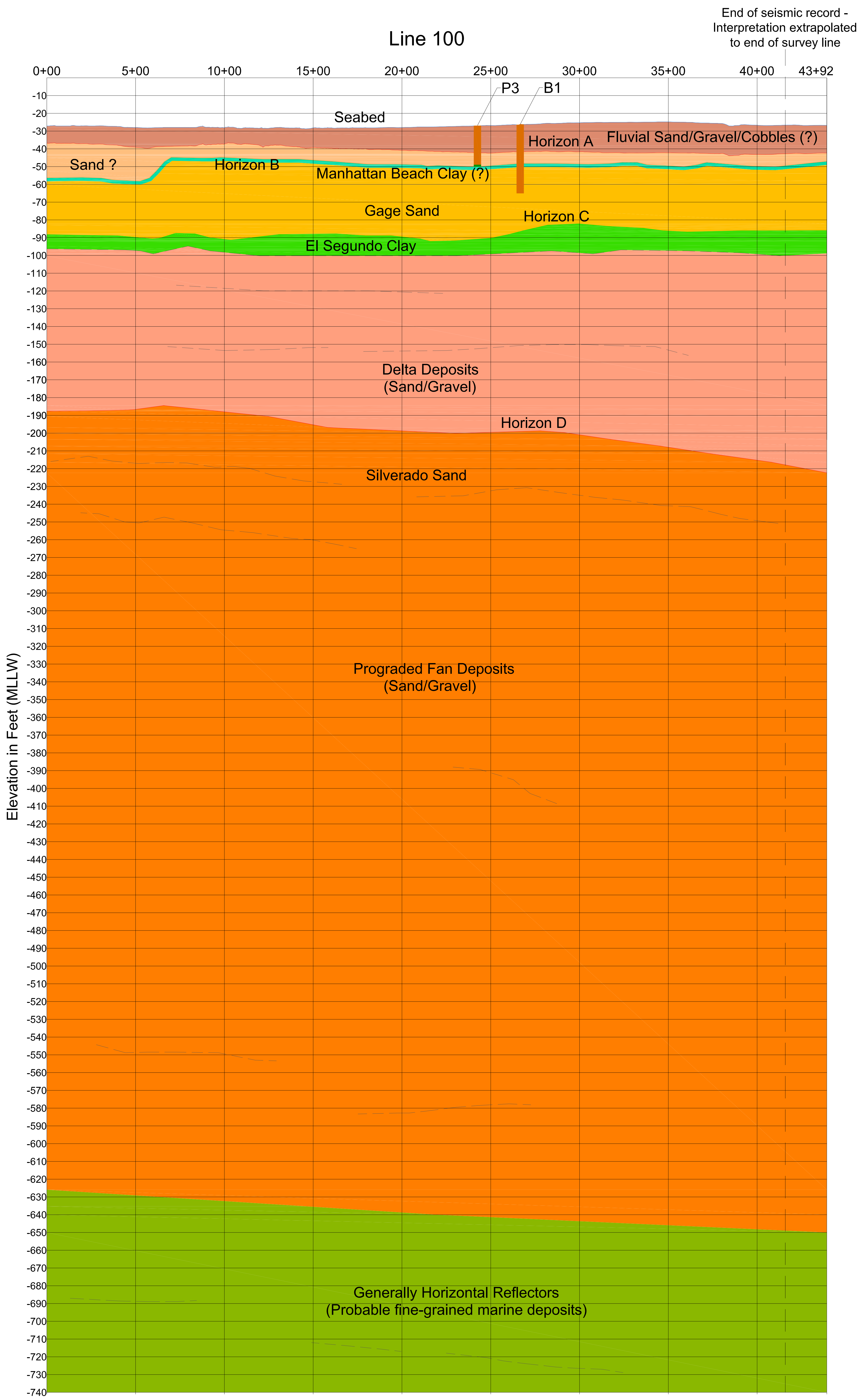
Mitigation Measure (MM)	Location and Scope of Mitigation	Effectiveness Criteria	Monitoring or Reporting Action	Responsible Party	Timing	Implementation Date(s) and Initials
			ability to respond to worst-case spill.			
MM HAZ-1: Oil Spill Contingency Plan (OSCP) Required Information.	Outlined under **Hazards and Hazardous Materials** (above)					
MM HAZ-2: Vessel fueling restrictions.	Outlined under **Hazards and Hazardous Materials** (above)					
MM HAZ-3: OSCP equipment and supplies.	Outlined under **Hazards and Hazardous Materials** (above)					
MM BIO-9: Limitations on Survey Operations in Select MPAs.	Outlined under **Biological Resources** (above)					
MM REC-1: U.S. Coast Guard (USCG), Harbormaster, and Dive Shop Operator Notification.	All California waters where recreational diving may occur; as a survey permit condition, the CSLC shall require Permittees to provide the USCG with survey details, including information on vessel types, survey locations, times, contact information, and other details of activities that may pose a hazard to divers so that USCG can include the information in the Local Notice to Mariners, advising vessels to avoid potential hazards near survey areas. Furthermore, at least twenty-one (21) days in advance of in-water activities, Permittees shall: (1) post such notices in the harbormasters' offices of regional harbors; and (2) notify operators of dive shops in coastal locations adjacent to the proposed offshore survey operations.	No adverse effects to recreational divers from survey operations.	Notify the USCG, local harbormasters, and local dive shops of planned survey activity. Submit Final Monitoring Report after completion of survey activities.	OGPP permit holder.	Prior to survey.	8/12/15 CAD

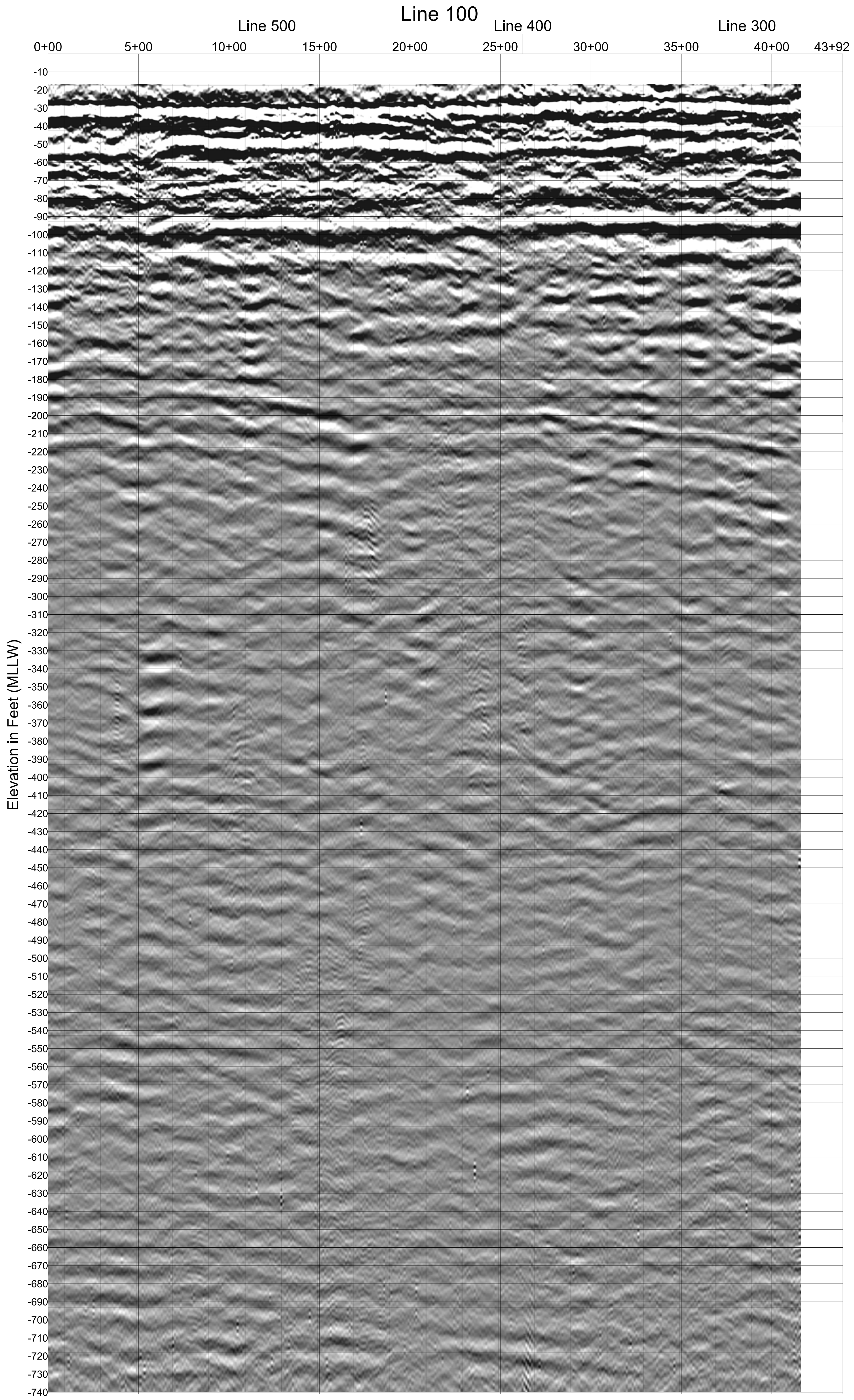
EXHIBIT H

Mitigation Measure (MM)	Location and Scope of Mitigation	Effectiveness Criteria	Monitoring or Reporting Action	Responsible Party	Timing	Implementation Date(s) and Initials
MM FISH-1: U.S. Coast Guard (USCG) and Harbormaster Notification.	All California waters; as a survey permit condition, the CSLC shall require Permittees to provide the USCG with survey details, including information on vessel types, survey locations, times, contact information, and other details of activities that may pose a hazard to mariners and fishers so that USCG can include the information in the Local Notice to Mariners, advising vessels to avoid potential hazards near survey areas. Furthermore, at least twenty-one (21) days in advance of in-water activities, Permittees shall post such notices in the harbormasters' offices of regional harbors.	No adverse effects to commercial fishing gear in place.	Notify the USCG and local harbormasters of planned survey activity. Submit Final Monitoring Report after completion of survey activities.	OGPP permit holder.	Prior to survey.	8/12/15 CJP
MM FISH-2: Minimize Interaction with Fishing Gear.	To minimize interaction with fishing gear that may be present within a survey area: (1) the geophysical vessel (or designated vessel) shall traverse the proposed survey corridor prior to commencing survey operations to note and record the presence, type, and location of deployed fishing gear (i.e., buoys); (2) no survey lines within 30 m (100 feet) of observed fishing gear shall be conducted. The survey crew shall not remove or relocate any fishing gear; removal or relocation shall only be accomplished by the owner of the gear upon notification by the survey operator of the potential conflict.	No adverse effects to commercial fishing gear in place.	Visually observe the survey area for commercial fishing gear. Notify the gear owner and request relocation of gear outside survey area. Submit Final Monitoring Report after completion of survey activities.	OGPP permit holder.	Immediately prior to survey (prior to each survey day).	8/12/15 CJP 9/3/15 CJP
MM FISH-1: USCG and Harbormaster Notification.	Outlined under **Commercial and Recreational Fisheries** (above)					

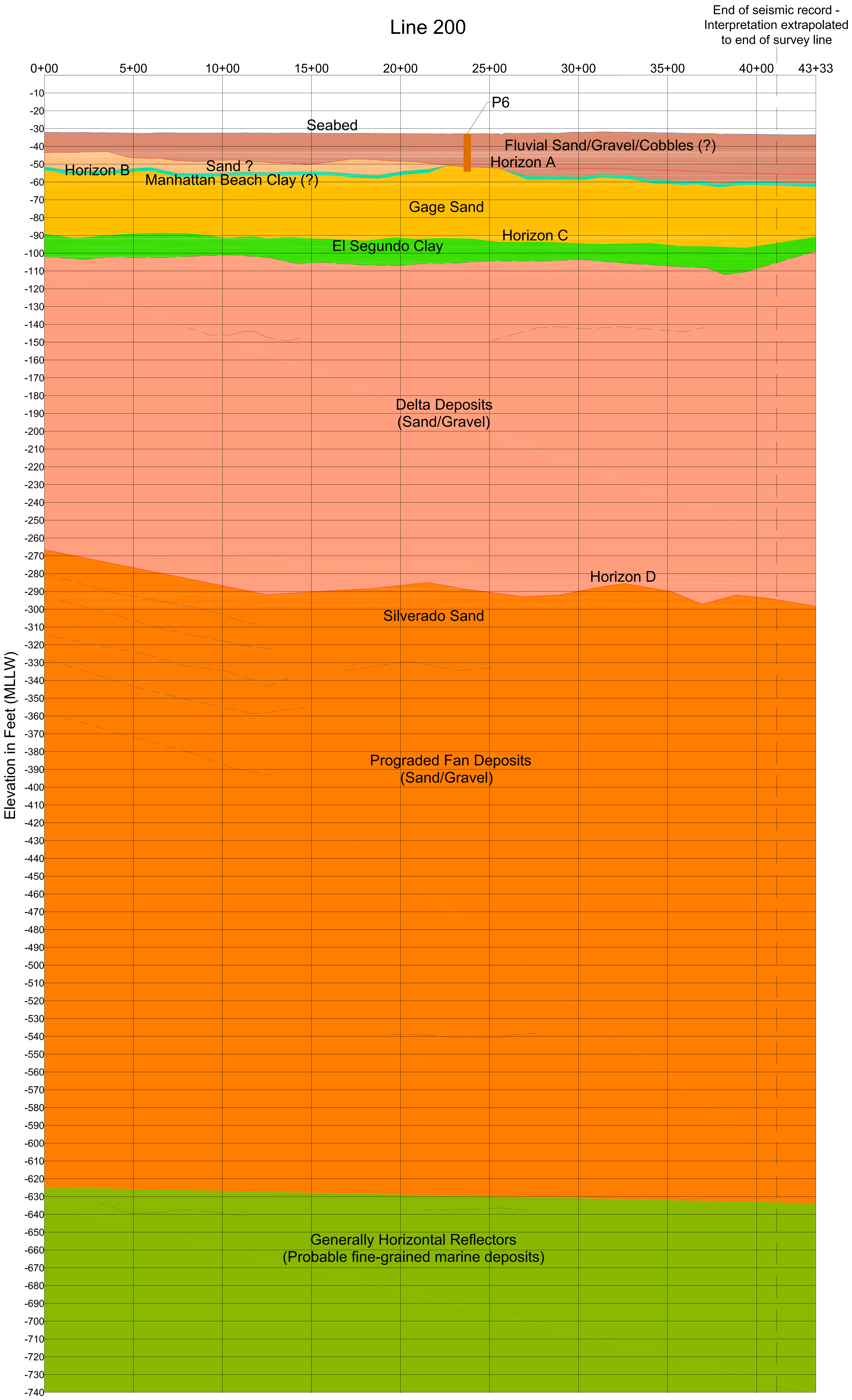
Acronyms/Abbreviations: CARB = California Air Resources Board; CDFW = California Department of Fish and Wildlife; CSLC = California State Lands Commission; dB = decibels; kHz = kilohertz; MPA = Marine Protected Area; MWCP = Marine Wildlife Contingency Plan; MWM = Marine Wildlife Monitor; m= meter(s); NOAA = National Oceanic and Atmospheric Administration; NO_x = Nitrogen Oxide; OGPP = Offshore Geophysical Permit Program; OSCP = Oil Spill Contingency Plan; USCG = U.S. Coast Guard

C PROFILES


End of seismic record -
Interpretation extrapolated
to end of survey line
Line 100
0+00 5+00 10+00 15+00 20+00 25+00 30+00 35+00 40+00 43+92
P3
B1
Seabed
Horizon A
Fluvial Sand/Gravel/Cobbles (?)
Sand ?
Horizon B
Manhattan Beach Clay (?)
Gage Sand
Horizon C
El Segundo Clay
Delta Deposits
(Sand/Gravel)
Horizon D
Silverado Sand
Prograded Fan Deposits
(Sand/Gravel)
Generally Horizontal Reflectors
(Probable fine-grained marine deposits)
Elevation in Feet (MLLW)
-10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220 -230 -240 -250 -260 -270 -280 -290 -300 -310 -320 -330 -340 -350 -360 -370 -380 -390 -400 -410 -420 -430 -440 -450 -460 -470 -480 -490 -500 -510 -520 -530 -540 -550 -560 -570 -580 -590 -600 -610 -620 -630 -640 -650 -660 -670 -680 -690 -700 -710 -720 -730 -740


Line 100
Line 500
Line 400
Line 300
0+00 5+00 10+00 15+00 20+00 25+00 30+00 35+00 40+00 43+92
Elevation in Feet (MLLW)
-10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220 -230 -240 -250 -260 -270 -280 -290 -300 -310 -320 -330 -340 -350 -360 -370 -380 -390 -400 -410 -420 -430 -440 -450 -460 -470 -480 -490 -500 -510 -520 -530 -540 -550 -560 -570 -580 -590 -600 -610 -620 -630 -640 -650 -660 -670 -680 -690 -700 -710 -720 -730 -740

Line 200



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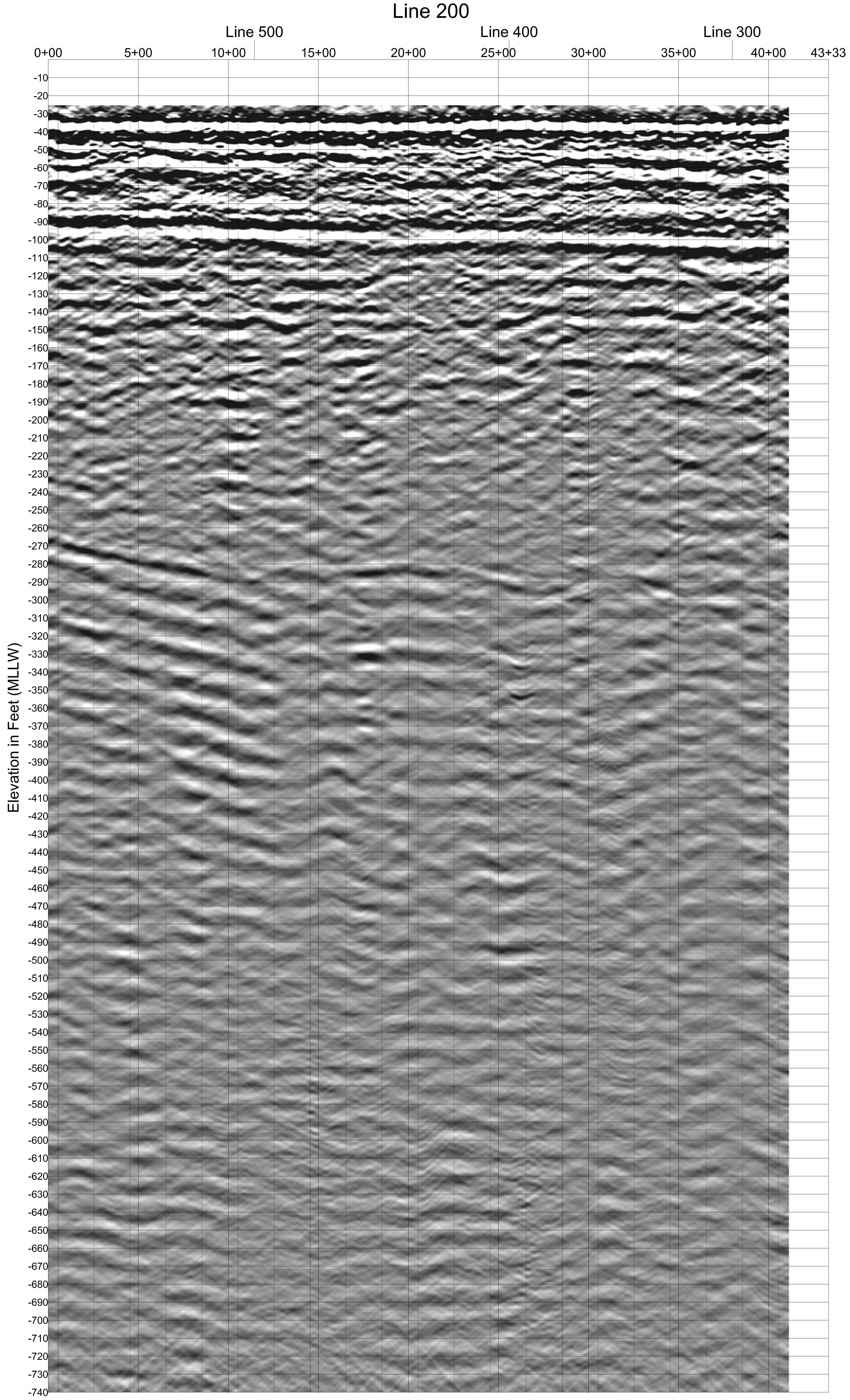

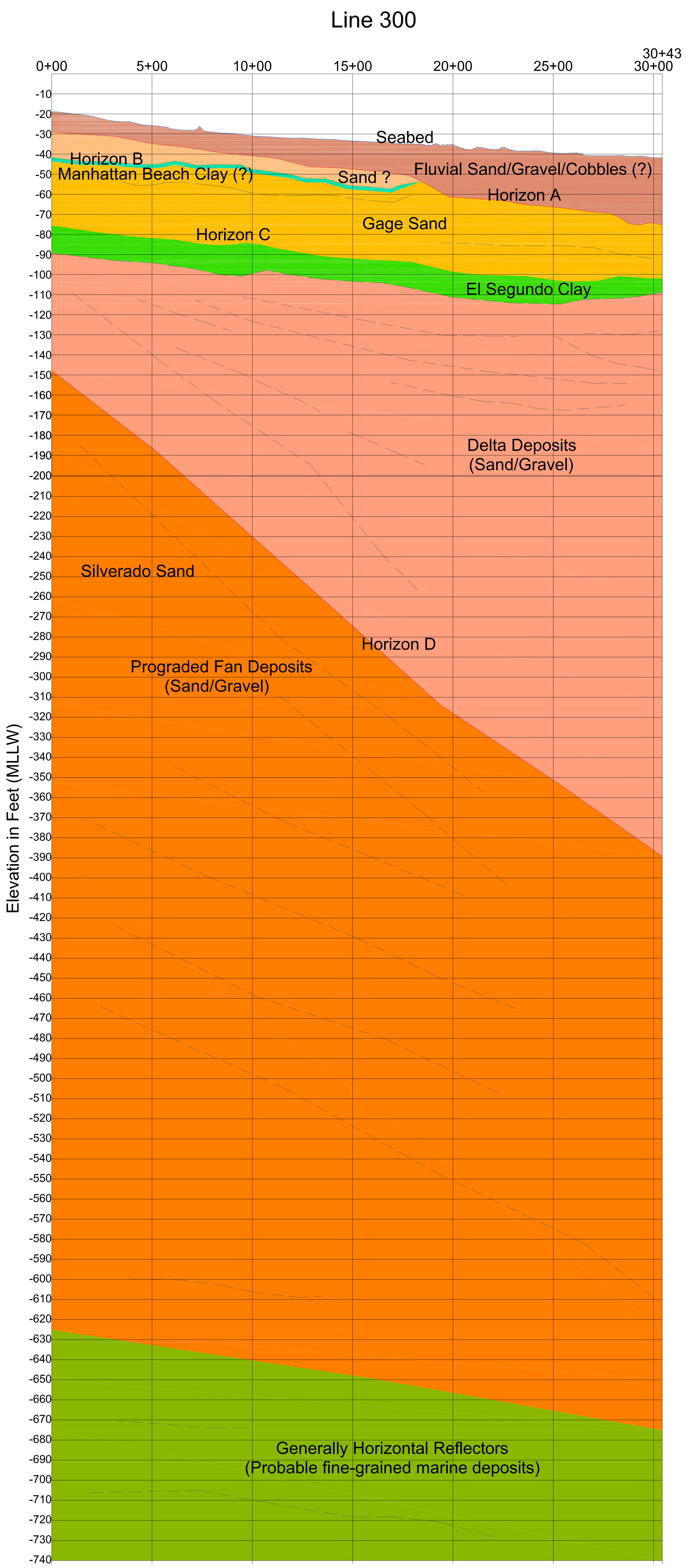
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5+00
10+00
15+00
20+00
25+00
30+00
30+43
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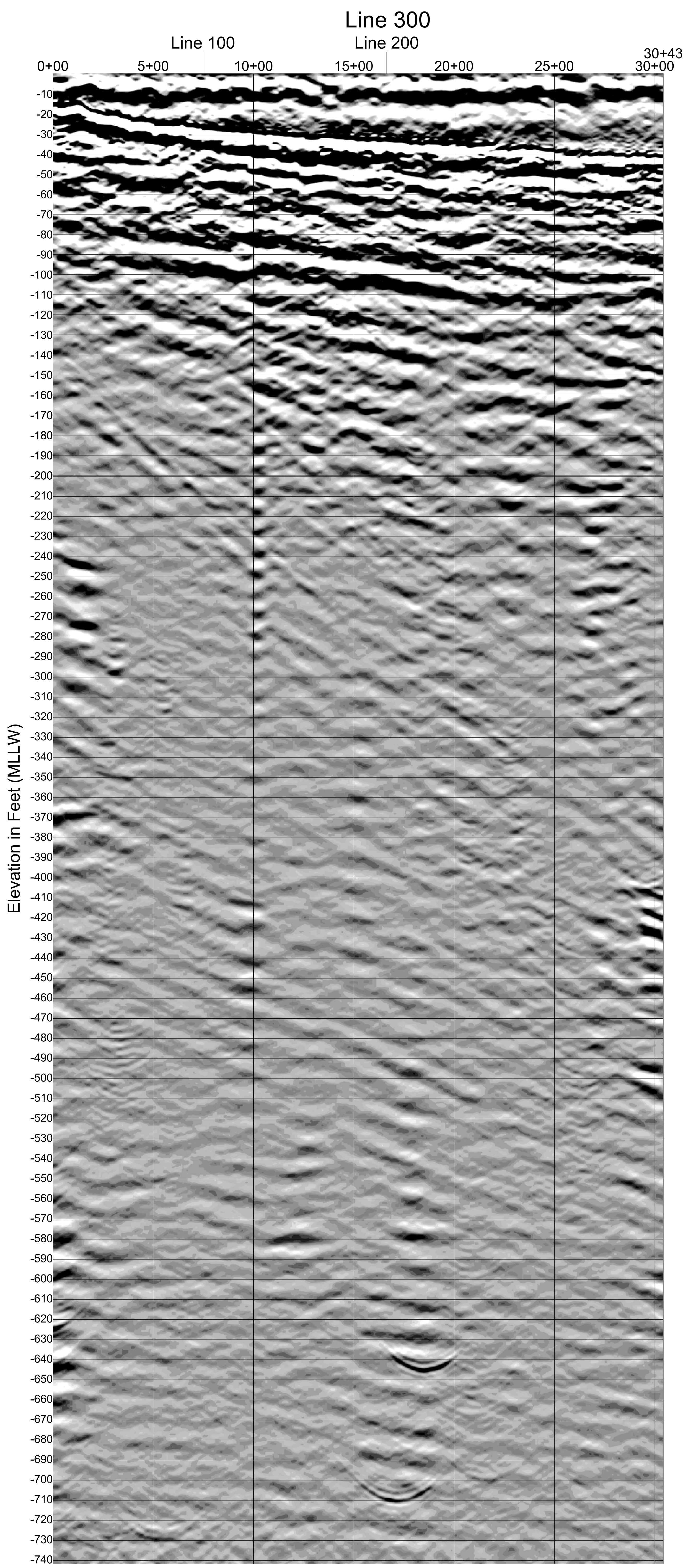
Elevation in Feet (MLLW)
Seabed
Horizon B
Manhattan Beach Clay (?)
Sand ?
Fluvial Sand/Gravel/Cobbles (?)
Horizon A
Gage Sand
Horizon C
El Segundo Clay
Delta Deposits
(Sand/Gravel)
Silverado Sand
Horizon D
Prograded Fan Deposits
(Sand/Gravel)
Generally Horizontal Reflectors
(Probable fine-grained marine deposits)


Line 300
Line 100
Line 200
0+00
5+00
10+00
15+00
20+00
25+00
30+00
30+43
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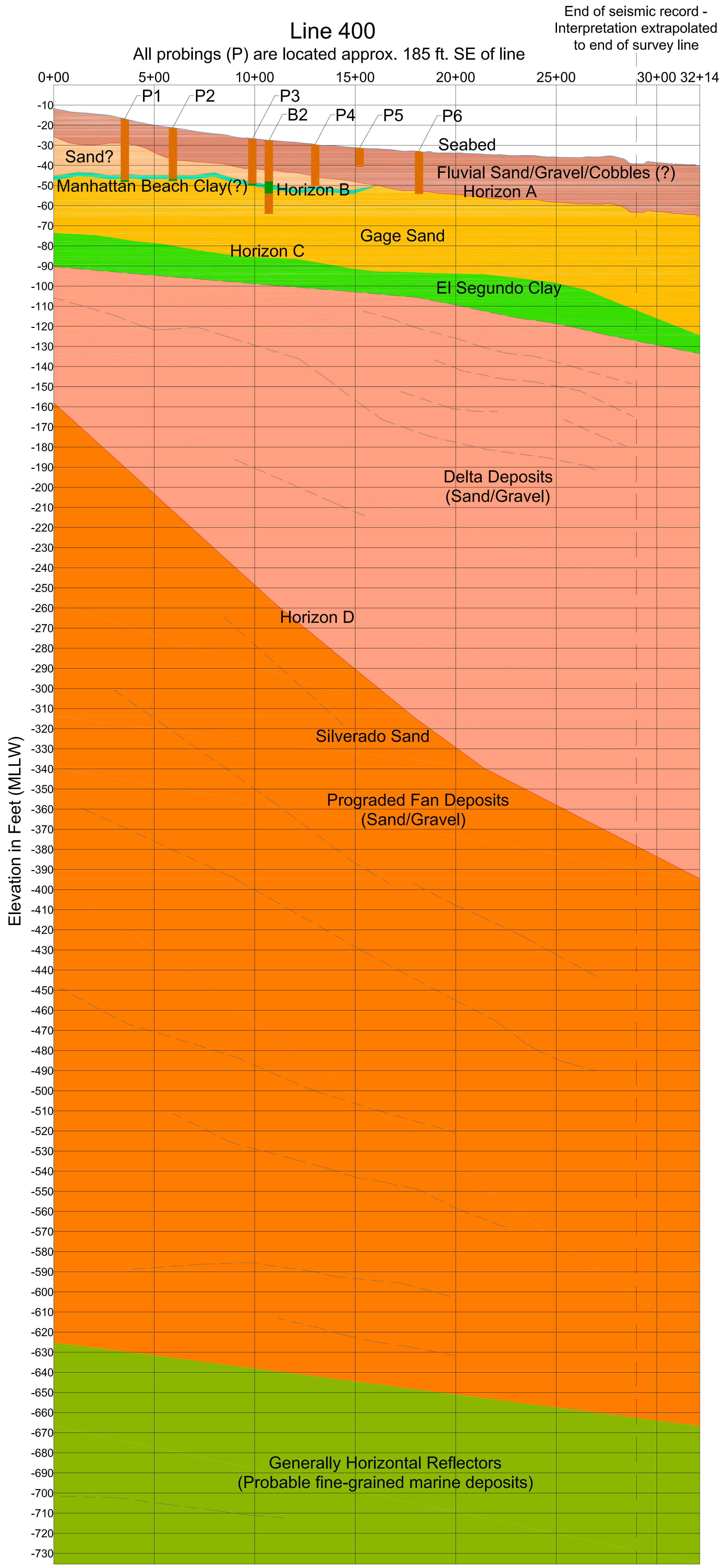
Elevation in Feet (MLLW)

Line 400

All probings (P) are located approx. 185 ft. SE of line



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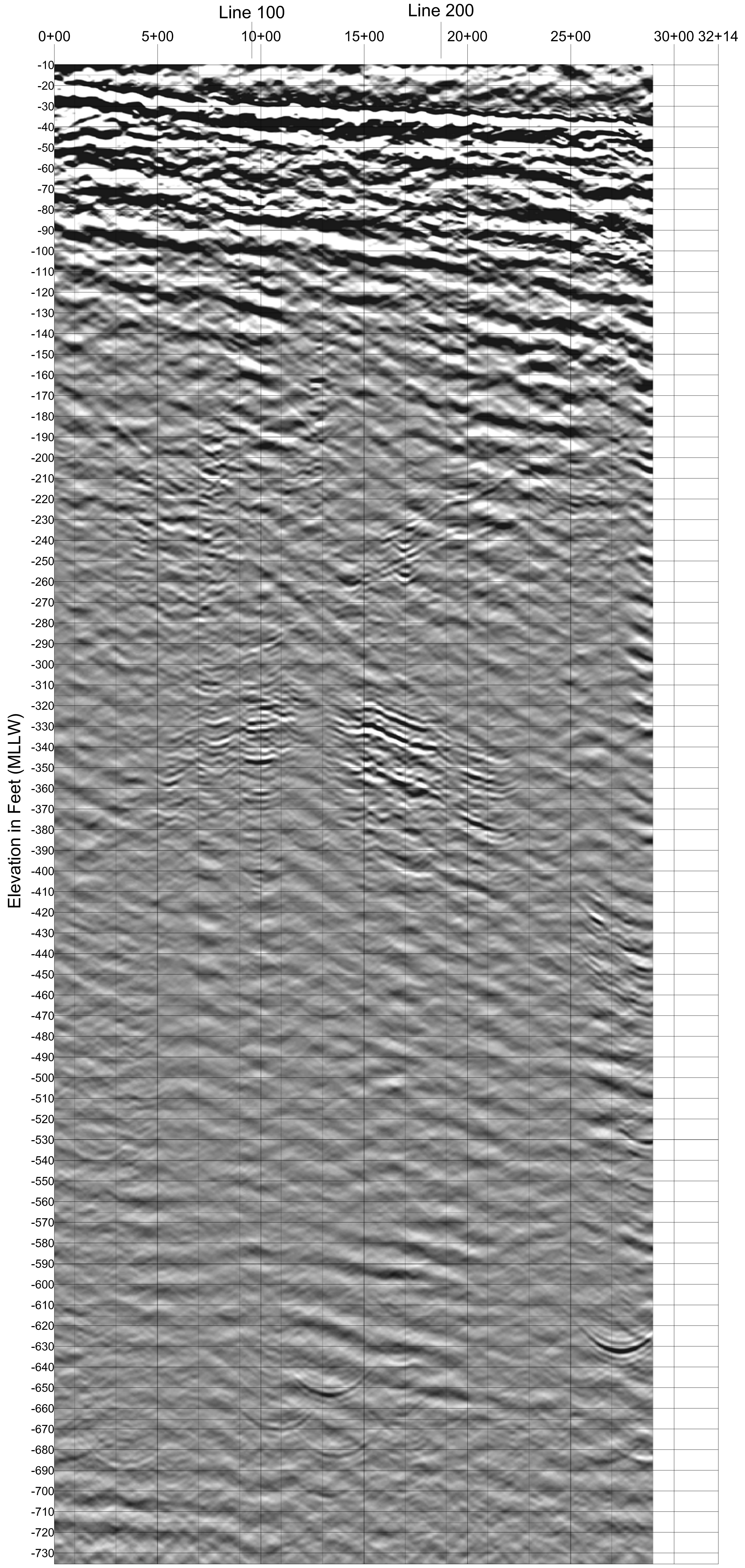

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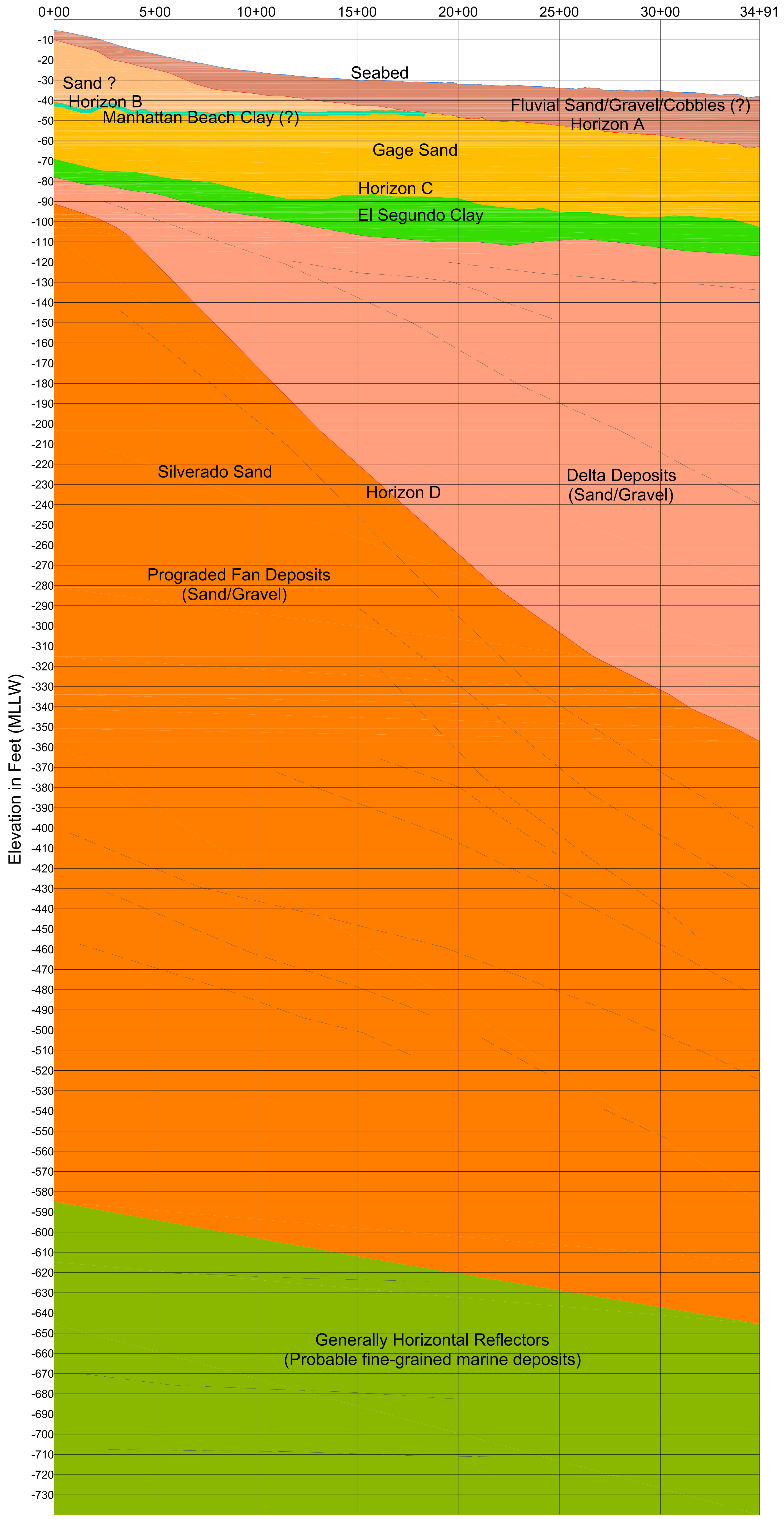
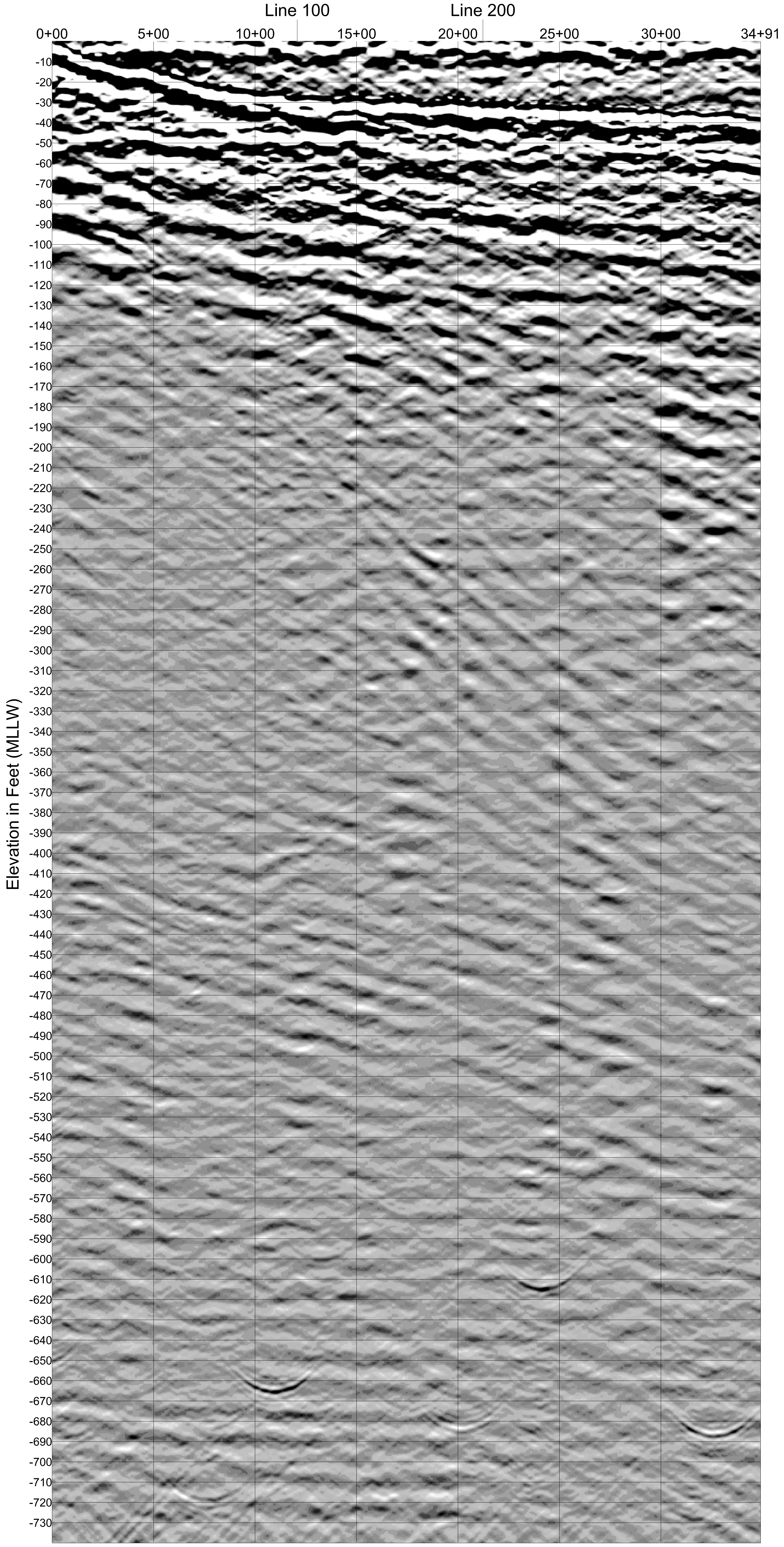


Line 500



APPENDIX J
Groundwater Flow Model
Proposed El Segundo Desalination Facility

Appendix J

Groundwater Flow Model

Proposed El Segundo Desalination Facility

1. GROUNDWATER FLOW MODEL

Based on review of offshore and onshore hydrogeologic data including the Summer 2015 field investigations, Geosyntec developed a three-dimensional numerical model of the area as a tool to simulate groundwater flow to assess the feasibility of subsurface seawater intakes (SSIs) to provide source water to at the design flow rate of 40 MGD to the proposed Desal Facility at the NRG Facility in El Segundo. The model was used to specifically assess

- the ability of the different SSIs to provide 40 MGD,
- the maximum yield of the different SSIs, and
- the amount of water withdrawn from inland sources, in particular the injection barrier of West Coast Basin Barrier Project.

This section provides documentation of the numerical model construction and model results.

1.1 Model Construction

The groundwater flow model was developed using MODFLOW, a widely used public domain groundwater modeling software available from the United States Geological Survey (USGS, http://water.usgs.gov/nrp/gwsoftware/modflow.html). The commercial software, Visual MODFLOW (Schlumberger Water Services, http://www.swstechnology.com), was used for pre- and post-processing of the MODFLOW simulations. The groundwater model simulations were all steady-state flow solutions.

1.1.1 Model Domain and Grid

The model domain and grid are illustrated in Figure J.1. The model domain is 30,000 feet wide in the east-west direction and 16,500 feet wide in the north-south direction. The orientation of the model domain generally aligns the columns of the model grid with the coastline. The eastern edge of the model domain corresponds to the approximate location of the West Coast Basin Injection Barrier. The model domain extends approximately 18,900 feet offshore to the west, well beyond the potential offshore extent of any SSIs and to minimize the influence of boundary conditions on the model results; approximately 3,700 feet north of the NRG facility to the northern extent of the injection barrier; and approximately 10,000 feet south of the NRG facility to include the injection barrier influence south of the NRG facility where it is closest to the shore.

Grid cell horizontal dimensions vary from approximately 50 by 50 feet within 2,000 feet north and south of the NRG facility and within 2,000 feet onshore and offshore of the coastline, to as large as 250 by 250 feet near the eastern margin and 400 by 250 feet near the western margin of the model domain. The 50 foot grid-cell size around the NRG facility provides sufficient resolution of variation in hydraulic head in the vicinity of simulated wells beneath the shoreline. The elevation of the base of the model ranges from to -800 ft MSL to -600 ft MSL, at the offshore and inland margins, respectively, and corresponds to the mapped extent of the Silverado aquifer based on the offshore seismic reflection survey. The numerical grid consists of 134 rows, 176 columns, and 12 layers.

1.1.2 Model Layers

The model layering is based on the hydrostratigraphy inferred from the following sources with refinements of the vertical discretization to facilitate representation of SSIs:

- Boring logs of onshore and offshore borings and onshore CPT data (see Section 3.1 in the main report);
- Profiles developed based on the seismic reflection survey conducted by Fugro in September 2015 (see Section 3.2.3 in the main report and Appendix I);
- Numerical model of the West Coast Basin Barrier (e.g. Intera, 2015);

Layer 1 represents the hydraulic head of ocean. The inland portion of Layer 1 is 10 feet thick and inactive. The bottom of Layer 1 offshore is the seafloor.

Layer 2 represents the mainly fine-medium sand and some gravel sediments beneath the ground surface (and seafloor) (Appendix F; Section 3.2.4), consistent with interpretation of the seismic reflection survey conducted by Fugro (Appendix I).

Layer 3 represents the upper silt and clay layer based on multiple boring logs (see Section 3.1 in the main report), onshore CPT data collected in August 2015 (see Section 3.2.2 in the main report and Appendix H) and the seismic reflection survey (see Section 3.2.3 in the main report and Appendix I). The thickness of 2 feet of this layer was defined to be consistent with the profiles developed based on the seismic reflection survey. The bottom of this layer was not clearly identified with the seismic reflection survey (see Section 3.2.4 in the main report), and the layer might be thicker; therefore defining a 2 feet thickness is a conservative assumption that will maximize the connection between the Gage aquifer and the ocean.

Layers 4 - 6 represent the fine-medium sand to gravelly sand that makes up the Gage Aquifer. The Gage aquifer is approximately 35 feet thick to be consistent with the profiles developed based on the seismic reflection survey. Three model layers within the Gage Aquifer facilitate representation of vertical gradients and of pumping from HDD wells and radial collectors from specific depth intervals within the Gage Aquifer (see Section 1.1.5).

Layer 7 represents the lower clay and silt interval, which corresponds to the El Segundo Aquitard. This layer is approximately 10 feet thick and is consistent with onshore boring logs and the interpreted profiles based on the seismic reflection survey.

Layers 8 – 12 represent the gravelly sand with silt and clayey interbeds of the Silverado Aquifer. Five model layers within the Silverado Aquifer facilitate representation of pumping from slant (angle) wells, and representation of varying hydraulic properties with depth in the Silverado Aquifer based on the West Coast Basin Barrier model (e.g. Intera, 2015).

The model layers beneath the ocean slope parallel to the ocean floor. The landward model layers are horizontal starting with the bottom of Layer 2.

Figure J.2 shows a comparison of a cross-section through the model and an interpreted geological profile based on the seismic reflection survey.

1.1.3 Hydraulic Properties

Each cell in the numerical model grid is assigned a hydraulic conductivity. The hydraulic gradient and the hydraulic conductivity determine the rate at which water flows through the subsurface (and model grid cell).

Horizontal and vertical hydraulic conductivity (Kh and Kv) of 75 and 2 feet per day (ft/d), respectively, is assigned to Model Layers 1 and 2, consistent with values assigned in the vicinity of the NRG facility in the corresponding layers (Layers 1 and 2) in the West Coast Basin Barrier model, where values of 50 to100 and 1 to 2 ft/d were defined for Kh and Kv, respectively.

Kh and Kv of 0.1 and 0.01 ft/d is assigned to Layer 3, which represents the upper clay layer. The Kh value of 0.1 ft/d is consistent with the hydraulic conductivity estimated with the CPT conducted onshore in August 2015 (see Section 3.2.2 in the main report and Appendix G). A ratio of 10:1 defines the vertical hydraulic conductivity of the fine-grained interval. A Kh to Kv ratio of 10:1 provides a reasonable maximum hydraulic conductance across the upper silt and clay layer since larger values of anisotropy (100 or more) are common in model layers representing unconsolidated alluvial sediments with clay layers (e.g. Anderson et al, 2015).

Kh and Kv of 50 and 1 ft/d is assigned to Layers 4 to 6, representing the Gage aquifer, consistent with values 50 and 1 ft/d for Kh and Kv, respectively, assigned in the vicinity of the NRG facility to the corresponding depth intervals in the West Coast Basin Barrier model (Layer 3).

Kh and Kv of 0.01 and 0.001 ft/d if assigned to Layer 7, which represents the lower clay layer (El Segundo Aquitard). The Kh value of 0.01 ft/d is consistent with the hydraulic conductivity estimated with the CPT conducted onshore in August 2015 (see Section 3.2.2 in the main report and Appendix H). A ratio of 10:1 defines the vertical hydraulic conductivity of the fine-grained interval. As discussed above for Layer 3, a Kh to Kv ratio of 10:1 provides a reasonable maximum hydraulic conductance across the layer representing alluvial deposits with interbeds of silt and clay.

Kh and Kv of 150 and 5 ft/d is assigned to Layer 8, representing the upper portion of the Silverado Aquifer, consistent with values of 150 to 200 and 5 to 10 ft/d for Kh and Kv, respectively, assigned in the vicinity of the NRG facility in the corresponding depth interval in the West Coast Basin Barrier model (Layer 4).

Similarly, and consistent with values assigned in the vicinity of the NRG facility to the corresponding depth intervals in the West Coast Basin Barrier model (Layers 5 – 8, e.g. Intera, 2015), Kh and Kv of 70 and 1.5 ft/d is assigned to Layer 9, 20 and 1 ft/d to Layers 10 and 11, and 15 and 1 ft/d to Layer 12.

The assigned model thickness and hydraulic conductivity for the two fine-grained intervals (Layers 3 and 7) provide an optimistic representation of hydraulic conductance across these layers, which results in an optimistic assessment of the feasibility of subsurface intakes to provide a sufficient sustainable yield of seawater for the proposed Desal Facility.

1.1.4 Boundary Conditions

Constant hydraulic heads ranging from 6.5 to 15 ft were specified for all layers at the up-gradient margin (eastern edge of the model) along the West Coast Basin Injection Barrier based on groundwater elevations simulated in the West Coast Basin Barrier model (Figure 6, Intera, 2015).

The offshore margin (western edge of the model) was assigned a constant head of 1 feet MSL. A constant head of 1 feet MSL was also specified for all cells in the offshore portion of Layer 1, which represents the ocean. Although the model does not include representation of variation in water density with salinity, the specified ocean boundary condition head one foot above sea level provides additional hydraulic head that increases flux from the ocean and coastal aquifers[1].

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[1] Sea water density is approximately 2.5% greater than freshwater. The extra foot of constant head is equivalent to the additional density of a 40 ft thickness of sea water.

The northern margin was assigned a general head boundary acting at a distance of 10,000 feet with head varying linearly from 1 foot at the shoreline to 10 feet at the inland margin[2].

A uniform recharge rate of 1 inch per year was assigned to the uppermost active layer in the model.

1.1.5 Model Setup for SSIs

The model was used to assess potential production rate and the amount of water withdrawn from inland sources for four SSI technologies:

- Vertical wells;
- Radial collector wells;
- HDD wells; and
- Slant wells.

Vertical wells

Figure J.3 shows a plan view and cross section of the vertical wells layout. A series of 10 vertical wells is defined parallel to the shoreline inside the NRG Facility footprint. The spacing between the vertical wells is approximately 200 feet. The vertical well screens are placed in Layers 2 to 11, corresponding to the Gage Aquifer and the upper 120 feet of the Silverado Aquifer. The depth of the vertical wells is approximately 200 feet below ground surface (ft bgs), corresponding to 175 feet below sea level (ft BSL). The total flow rate was equally divided between the vertical wells and the vertical flow distribution is proportional to the transmissivity of the layers.

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[2] Flux associated with a general head boundary in MODFLOW depends on the conductance (C) and hydraulic gradient. C = KA/L where K = hydraulic conductivity, A = cross-sectional area of each cell parallel to the boundary, and L = distance perpendicular to the boundary to the specified general head (10,000 ft).

Radial collector wells

Figure J.4 shows a plan view and cross section of the radial collector wells layout. A series of 6 clusters of radial collector wells is defined parallel to the shoreline inside the NRG Facility footprint. Each cluster consists of three horizontal collector wells radiating out from a central caisson. The spacing between the caissons is approximately 250 feet at the NRG facility and the spacing between the collector wells is approximately 75 feet at the western extent of the horizontal wells. Each collector well is in Layer 5, corresponding to the middle of the Gage aquifer, approximately 50 feet below the sea floor. This corresponds to the horizontal collector wells being drilled approximately 75 ft bgs from caissons at the NRG Facility. Each horizontal collector screen extends between 150 and 300 feet from the caisson location. The desired flow rate was equally distributed between the collectors and along their lengths.

HDD wells

Figure J.5 shows a plan view and cross section of the HDD wells layout. A series of 13 HDD wells is represented parallel to the shoreline with the well heads inside the NRG Facility footprint. To simplify the model representation, the HDD wells are parallel to each other and not in a fan shape. The resulting maximum separation minimizes interference between the wells and therefore the model likely results in an optimistic yield from HDD wells. The spacing between the HDD wells is approximately 200 feet. Each well is screened in Layer 5, corresponding to the middle of the Gage aquifer approximately 50 feet below the sea floor. This configuration corresponds to the HDD wells being drilled to a depth of approximately 80 ft bgs from the well head locations at the NRG Facility.

Each HDD screen extends between 550 and 2,050 feet from the NRG Facility, corresponding to between 350 and 1,850 feet from the shoreline (Figure J.5). Because of the long screen of the HDD wells and expected proportionally greater withdrawal rate from the seaward end of the wells, a constant head boundary is used to represent pumping from the HDD wells instead of a specified flow rate. The constant head at the HDD well cells is specified at an elevation equivalent to the top of the upper clay layer, which results in approximately 65 feet of drawdown of hydraulic head at the HDD wells compared to ambient conditions.

Slant wells

Figure J.6 shows a plan view and cross section of the slant wells layout. A series of 10 slant wells is represented, drilled toward the ocean from inside the NRG Facility footprint. The spacing between the slant wells is approximately 200 feet. The slant well screens are in Layers 4 to 11, corresponding to the Gage Aquifer and the upper 120 feet of the Silverado Aquifer. The depth of the screened interval for each slant well extends from approximately between 35 and 170 feet below ft BSL, corresponding to a drilling angle of 20°. The model pumping rate was equally divided between the slant wells. To lessen excessive drawdown of water levels within the Gage Aquifer and maximize production potential from the slant wells, the specified pumping rate from the screened interval in the Gage Aquifer was decreased by 50% relative to the distribution proportional to the transmissivity, and pumping from the Silverado Aquifer was increased accordingly.

1.2 Model Results

The model results show that 40 MGD is not a sustainable flow rate from any of the modeled SSIs, if the well heads are limited to the NRG Facility.

Based on the model calculations, the maximum sustainable yields for SSIs with well head infrastructure completed in the NRG Facility footprint are summarized in Table J .1 and below:

- Vertical Wells: about 15 MGD. 56% of the water pumped by the wells originates from inland sources, including the West Coast Basin Injection Barrier;
- Radial Collector Wells: less than 10 MGD. Because the sustainable flow rate is well below the design intake rate, the proportion of water from inland sources was not assessed;
- HDD Wells: about 18 MGD. 8% of the water pumped originates from inland sources, including the West Coast Basin Injection Barrier;
- Slant Wells: about 16 MGD. 55% of the water pumped originates from inland sources, including the West Coast Basin Injection Barrier;

Figure J.7 shows contours of model groundwater levels and some flow paths with pumping of 18 MGD from 13 HDD wells in the Gage Aquifer beneath the shoreline adjacent to the NRG Facility. Figure J.8 shows contours of calculated drawdown of groundwater levels in the Gage Aquifer induced by the pumping of 18 MGD from 13 HDD wells. The calculated drawdown of groundwater levels exceeds 5 feet to a distance of approximately 3,000 feet inland from the shoreline, which includes areas underlain by contaminated groundwater and coastal aquifers de-designated for municipal use (California Water Board, 1998, 1999).

Figure J.9 shows the model groundwater levels and some flow paths with pumping of 16 MGD from 10 Slant Wells screened in both the Gage and Silverado Aquifers beneath the shoreline adjacent to the NRG Facility. Figure J.10 shows contours of calculated drawdown of groundwater levels in the Gage Aquifer induced by the pumping of 16 MGD from 10 HDD wells. The calculated drawdown of the groundwater levels in the Gage Aquifer exceeds 5 feet to a distance of approximately 4,000 feet inland from the shoreline, which includes areas underlain by contaminated groundwater and coastal aquifers de-designated for municipal use (California Water Board, 1998, 1999).

The drop in groundwater levels that would be caused by pumping of groundwater along the coastal margin of El Segundo Beach even at rates on the order of 20 MGD could result in subsidence of the ground surface,[3] which could impact the structural integrity of the NRG facility, the Chevron Refinery, the proposed Desal Facility and other structures in the vicinity.

As discussed above, the model is designed to provide an optimistic assessment of the potential yield from SSIs at El Segundo. If the actual vertical hydraulic conductivity of the two fine-grained intervals is lower than assigned in the model, the hydraulic connection between SSIs and the ocean would be less, potential sustainable yield from SSIs would likely be lower, and influence of SSI pumping on inland coastal aquifers and the injection barrier would be greater.

In conclusion, calculations with a site-specific groundwater model indicate that pumping at 40 MGD is not sustainable for any of the modeled SSI technologies (vertical wells, slant wells, radial collector wells, and HDD wells), when the well-head

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[3] Groundwater pumping from unconsolidated alluvial aquifer systems has resulted in significant land subsidence at many localities in the world, particularly in settings were an alluvial aquifer is overlain by a fine-grained confining layer (e.g. Freeze and Cherry, 1979).

infrastructure is limited to the NRG Facility. Moreover, pumping from the SSIs, even at reduced sustainable rates, would withdraw a substantial amount of water from the West Coast Basin Injection Barrier and areas de-designated for municipal water supply.

2. REFERENCES

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Intera, 2015. Technical Memorandum, West Coast Basin Barrier 2015 Recycled Water Simulations. March 23.

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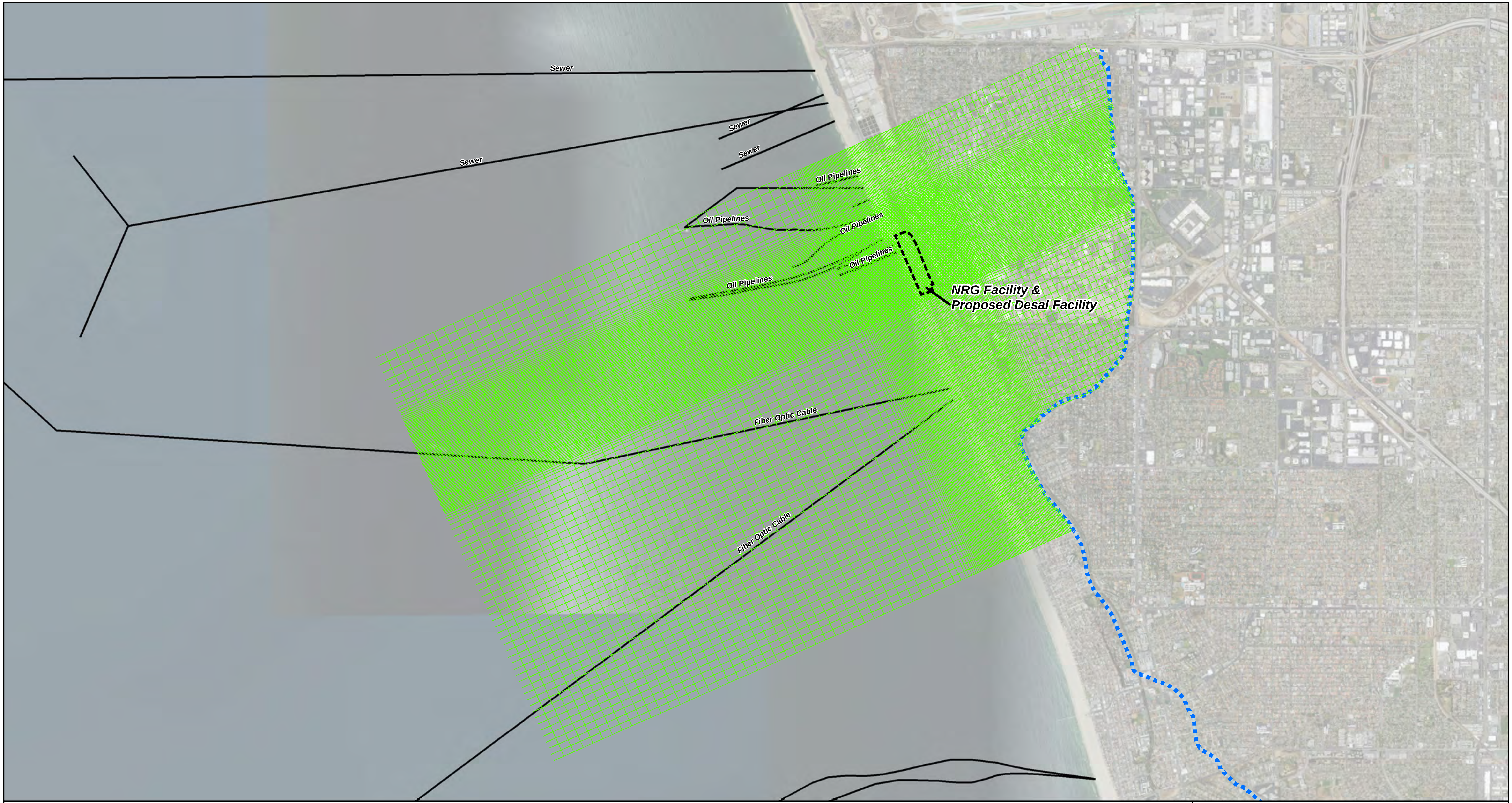

Legend

Model Domain

West Coast Basin Injection Barrier

N

0 3,500 Feet

Model Domain and Grid

Subsurface Seawater Intake Study
West Basin Municipal Water District

Geosyntec consultants

LA0324	October 2015

Figure J.1

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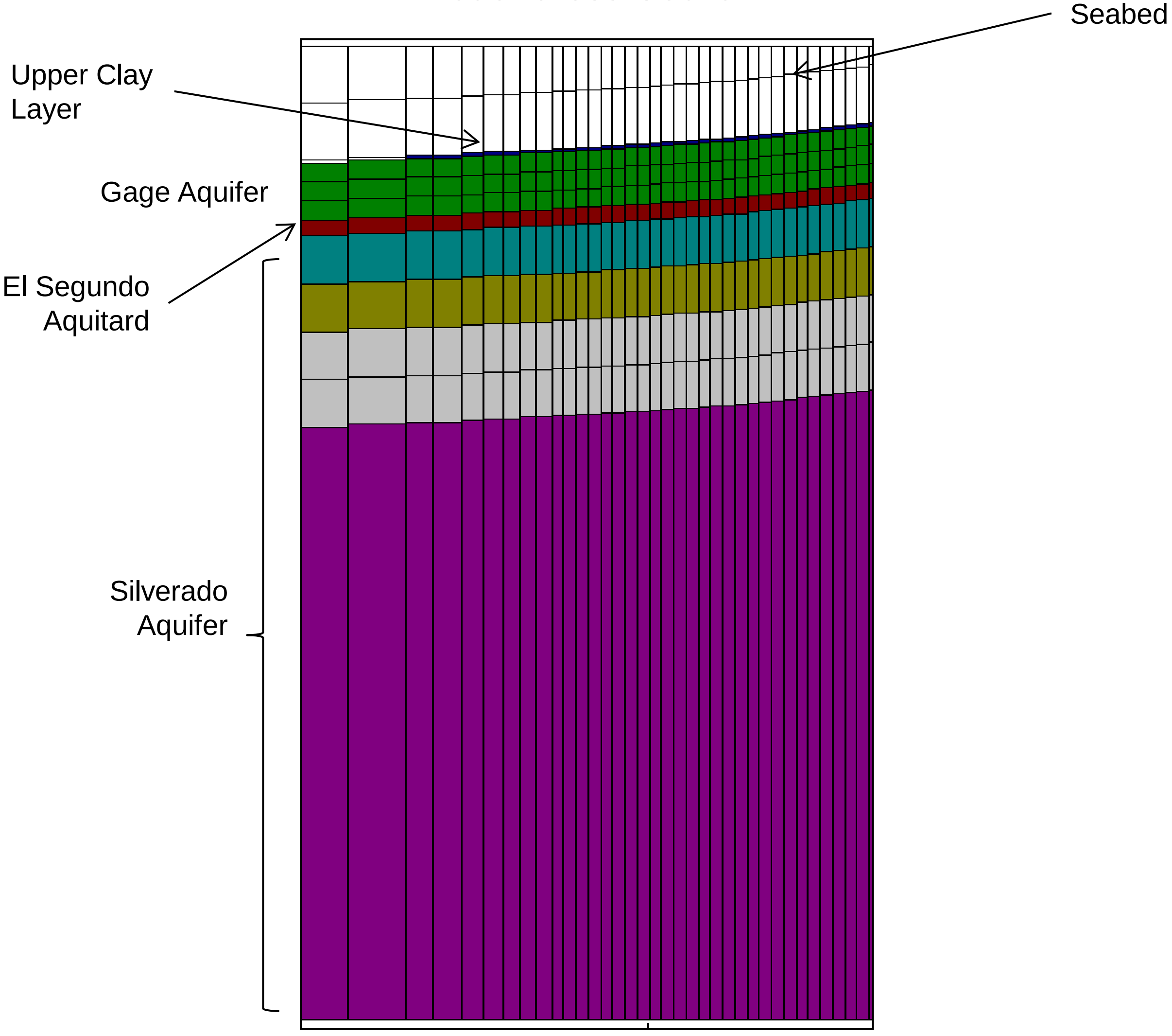
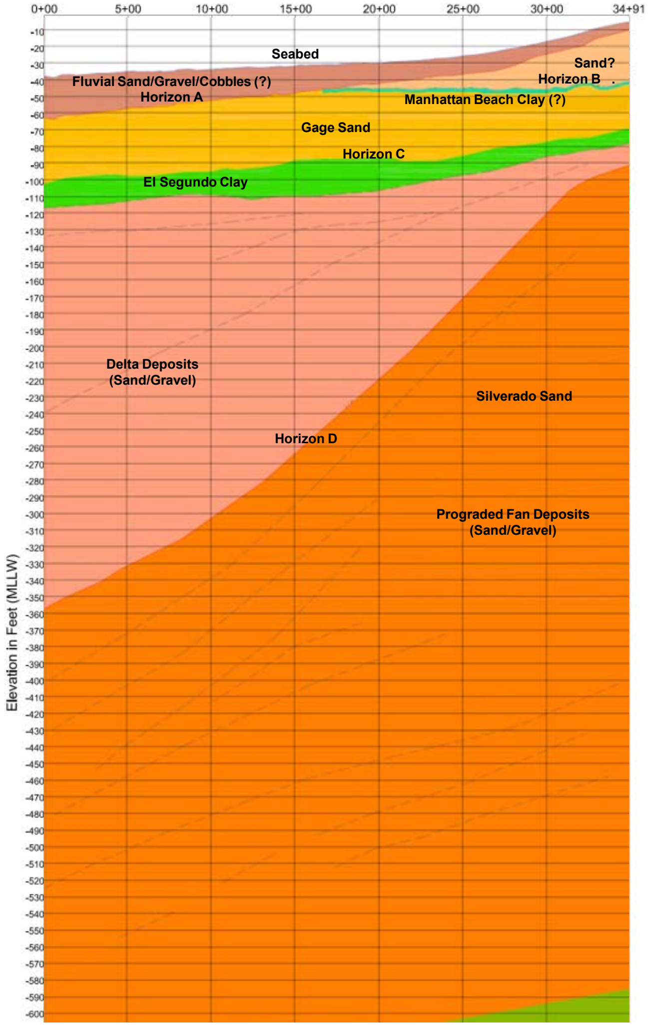
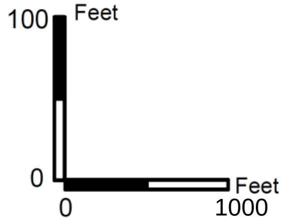
Model Cross-Section



Interpreted Profile



Notes: Interpreted profile is based on the seismic reflection survey along Line 500 (Figure 3.4). All data and results are presented in Appendix E.



Model Cross-Section and Interpreted Profile

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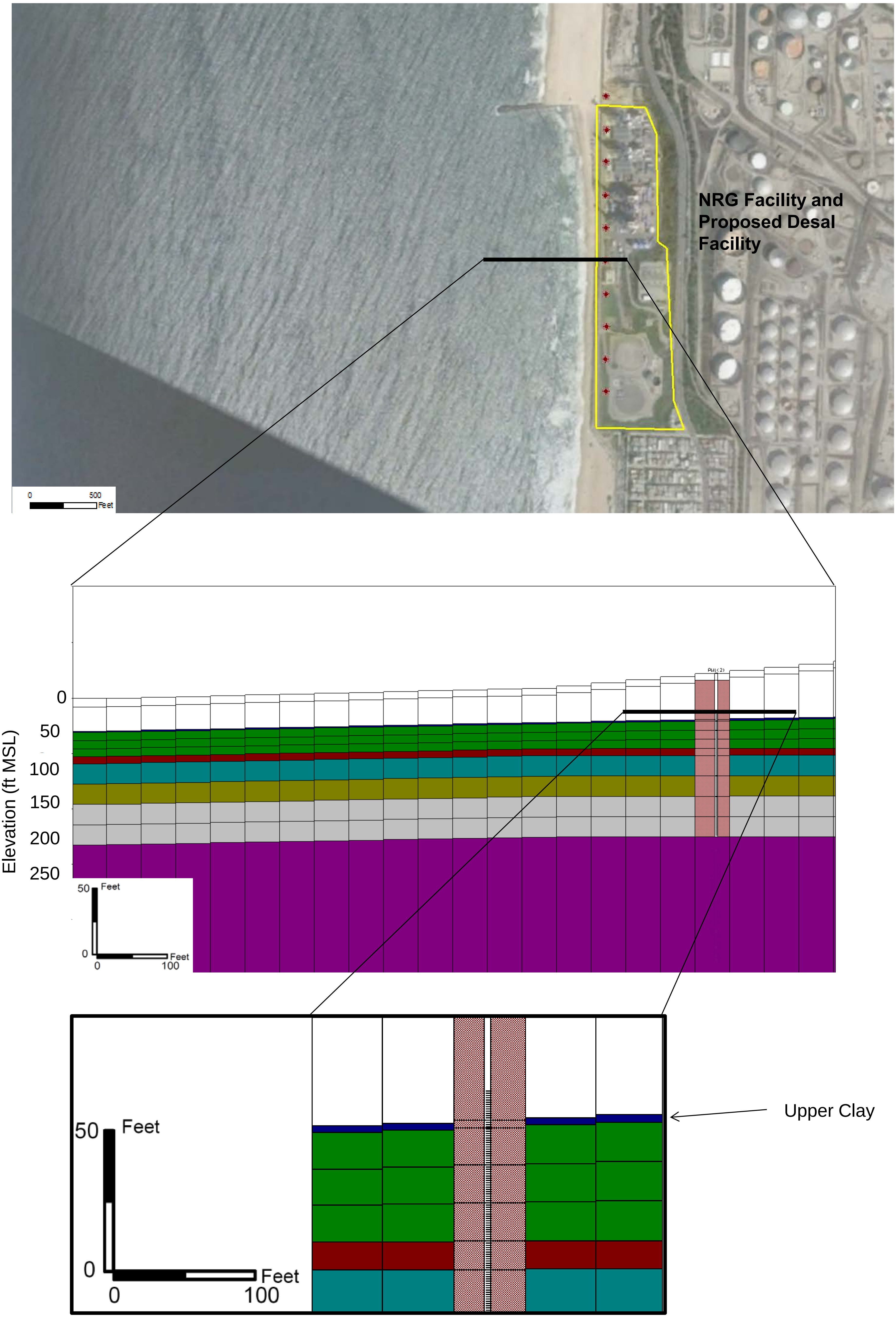
West Basin Municipal Water District

Geosyntec consultants

LA3024	November 2015	**Figure J.2**



Notes:
The cross-section shows the representation of a vertical well in the MODFLOW numerical groundwater model.
In the model, each of the 10 hypothetical vertical wells is represented by pumping to a depth of approximately 200 feet.

✦ Well location (plan view)

▨ Model cell from which pumping occurs (cross-section)

N

Model Setup for Vertical Wells

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West Basin Municipal Water District

Geosyntec
consultants

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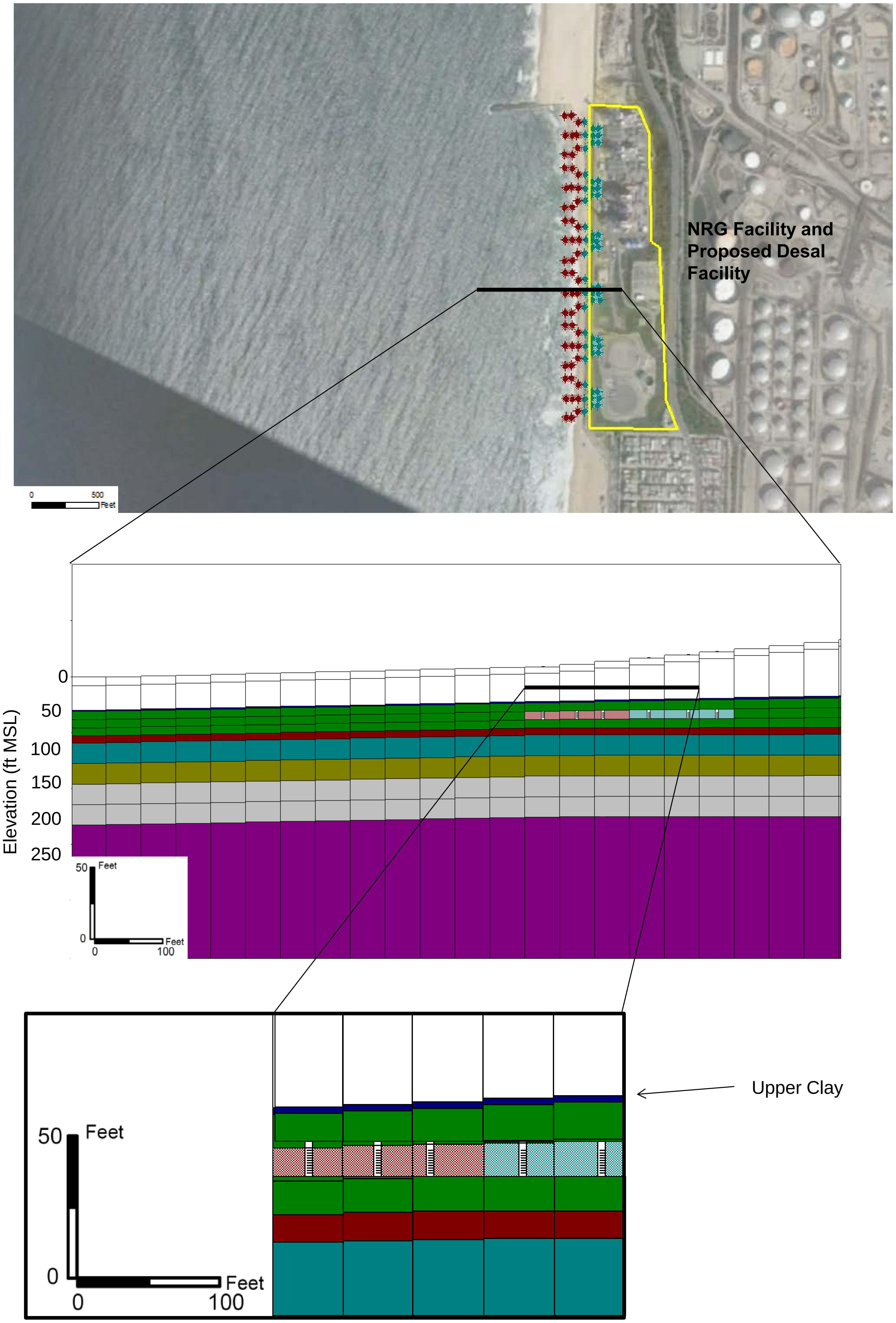
Figure

J.3



Notes:
The cross-section shows the representation of a radial well in the MODFLOW numerical groundwater model.
In the model, each of the six (6) hypothetical clusters of radial wells is represented by pumping in layer 5, the middle of the Gage Aquifer.

✱	Active well screen location (plan view)
✱	Inactive well location to represent well alignment (plan view)
▨	Model cell from which pumping occurs (cross-section)

N

Model Setup for Radial Wells

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Figure
J4

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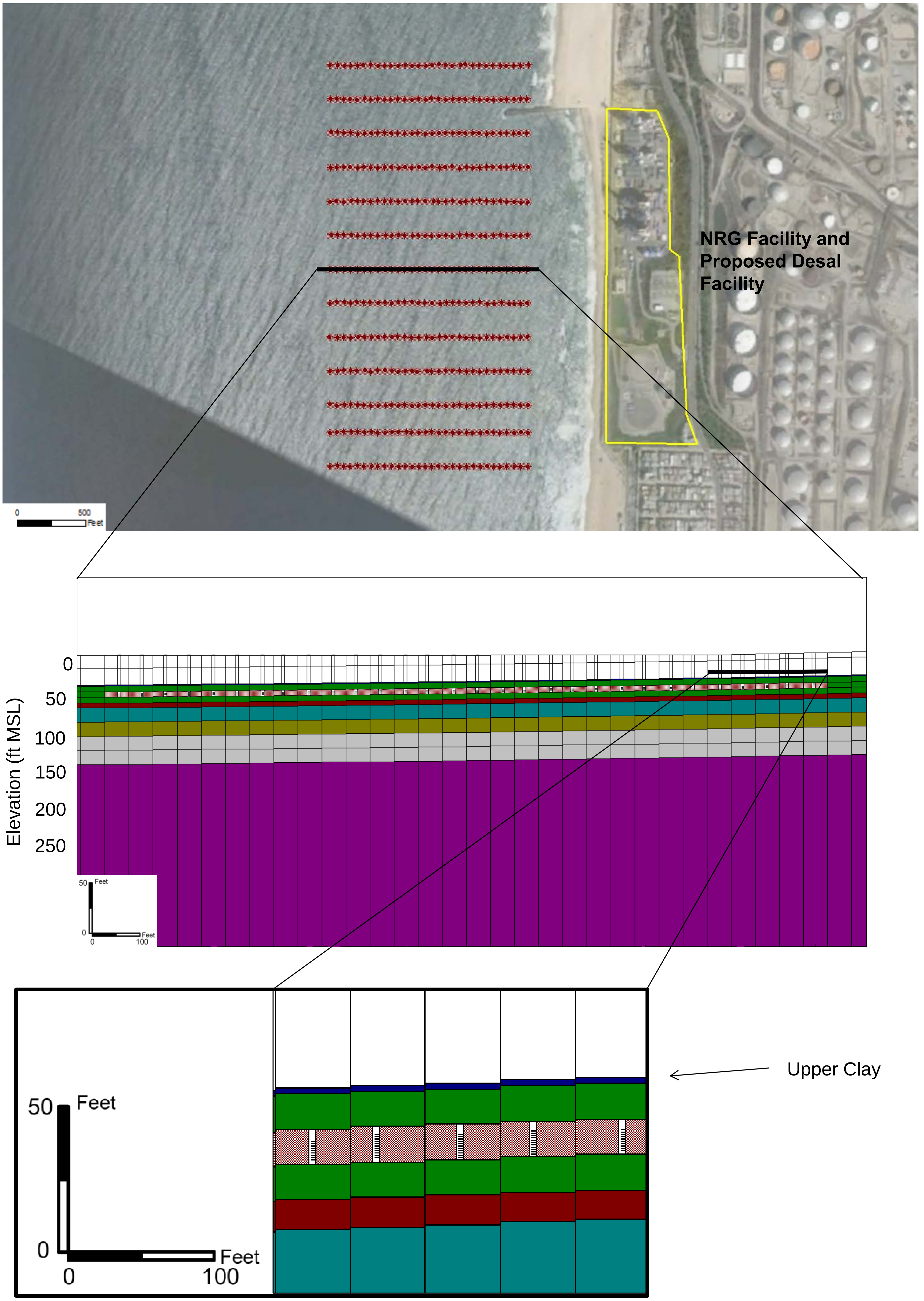

Notes:
The cross-section shows the representation of a HDD well in the MODFLOW numerical groundwater model.
In the model, each of the 13 hypothetical HDD wells is represented by pumping from layer 5, the middle of the Gage Aquifer.

✦ Well screen location (plan view)

▨ Model cell from which pumping occurs (cross-section)

N

Model Setup for HDD Wells

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Figure

J.5

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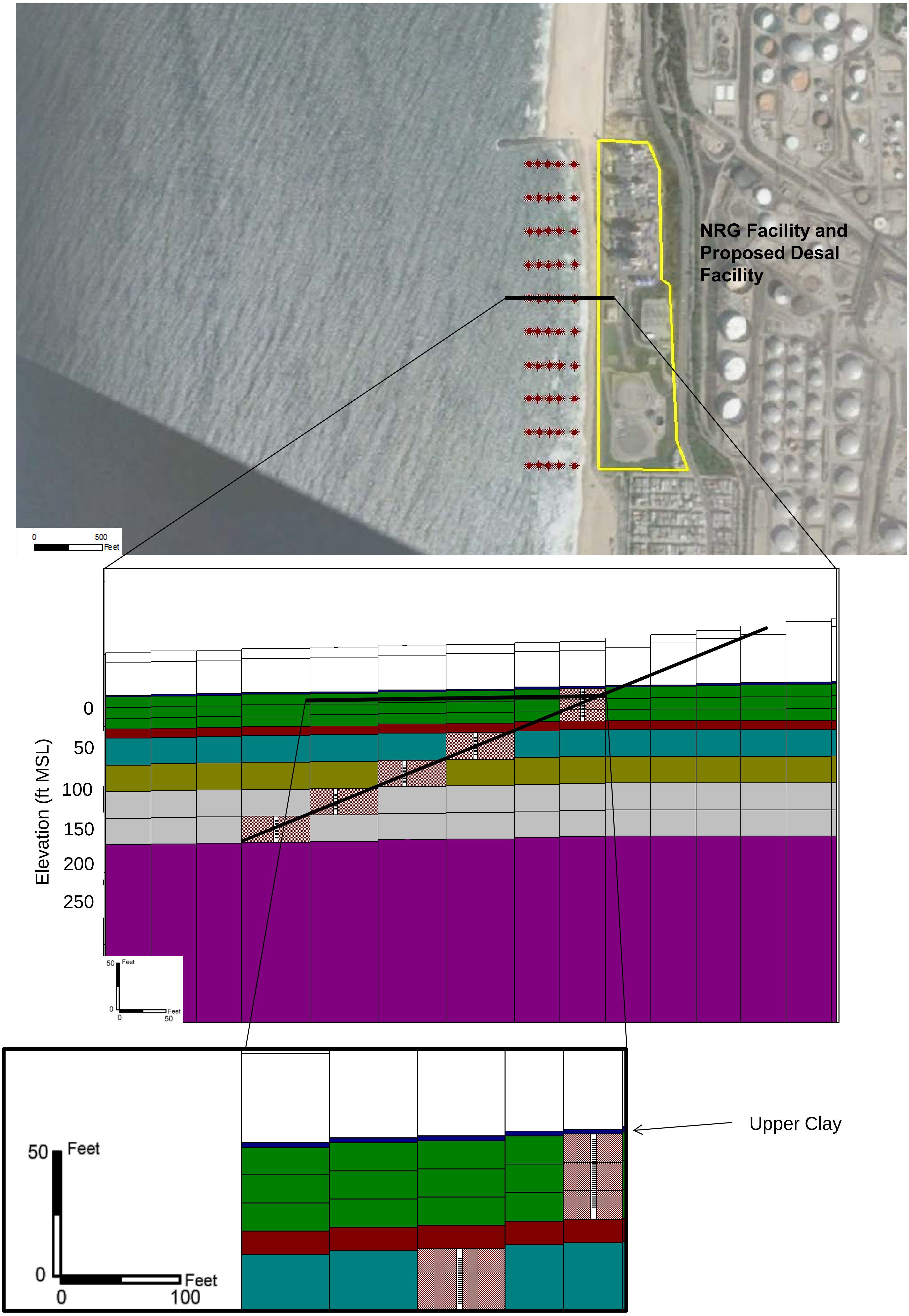

Notes:
The cross-section shows the representation of a slant well in the MODFLOW numerical groundwater model.
In the model, each of the five (5) hypothetical slant wells is represented by pumping from 3 cells in the Gage Aquifer and 4 consecutive cells in the Silverado Aquifer.
The slant well begins at the western edge of the NRG facility and is drilled at an angle of 20 degrees to a total vertical depth of ~200 feet.

✦	Well sscreen location (plan view)
▨	Model cell from which pumping occurs (cross-section)

Model Setup for Slant Wells

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Figure

J.6

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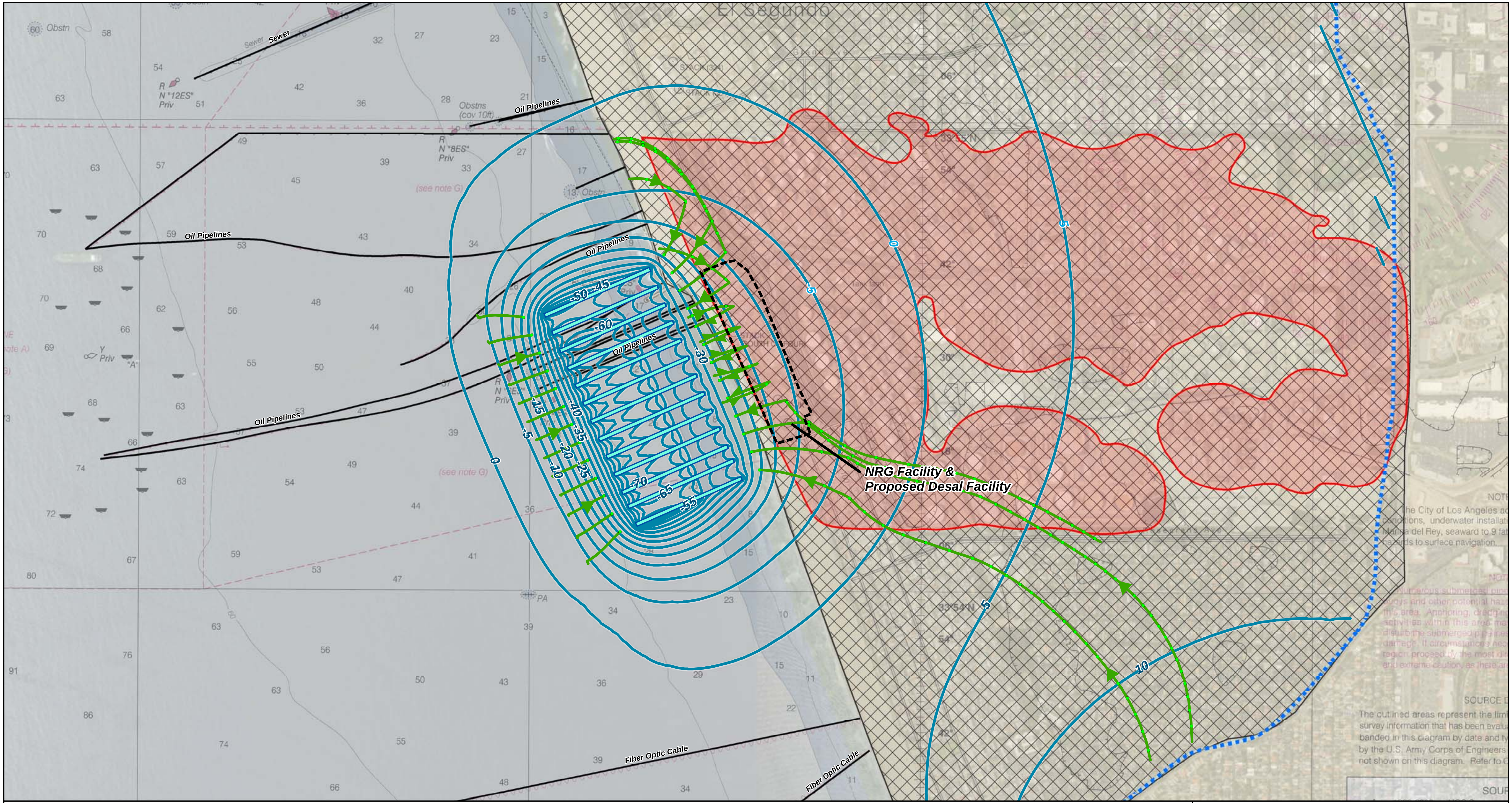

Legend

HDD Well Screen

Water Level in Gage Aquifer

Groundwater Flow Pathlines
(Travel time between dots is 180 days)

West Coast Basin Injection Barrier

Area Dedesignated for Municipal Water Supply (LARWQCB, 1998)

Extent of Contaminated Groundwater Associated with Refinery and Power Plant Operations (e.g. Trihydro, 2014)

Notes:
HDD - Horizontal Directional Drilling
MGD - Millions of Gallons per Day
Pathlines based on particle back-tracking beginning in Model Layer 5 near the HDD wells.
Offshore infrastructure source: NOAA Raster Nautical Charts, NOAA Office of Coast Survey.
Bathymetry source: NOAA - http://egisws02.nos.noaa.gov/arcgis/services

N

0 1,200
Feet

Simulated Water Level and Particle Tracking in Gage Aquifer for HDD Wells Pumping at 18 MGD

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West Basin Municipal Water District

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Figure

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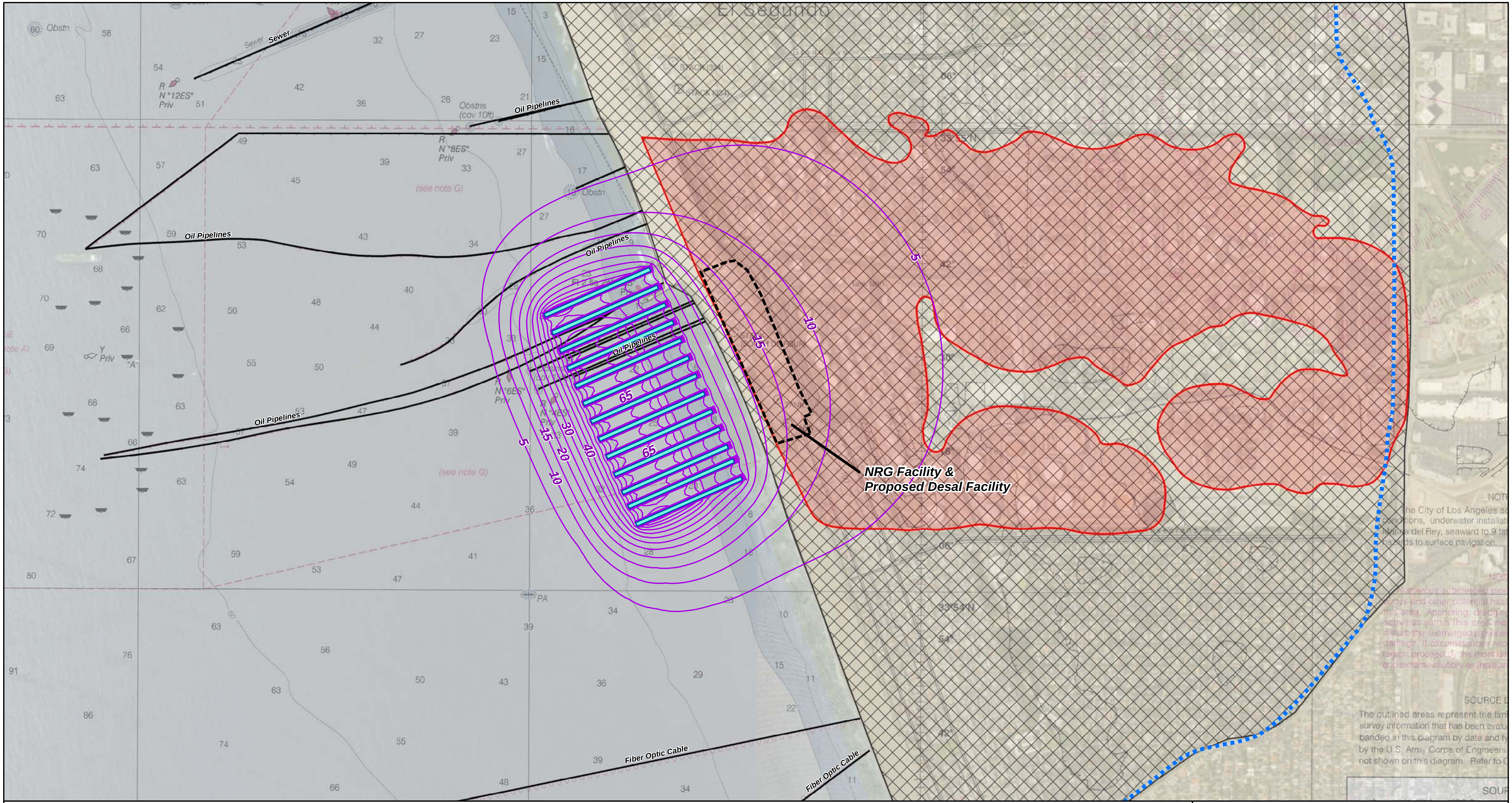

Legend

▭ HDD Well Screen

—10— Drawdown in Gage Aquifer [ft]

▪▪▪▪▪ West Coast Basin Injection Barrier

☒ Area Dedesignated for Municipal Water Supply (LARWQCB, 1998)

🟥 Extent of Contaminated Groundwater Associated with Refinery and Power Plant Operations (e.g. Trihydro, 2014)

Notes:
HDD - Horizontal Directional Drilling
MGD - Millions of Gallons per Day
Offshore infrastructure source: NOAA Raster Nautical Charts, NOAA Office of Coast Survey.
Bathymetry source: NOAA - http://egisws02.nos.noaa.gov/arcgis/services

N

0 1,200
Feet

Simulated Water Level Drawdown in Gage Aquifer for HDD Wells Pumping at 18 MGD

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West Basin Municipal Water District

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Figure
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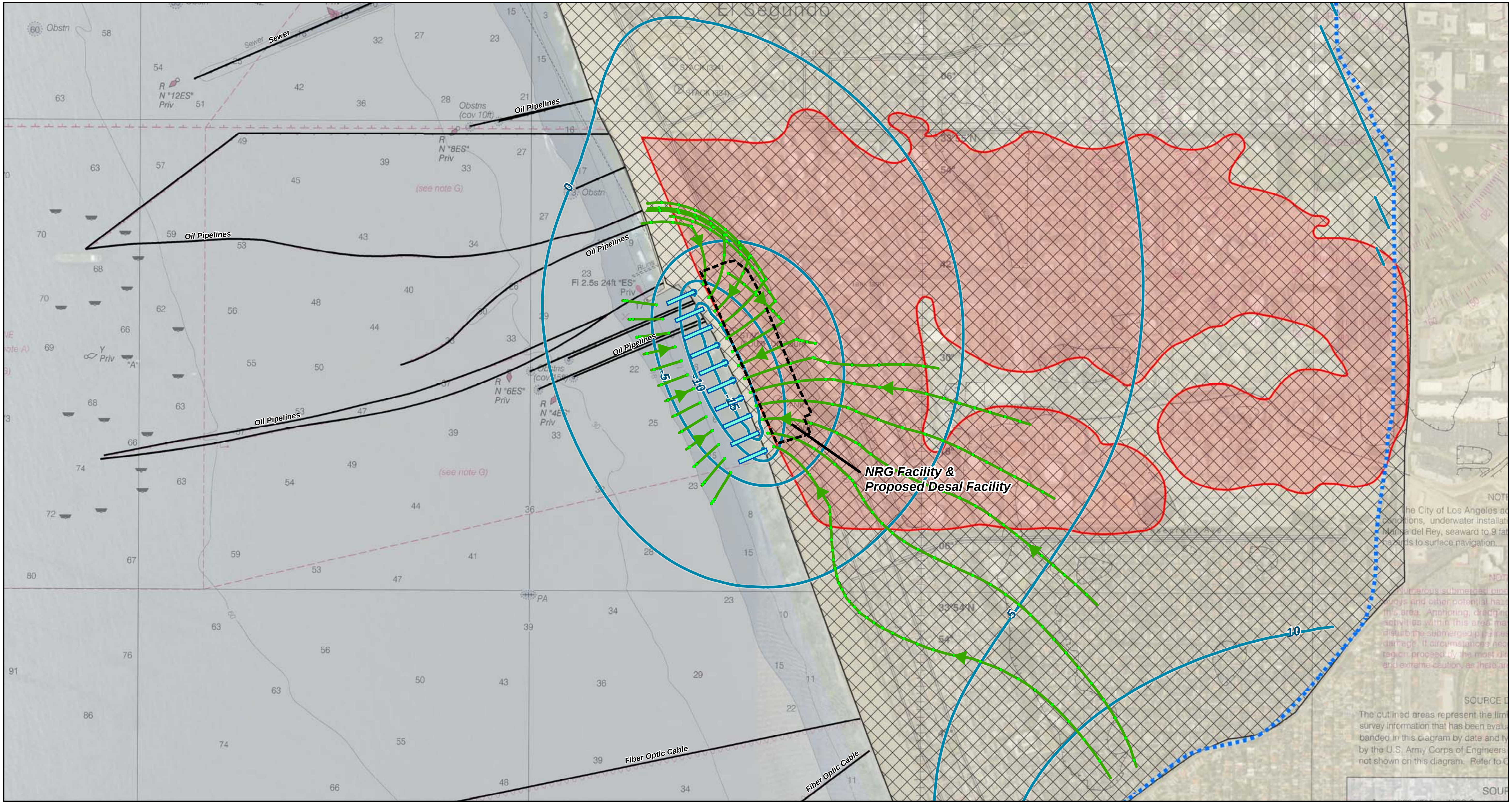

Legend

- ▭ Slant Well Screen
- —10— Water Level in Gage Aquifer
- Groundwater Flow Pathlines
  (Travel time between dots is 180 days)
- ■ ■ ■ ■ West Coast Basin Injection Barrier
- ⊠ Area Dedesignated for Municipal Water Supply (LARWQCB, 1998)
- 🟥 Extent of Contaminated Groundwater Associated with Refinery and Power Plant Operations (e.g. Trihydro, 2014)

Notes:
HDD - Horizontal Directional Drilling
MGD - Millions of Gallons per Day
Pathlines based on particle back-tracking beginning in Model Layer 5 near the HDD wells.
Offshore infrastructure source: NOAA Raster Nautical Charts, NOAA Office of Coast Survey.
Bathymetry source: NOAA - http://egisws02.nos.noaa.gov/arcgis/services

N

0 1,200 Feet

Simulated Groundwater Levels and Pathlines in Gage Aquifer for Slant Wells Pumping at 16 MGD

Subsurface Seawater Intake Study
West Basin Municipal Water District

Geosyntec
consultants

LA0324 November 2015

Figure
J.9

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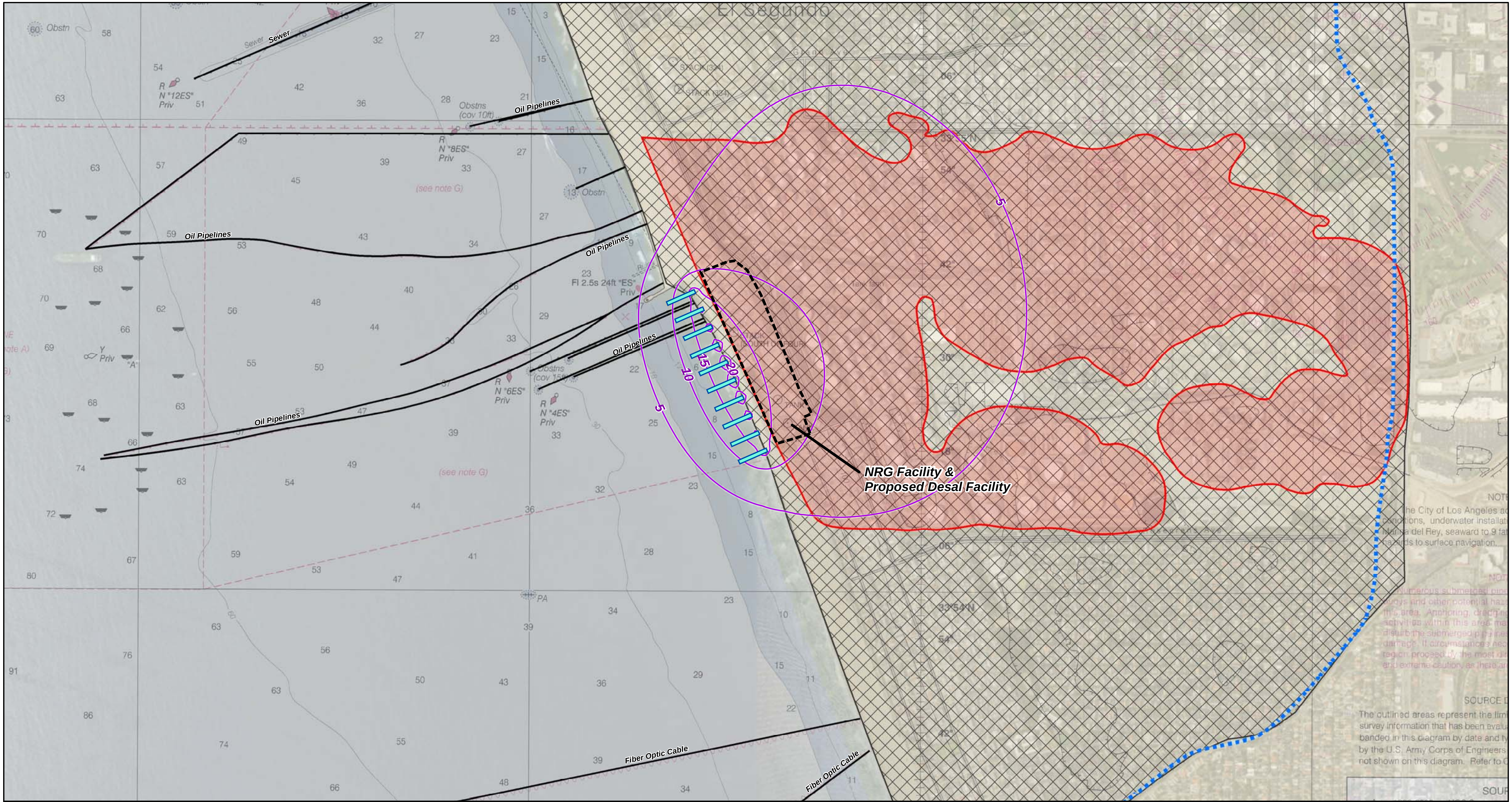

Legend

▬ Slant Well Screen

—10— Drawdown in Gage Aquifer [ft]

■■■■■■ West Coast Basin Injection Barrier

☒ Area Dedesignated for Municipal Water Supply (LARWQCB, 1998)

🟥 Extent of Contaminated Groundwater Associated with Refinery and Power Plant Operations (e.g. Trihydro, 2014)

Notes:
HDD - Horizontal Directional Drilling
MGD - Millions of Gallons per Day
Offshore infrastructure source: NOAA Raster Nautical Charts, NOAA Office of Coast Survey.
Bathymetry source: NOAA - http://egisws02.nos.noaa.gov/arcgis/services

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0 1,200 Feet

Simulated Water Level Drawdown in Gage Aquifer for Slant Wells Pumping at 16 MGD

Subsurface Seawater Intake Study
West Basin Municipal Water District

Geosyntec consultants

Figure

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APPENDIX K

Coastal Processes and Seafloor Stability Analysis of Shallow Sub-Seabed Intake Systems for the West Basin Municipal Water District Sea Water Desalination Project

Coastal Processes and Seafloor Stability Analysis of Shallow Sub-Seabed Intake Systems for the West Basin Municipal Water District Sea Water Desalination Project

Prepared by:
Scott A. Jenkins, Ph. D.
Michael Baker International
29 September, 2015
Revision 1

Submitted to
Diane Gatza
Desalination Manager
West Basin Municipal Water District.

EXECUTIVE SUMMARY: This study provides a seafloor stability analysis for shallow sub-seabed intake systems and discharge diffusers for the proposed West Basin Municipal Water District Sea Water Desalination Project which would supplement the District's water resources. The characteristic of an optimal sea floor for this purpose is one that is neither erosional nor depositional over the long-term, and one that is within a feasible hydraulic pathway to the launch points for the subsurface intake and concentrate discharge facilities. Two candidate sites were considered in Santa Monica Bay. One utilizes existing infrastructure on the site of the AES Redondo Beach Generating Station (*RBGS*). This site was used for the West Basin Municipal Water District's ocean water desalination demonstration facility (DDF). The second candidate site in Santa Monica Bay considered is the NRG El Segundo Generating Station (*ESGS*).

We consider only shallow subsurface intake technology because any subsurface intake system that taps into deep coastal aquifers (e.g. slant wells and vertical wells) would likely have additional environmental permitting issues due to adverse effects upon nearshore groundwater. Therefore we focus on shallow infiltration technologies that rely on minimal sediment cover (on the order of tens of feet) such as: *Sub-surface (seabed) Infiltration Galleries (SIG), Beach Infiltration galleries (BIG),* and advanced horizontal well technology like *the Neodren™ Seawater Intake.*

We review the findings of the *Independent Science and Technology Advisory Panel* (ISTAP) appointed by the California Coastal Commission who considered several coastal processes and construction aspects for implementing SIG and BIG intake technology at the Huntington Beach Desalination Facility (HBDF). The constructability of SIG's and BIG's at the RBGS and ESGS sites is questionable because it requires excavation of a dredged pit to elevations of 10 feet below the ambient seabed in which the infiltration branch pipe segments and engineered fill are subsequently placed. This installation is problematic and time consuming in high-energy sea states, which are common near the RBGS & ESGS sites. For this reason, the ISTAP concluded that the only sensible construction option for either a SIG or a BIG on an exposed open-ocean coastline is to first build a temporary pier from which the SIG and BIG holes can be dredged and the piping and engineered fill subsequently placed. This was found to be a very expensive construction option at Huntington Beach (these findings are addressed in

detail within the ISTAP Phase I and Phase II reports). On the other hand, the Neodren™ Seawater Intake is insulated from these construction problems due to its directional drilling techniques. Based on these considerations, we proceed with a sediment budget and seafloor stability analysis tailored to the Neodren™ system, as the SIG and BIG alternatives appear more costly and difficult to construct at either the ESGS or RBGS sites.

To make this assessment, we utilize the Coastal Evolution Model (CEM) to solve the sediment budget of the Santa Monica Littoral Cell, and to solve for the properties of the equilibrium beach and shore rise profiles over long historic periods. The Coastal Evolution Model was developed under a $1 million grant by the Kavli Foundation to make forecast predictions of the effects of sea level rise on the coastline of California, and was validated in the Oceanside Littoral Cell for the same period of record used in the present study.

The CEM determined that the shore-rise and bar-berm seafloor profiles in the neighborhood of Chevron Groin at the ESGS site are neither depositional nor erosional, a steady-state equilibrium condition that is optimal for an intake and discharge site. Based on 8,290 solutions over the 1980-2004 simulation period, the CEM calculates in Figure ES-1 that bottom profile perturbations caused by shoaling waves at the ESGS site near the Chevron Groin were found to cease seaward of the -15 m MSL depth contour, referred to as *closure depth*. In addition, the critical mass envelope is relatively thin at the Chevron Groin (cf: red envelope boundary in Figure ES-1) due to the stabilization action of the groin.

The critical mass determines the volume of sediment cover above the Neodren™ intakes that can be potentially eroded by the action of seasonal and episodic profile change or shoreline recession. The critical mass of sand on a beach is that required to maintain equilibrium beach shapes over a specified time, usually ranging from seasons to decades. The critical mass envelope in Figure ES-1 indicates that sand level variations due to beach profile changes are no more than 3.3 m across the bar-berm beach profile at the ESGS site, and no more than 1.5 m across the shore rise profile off shore. This fortuitous sediment transport behavior was linked to an offshore feature in the continental shelf bathymetry that created a *shadow zone* (area of diminished wave height) in the refraction pattern of the large waves from distant storms (Figure ES-2).

Based on the critical mass and closure depth calculations over a 20 year period, we conclude that the HDD pipeline routes posed for Neodren™ intakes provide at least a four-fold margin of safety against exposure by extreme event waves. The ESGS diffuser site as specified in the Master Plan is inside closure depth, but the 7 ft. tall riser pipe/nozzle assemblies in the ARCADIS designed diffusers should provide adequate free-board to prevent burial of the duckbill nozzles at the proposed depths of -10 to -11 m MSL at the proposed ESGS discharge site.

Sand level variations over a Neodren™ system placed off the RBGS site were found to be greater owing to positive divergence of littoral drift and episodic turbidity current activity in the *Redondo Submarine Canyon*. Figure ES-3 shows that historic beach and shore rise profile variations at a survey range on the north side of Redondo King Harbor show significantly greater vertical excursions in sand elevations, and those vertical elevation changes occur further offshore than at the Chevron Groin in Figure ES-1.

Comensurate with these empirical data, Figure ES-3 shows a greatly expanded critical mass envelope and deeper closure depths than found at the ESGS site, both based on long term CEM sediment budget calculations. The critical mass envelope in Figure ES-3 indicates that sand level variations due to beach profile changes are 3.6 m across the bar-berm beach profile at the RBGS site, but are also 2 m to 2.4 m across the shore rise profile off shore, while closure depth increases to -15.7 m. Based on the critical mass and closure depth calculations in Figure ES-3, we conclude that the HDD pipeline routes posed for Neodren™ intakes at the RBGS provide a three-fold margin of safety against exposure by extreme event waves, slightly less than found for the ESGS site but still adequate. The RBGS diffuser site as specified in the Master Plan is inside closure depth, (at a depth of between -6 m and -9 m MSL), but extending the riser pipes on the ARCADIS design diffusers by 2 ft. should provide adequate free-board to prevent burial of the duckbill nozzles.

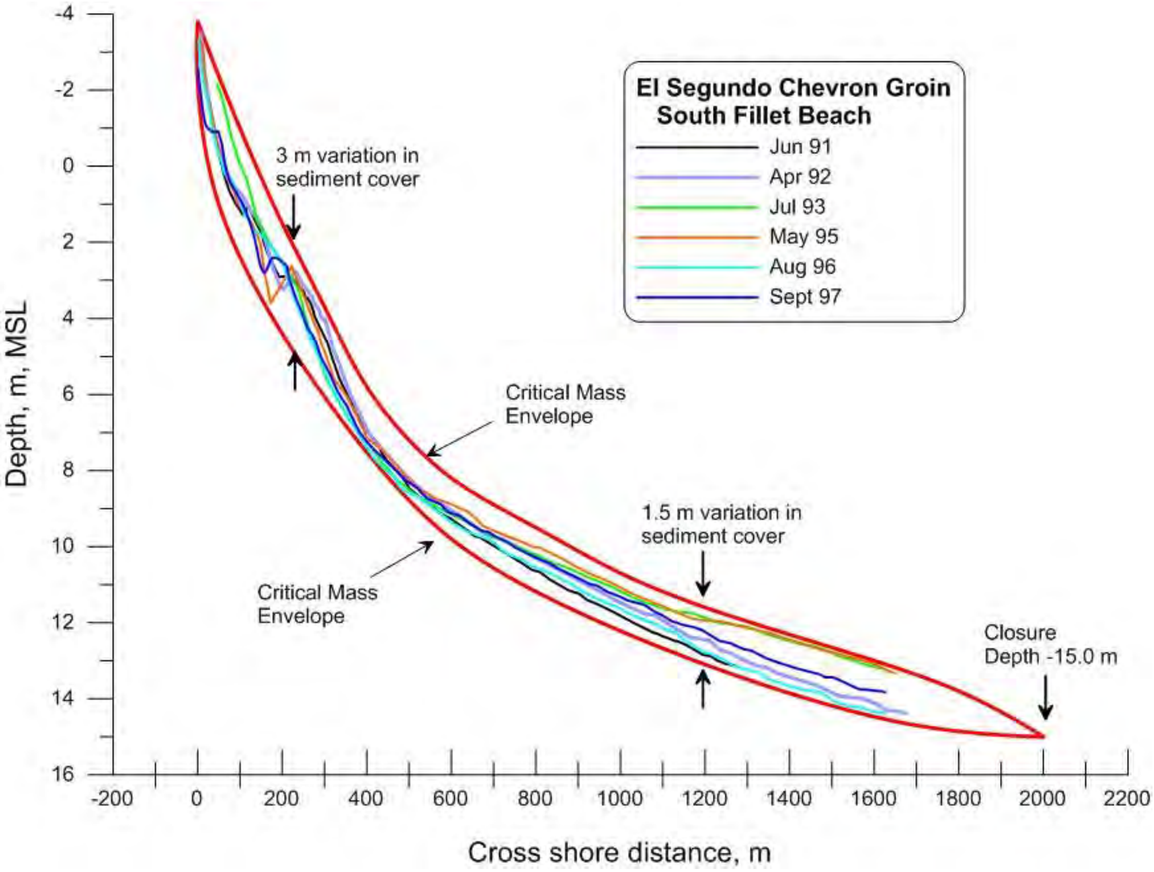


Figure ES-1: Critical mass envelope at historic Chevron Groin survey range, El Segundo, calculated by the calibrated CEM sediment budget based on the 20.6-year period of record CDIP monitored waves, Calleguas, Balona and Malibu Creek sediment flux APPNEDIX-A, and beach disposal of dredge material from the Marina Del Rey Dredging Project, (USACE, 1994 Measured beach profiles from Gadd et al., 2009. Closure depth = -15 m MSL calculated from equation (7). Critical mass volume = 2,941 m^3 per meter of shoreline calculated from equation (13).

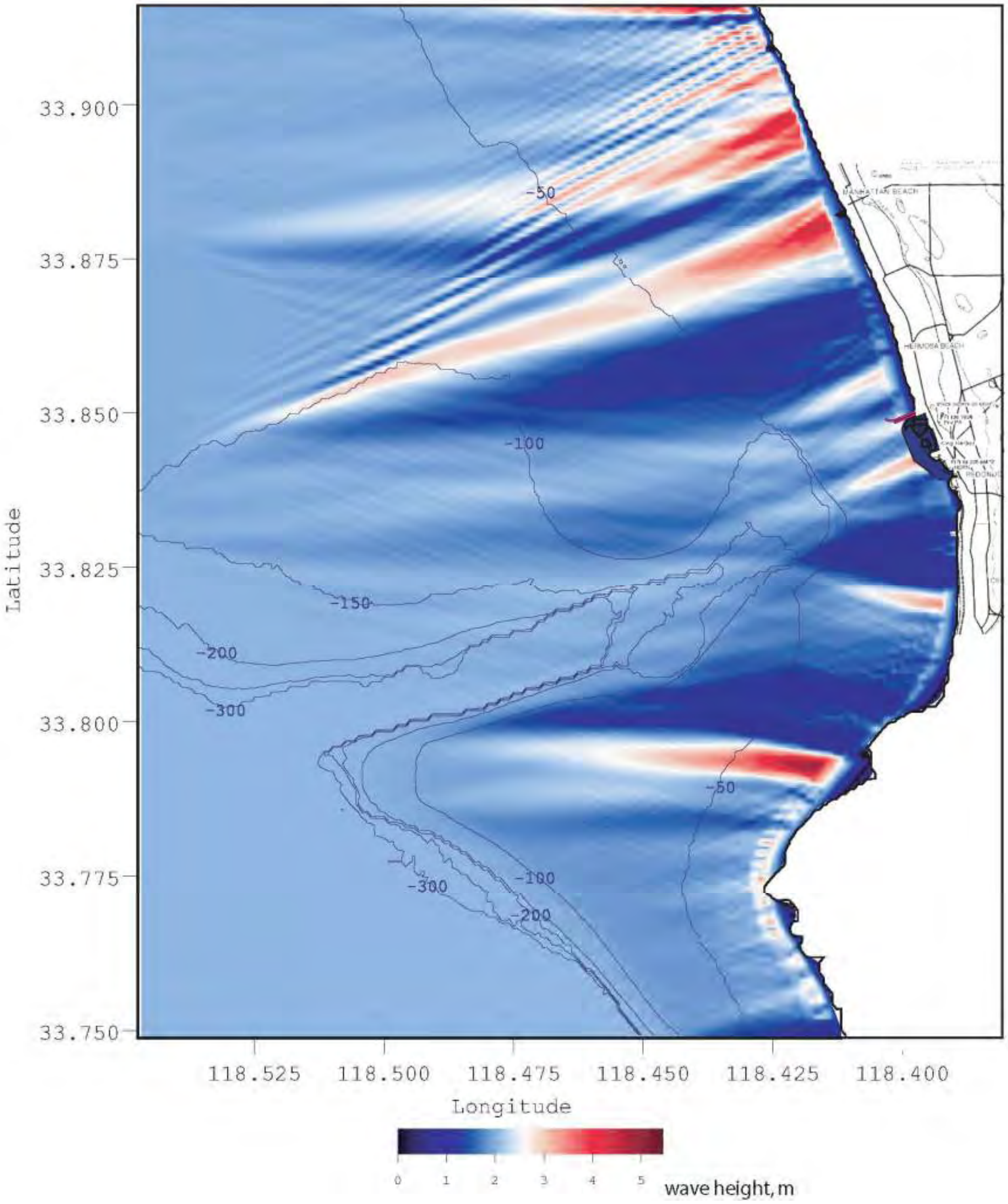


Figure ES-2: Refraction/diffraction pattern in the neighborhood of the RBGS and ESGS sites for the proposed West Basin Municipal Water District Sea Water Desalination Project. Note the large wave shadow in the region between the Redondo King Harbor and the Chevron Groin. Refraction/diffraction calculations based on deep water wave heights = 2.0 m and periods of 15 sec during the 13 January 1993 storm.

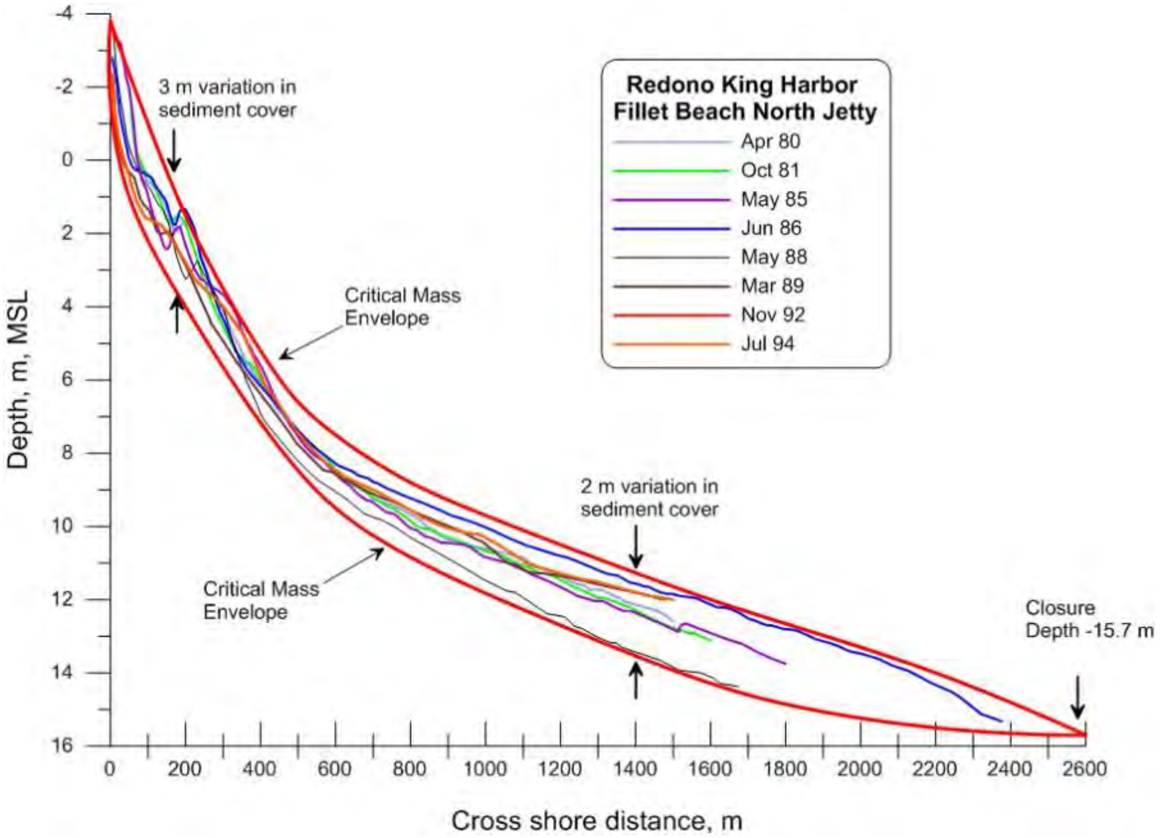


Figure ES-3: Critical mass envelope at historic north fillet beach Redon King Harbor, Redondo Beach, CA, calculated by the calibrated CEM sediment budget for the 20.6-year period of record (1980-2000) based on CDIP monitored waves, Calleguas, Balona and Malibu Creek sediment flux APPNEDIX-A, and beach disposal of dredge material from the Marina Del Rey Dredging Project, (USACE, 1994). Measured beach profiles from Gadd et al., 2009 and USACE, 1994. Closure depth = -15.7m MSL calculated from equation (7). Critical mass volume = 3,920 m^3 per meter of shoreline calculated from equation (13).

Coastal Processes and Seafloor Stability Analysis of Shallow Sub-Seabed Intake Systems for the West Basin Municipal Water District Sea Water Desalination Project

Prepared by:
Scott A. Jenkins, Ph. D.

1) Introduction:

The West Basin Municipal Water District (District) proposes to build and operate a seawater reverse osmosis (SWRO) desalination plant in the southern portion of Santa Monica Bay, which would supplement the District's water resources. Two candidate sites were considered in Santa Monica Bay. One utilizes existing infrastructure on the site of the AES Redondo Beach Generating Station (RBGS), Figure 1.1. This site was used for the West Basin Municipal Water District's ocean water desalination demonstration facility (DDF), and dilution modeling conducted for that project by Jenkins and Wasyl (2008) has shown that it is naturally endowed with adequate ambient mixing and advection for rather sizable prototype RO production facilities. The second candidate site in Santa Monica Bay considered is the El Segundo Generating Station (ESGS), Figure 1.1.

This report considers two *Phases* of project build-out at either site involving nominal product water plant production of 20 mgd, and 60 mgd:

Phase I: 20 mgd capacity plant, approximately 40 mgd of seawater would be drawn through four separate intake screens from the nearshore waters and pumped into the desalination facility. Since the SWRO process extracts typically 50% of the water as fresh water, a maximum of 20 mgd of RO-reject (brine) would be discharged into the Pacific Ocean through five separate diffuser ports, at a salinity of 67 ppt (parts per thousand); where the ocean has an average ambient salinity of 33.5 ppt).

Phase II: 60 mgd capacity plant, approximately 120 mgd of seawater would be drawn through four separate intake screens from the nearshore waters and a maximum of 60 mgd of brine would be discharged into the Pacific Ocean through five separate diffuser ports, at a salinity of 67 ppt.

Currently, two desalination plant location alternatives are being considered in the southwest sector of Santa Monica Bay. These are designated as:

RBGS: (AES Redondo Beach Generating Station), the more southerly site (Figure 1.1). Redondo Beach end of tunnel coordinates in UTM (m) are; Intake tunnel: 11S 370,140 m E - 3,746,387 m N; Discharge tunnel: 11S 370,193 m E - 3,746,362 m N.

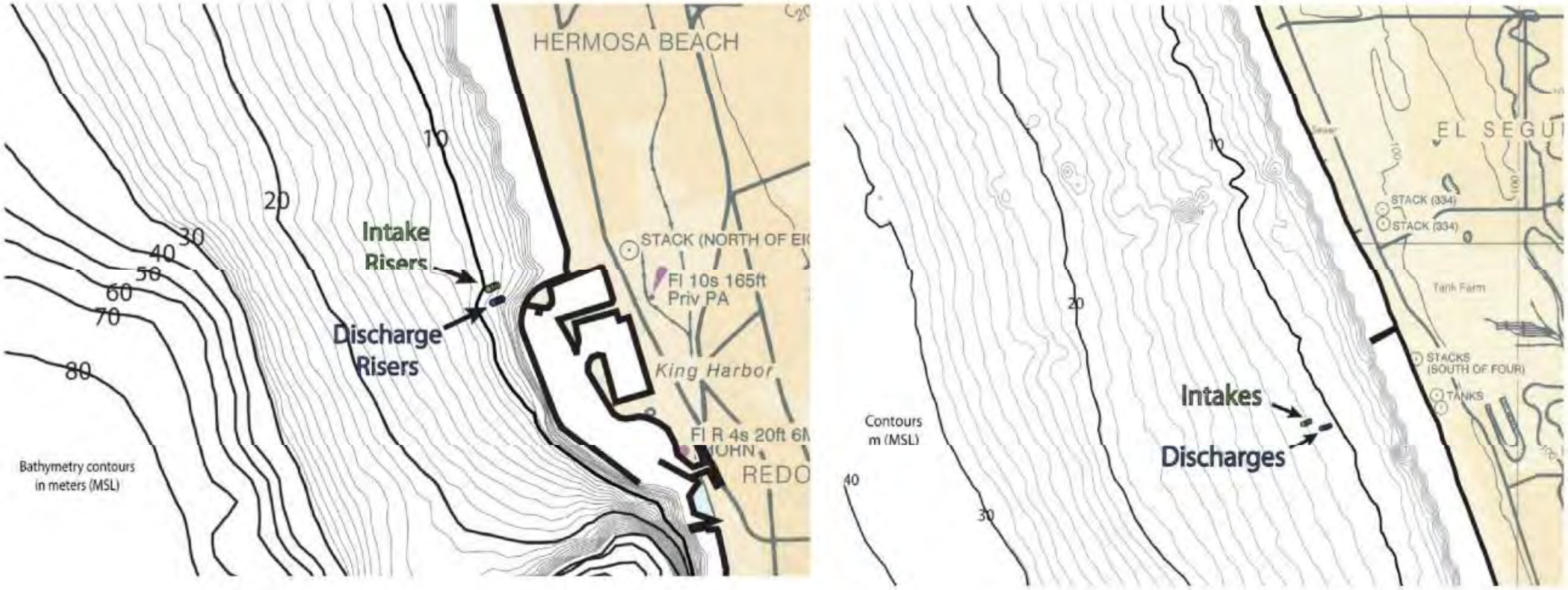


Figure 1.1 Coastal & Oceanographic Site Comparisons:

Redondo Beach:	El Segundo:
Discharges at: -6 m to -9m MSL	Discharges at: -10 m to -11m MSL
Intakes at: -8 m to -10m MSL	Intakes at: -10.5 m to -11.5 m MSL
Closure Depth: -15.7 m MSL	Closure Depth: -15 m MSL
Bottom Sediment: 76 % Sand, 24% Fines	Bottom Sediment: 82 % Sand, 18% Fines
Hard Bottom Habitat: North Harbor Jetty	Hard Bottom Habitat: Chevron Jetty
Terminal Littoral Transport Regime	Open-Ended Littoral Transport Regime
Submarine Canyon Ecology	Sandy Bottom Benthic Ecology
Paleo-Lagoonal Shoreline	Coastal Beach/Bluff Shoreline

ESGS: (NRG El Segundo Generating Station), the more northerly site (Figure 1.1). El Segundo end of tunnel coordinates in UTM (m) are: Intake tunnel: 11S 367,576 m E - 3,752,769 m N; Discharge tunnel: 11S 367,720 m E – 3,752,820 m N

Based on recent experience with the permitting of desalination projects, the most controversial and problematic aspect has been the choice intake technology. The impacts associated with entrainment and impingement of marine life by open ocean intakes has led to a search of technical options that minimize those marine life impacts and which are best suited to the site constraints and oceanographic conditions of a particular project.

Therefore we begin with a review of available sub-seabed intake technology alternatives, in order to select the technology that can be best adapted to the RBGS and ESGS sites.

2) Literature Review of Shallow Sub-Seabed Intake Technology

There are three types of shallow sub-seabed intake technologies: subsurface infiltration galleries (SIG), beach infiltration galleries (BIG); and advanced horizontal well technology (e.g. Neodren™ system). Here we review only the relevant literature on the SIG and BIG systems, as the Neodren™ system is considered in great detail elsewhere in the EIR documentation. We discover that the prior art on SIG's and BIG's is very limited on prototypic production scales in ocean environments; and has been performed at sites where the oceanographic conditions and coastal processes are very dissimilar to what is found at RBGS and ESGS. Only a very small amount of the literature on this prior art is found in peer-reviewed journals or technical reports from resource agencies. Most of it is found in conference proceedings where the objectivity and efficacy of the information can be questionable. Irrespective of the quality of the literature, it is clear that reportedly successful sub-seabed intake technologies (SIG in particular) have only been demonstrated in fetch-limited environments, those without open ocean exposure to distant swell waves. Consequently, vulnerability to wave erosion and vigorous littoral sediment transport has not been a factor. This is in sharp contrast to the RBGS and ESGS environment where long-period, high-energy waves from the Gulf of Alaska storms in winter, and from the Mexican tropical hurricanes and southern hemisphere storms in summer, have historically resulted frequent periods of high sea-states and massive beach and nearshore erosion, (USACE, 1993, Inman and Jenkins, 2004, a, b,& c). We identify the existing data bases that are required for assessment of the transferability of lessons learned from previous demonstrations of alternative intake technologies in clam-water environments to the high energy environment of RBGS and ESGS.

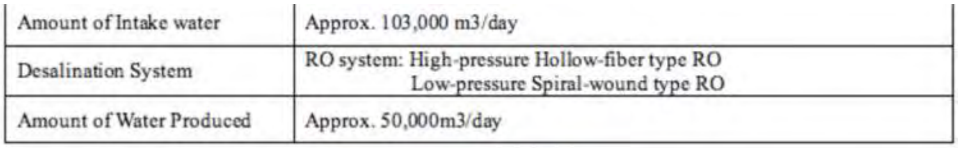
2.2) Subsurface Infiltration Gallery (SIG), Fukuoka, Japan: There is only one example in the world of a *Sub-surface (seabed) Infiltration Gallery* being used on prototypic production scale as an intake for an operational desalination facility. That example is at the Uminonakamichi Nata Seawater Desalination Center on the island of Kyushu in Fukuoka, Japan (referred to herein as the *Fukuoka Seabed Infiltration Gallery*

Intake). The Fukuoka Seabed Infiltration Gallery Intake was designed and constructed by the Obayashi Corporation, and is considered a proprietary intake system by that company. The infiltration gallery has an intake capacity of 27 mgd to meet Uminonakamichi Nata Seawater Desalination Center's 13 mgd production capacity. Although it has been in continuous use since beginning production in June 2005, it has not operated at full capacity. It consists of infiltration branch pipe segments connected to an infiltration main (Figure 2.1). The 64.2 m wide (210 ft.), 313.6 m (1,030 ft.) long gallery consists of a non-metallic header-lateral arrangement with 0.6 m (2 ft.) diameter laterals (Figure 2.2) attached to two 1.8 m (6 ft.) diameter headers. The headers are attached to a central concrete collection vault from which a single 1.58 m (5.2 ft.) pipe conveys the water to the plant. The gallery is located 650 m (2,132 ft.) offshore at a water depth of 11.5 m (38 ft.). The intake pipes themselves are located about 3.9 m (12.8 ft.) below the seabed, under 1.5 m (5 ft.) of graded sand, 0.3 m (1 ft.) of graded gravel and 2.1m (7 ft.) of coarse gravel, (Kawaguchi, A., 2007; Pankratz, 2014)

At full production, the gallery operates at a rate of 5.1m/d (0.087 gpm/ft.^{2}). The infiltration branch pipe segments are merely examples of a "*French Drain*" (buried pipes with holes along the pipe lengths), but in Japan, these are referred to as "*Toyo Drains*". The gallery is installed below layers of imported sand and gravel (engineered fill) in a pit excavated to about 13 ft. below the ambient seabed. The excavated area of seabed is approximately 215,280 square feet. The infiltrated water flows from the branch pipes to the infiltration main, and is then conveyed to the onshore intake tank (located below ground) by a transmission pipe. Water collected in the intake tank is then pumped to the desalination center. The infiltration system flows using the difference between the sea level and the water level in the intake tank and does not require pumping (other than the pumps for the intake tank).

The Fukuoka Seabed Infiltration Gallery Intake began testing and start-up in 2005 and full scale operation in 2006. A number of Japanese newspaper articles were published the first year after full scale operation proclaiming unqualified success for the Fukuoka Seabed Infiltration Gallery Intake; but since that time industry professionals who have visited the site have privately expressed concerns the Toyo Drains are clogging and intake water production is declining, (Kawaguchi, 2007).

Because the Obayashi Corporation regards its Seabed Infiltration Gallery Intake as a proprietary technology, it has been less than forthcoming on technical information; and has released very few details on maintenance issues and operational sustainability. However, since the Kawaguchi visit in 2007, there has been a recent update of on-the-ground intelligence of the Fukuoka Seabed Infiltration Gallery Intake, (Pankratz, 2014). Pankratz, reported that operations manager, (Taketo Tanaka), confirmed that virtually no maintenance of the infiltration gallery has been required, and that the head loss across the system remains almost unchanged from the day the plant was commissioned. The feed water has never been chlorinated, and neither the sand bed nor the piping network has required any cleaning. Divers inspect the surface of the seabed above the gallery one or two times per year, and have noted that the scouring action of the sea currents appears to keep the surface of the sand relatively clean. Operations manager, (Taketo Tanaka) also claims here has never been evidence of an accumulation of fish eggs or larvae on the seabed, and the low head loss across the system indicates a lack of biofouling, although the gallery piping has never been inspected, either by divers or cameras.



Amount of Intake water	Approx. 103,000 m3/day
Desalination System	RO system: High-pressure Hollow-fiber type RO Low-pressure Spiral-wound type RO
Amount of Water Produced	Approx. 50,000m3/day

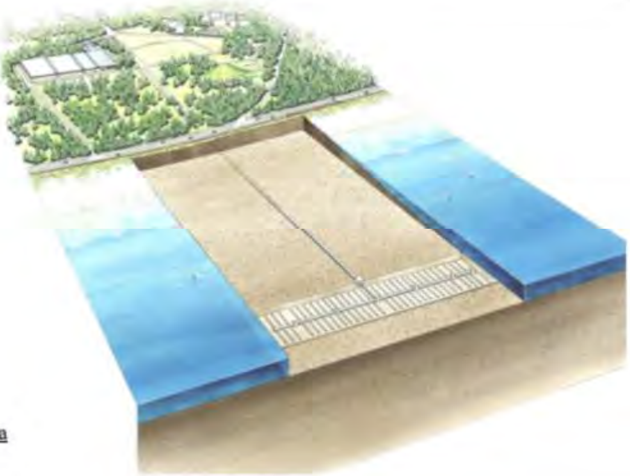


Fig.1 View from Sea

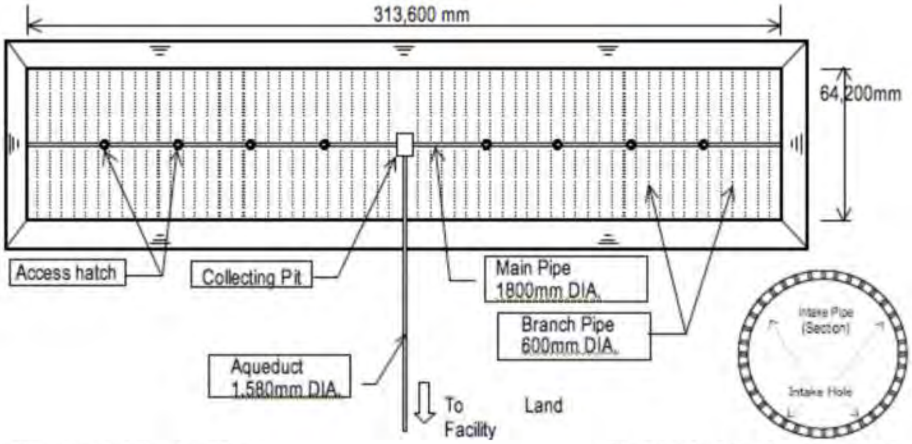


Fig.2 Intake Filtration (Plan)

Fig.3 Intake Filtration Pipe (Section)

Figure 2.1: The Obayashi SIG Sub-surface (seabed) Infiltration Gallery as deployed at the Uminonakamichi Nata Seawater Desalination Center on the island of Kyushu in Fukuoka, Japan (referred to herein as the *Fukuoka Seabed Infiltration Gallery Intake*).

Figure 2.2: Section of 0.6 m diameter perforated lateral branch pipe used in the Fukuoka Seabed Infiltration Gallery Intake, referred to as "*Toyo Drains*". The infiltration holes are large in comparison to the micron-scale infiltration holes of the Neodren horizontal well technology.

Pankratz, (2014) concludes his recent visit did not add to the hard data available on the Fukuoka intake, or infiltration galleries in general, but it did confirm that the system has performed as it was intended requiring virtually no maintenance and providing a reliable and consistent volume of almost particulate-free seawater. However some operating data has been previously published (Missimer, et. al., 2013). Monitoring of the Fukuoka feed-water pumped from the gallery shows a very significant improvement in water quality with the SDI being reduced from background levels exceeding 10 to consistently below 2.5 to the beginning of 2010 and mostly below 2.0 thereafter (Figure 2.3).

Another seabed infiltration gallery has been designed and constructed the City of Long Beach, CA, and installed inside the breakwater system of the Long Beach Harbor (Wang, et. al., 2007;). This system was in the testing phase for a significant time period with infiltration rates ranging from 2.9 to 5.8 m/d (Allen, et. al., 2008). This testing revealed substantial reduction in turbidity, SDI_{15}, total dissolved carbon (TDC), and heterotrophic total plate counts (mHPCs) with initially some reduction in concentrations of DOC and AOC before the system was shot down due to filter clogging (Missimer, et. al.,2013).

Fukuoka is located on the north-west side of the island of Kyushu Japan on the Korea Straits that connects the East China Sea to the southwest with Sea of Japan to the northeast. Ocean waves at the site of the Fukuoka Seabed Infiltration Gallery Intake are fetch limited (not exposed to long-period, open ocean swell waves[1]) due to the narrows of the Korea Straits; and the coastal oceanography and sediment transport is dominated by the Tsushima Warm Current (TWC) flowing through the Korea Straits into the semi-enclosed Sea of Japan. The fetch limited offshore environment off Fukuoka promotes long periods of calm sea states, which diminish the rigors of offshore construction of a SIG in 11.5 m of local water depth. These calm sea-states allow the 10 ft. deep dredged hole in which the SIG piping is installed to be maintained without wave-induced scour and erosion collapsing the hole or infilling it before piping installation is complete, and also allows the engineered fill to be subsequently placed without loss of the fill material. The calm sea-states also maximize the half-life of the engineered fill after placement because wave erosion is minimal. Such fortuitous and persistent calm sea-sates do not exist at WBDF, where calm sea-states seldom persist for any significant length of time, (Inman and Jenks, 2004 a & b; see Section 6 for more detail).

There are also climatological differences that are relevant to the post construction sustainability of a SIG. The RBGS and ESGS sites are subjected to deep El Nino cycles, with long periods of dry conditions, followed by powerful winter-time El-Nino storms. The El Nino winter storms cause massive erosion and sediment delivery from the semi-arid (and highly erodible) watershed (Inman and Jenkins, 1999, 2004c).

Fukuoka on the other hand has a humid subtropical climate with hot humid summers and relatively mild winters. Fukuoka's weather, as well as the sediment yield of the regional watersheds, is controlled by the Korean Monsoon that produces on average about 1,600 mm (63 in) of precipitation per year, with a stretch of more intense precipitation between the months of June and September. These high rainfall amounts falling on the high relief topography surrounding Fukuoka, result high inter-annual yields of sediment flux into the local coastal ocean, particularly fluxes of fine-grained sediments derived from the volcanic clays that predominate in the regional watersheds.

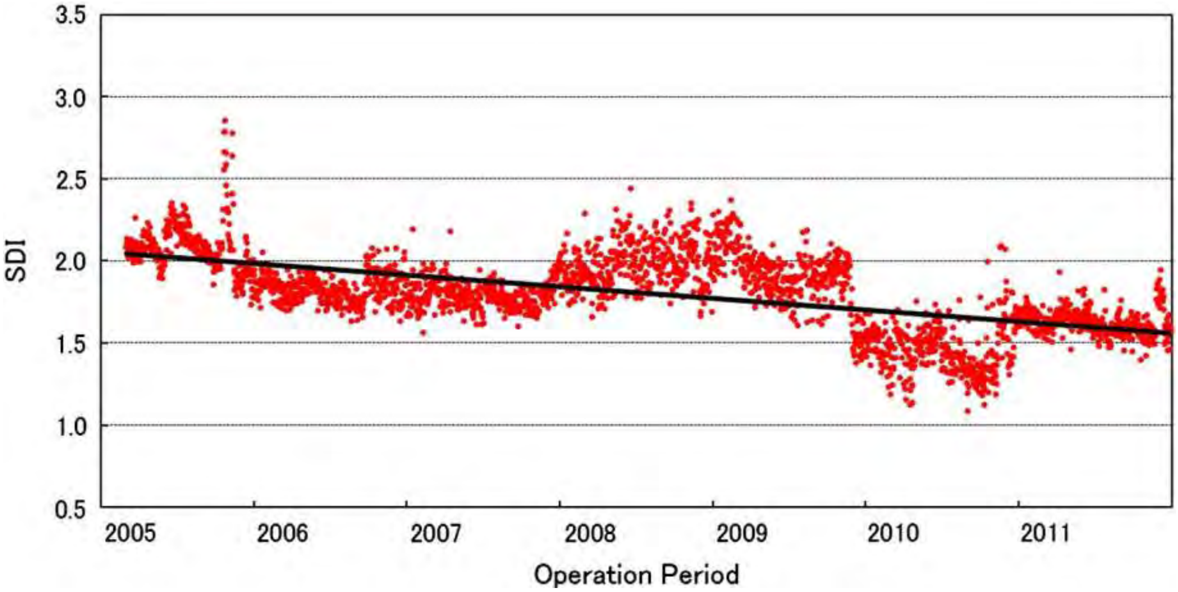


Figure 2.3: Long-term variation in the silt SDI of water coming from the seabed gallery at Fukuoka, Japan. The water quality has been consistently good and has improved during the life of the facility.

The formation of the TWC-influenced sediment deposits shifted towards shallower water regions during postglacial sea-level rise, (Nishida and Ikehara, 2006); and this long-term shift in combination with the high seasonal fluxes of fine-grained sediments from the local watersheds has produced a highly dissimilar set of conditions relative to the RBGS & ESGS sites, (see Section 6 for more detail on RBGS and ESGS comparisons).

Conditions at the Long Beach experimental SIG are climatologically, geomorphically and oceanographically quite similar to the RBGS & ESGS sites due to the close proximity of one to the other; with one major exception. The Long Beach experimental SIG is located inside the breakwater system of the Long Beach/Los Angeles Harbor, where it is completely sheltered from wave exposure. Because of this wave sheltering, the Long Beach experimental SIG was built on the bar-berm section of the beach profile, allowing shoreline access of the construction equipment for excavation of the gallery and placement of the piping. This is profoundly different from the wave conditions and construction environment at the RBGS and ESGS, which lies on the exposed open coast of the RBGS and ESGS sites. At both the RBGS and ESGS sites a SIG will have to be built far offshore of the beach to avoid wave erosion, in rough water conditions with exposure to both local and distant open ocean storm waves.

This fundamental siting difference makes constructability of a SIG in the waters offshore of the RBGS and ESGS sites significantly more challenging than what was experienced at the Long Beach experimental SIG, and potentially problematic (see Section 6 for more detail on RBGS and ESGS comparisons).

To deal with the problems of constructing a SIG along exposed high energy coastlines, Dr. Robert Bittner of the Independent Science and Technology Advisory Panel (ISTAP) appointed by the California Coastal Commission suggested looking at installing the SIG drain and piping system in precast concrete boxes and then excavating a trench offshore with a dredge, followed by dropping precast concrete boxes into the trench. This is a very intriguing idea. The closest proxy to this idea is probably the precast concrete boxes used to build the tactical harbor breakwater referred to as *Mulberry* for the Normandy Invasion. Figure 2.4 shows a construction photo of some of the precast concrete boxes used in Mulberry in a shipyard in the south of England prior to the Normandy Invasion. From the scale of ladders shown in the photo, the Mulberry concrete box modules appear to be roughly comparable in size to what Dr. Bittner is proposing for a SIG to be installed at the Huntington Beach Desalination Facility, (HBDF), a site very similar to ESGS in terms of wave exposure. Figure 2.5 shows the Mulberry concrete box modules in a neatly deployed detached breakwater system off Normandy, 5 days after D-Day, creating a tactical harbor known as *Port Winston*. Figures 2.6 & 2.7 show how the Mulberry concrete boxes look 60 years later resting on the seabed off Normandy France. It is apparent that the orderly arrangement of these boxes has been completely disrupted by the ensuing English Channel storms, and many of the boxes have also been tilted by the action of non-uniform subsidence and burial. There is also evidence of pronounced scour around some of the boxes that have subsided and tilted (Figure 2.7).

From these examples off Normandy, the primary concern with the concrete boxed modular SIG is how to keep it level and well-ordered over time, regardless of whether it is set in a trench or is simply lying proud on the seabed. Non-uniform subsidence over time can arise from a variety of factors, including cyclical liquefaction and scour by the shoaling wave pressure and velocity fields, non-uniformities in the seabed sediment stratigraphy, and large scale bedforms that apply uneven dispersive (granular) pressures around the sides of the boxes, as found around the ship wreck off Normandy in Figure 2.8. The scour, liquefaction and bedform factors can be largely remediated by moving the SIG offshore into deeper water beyond influences of shoaling wave pressure and motion. Offshore of RBGS and ESGS, wave effects should vanish at water depths of between 70 ft. and 90 ft. given the wave periods typical of the highest 13 % of incident waves. At those depths, it would be difficult to dredge a trench, but there seems to be no reason why the concrete boxed modular SIG couldn’t simply rest proud on the seafloor, where it would create a very substantial artificial reef to attract sea life. However, there are several

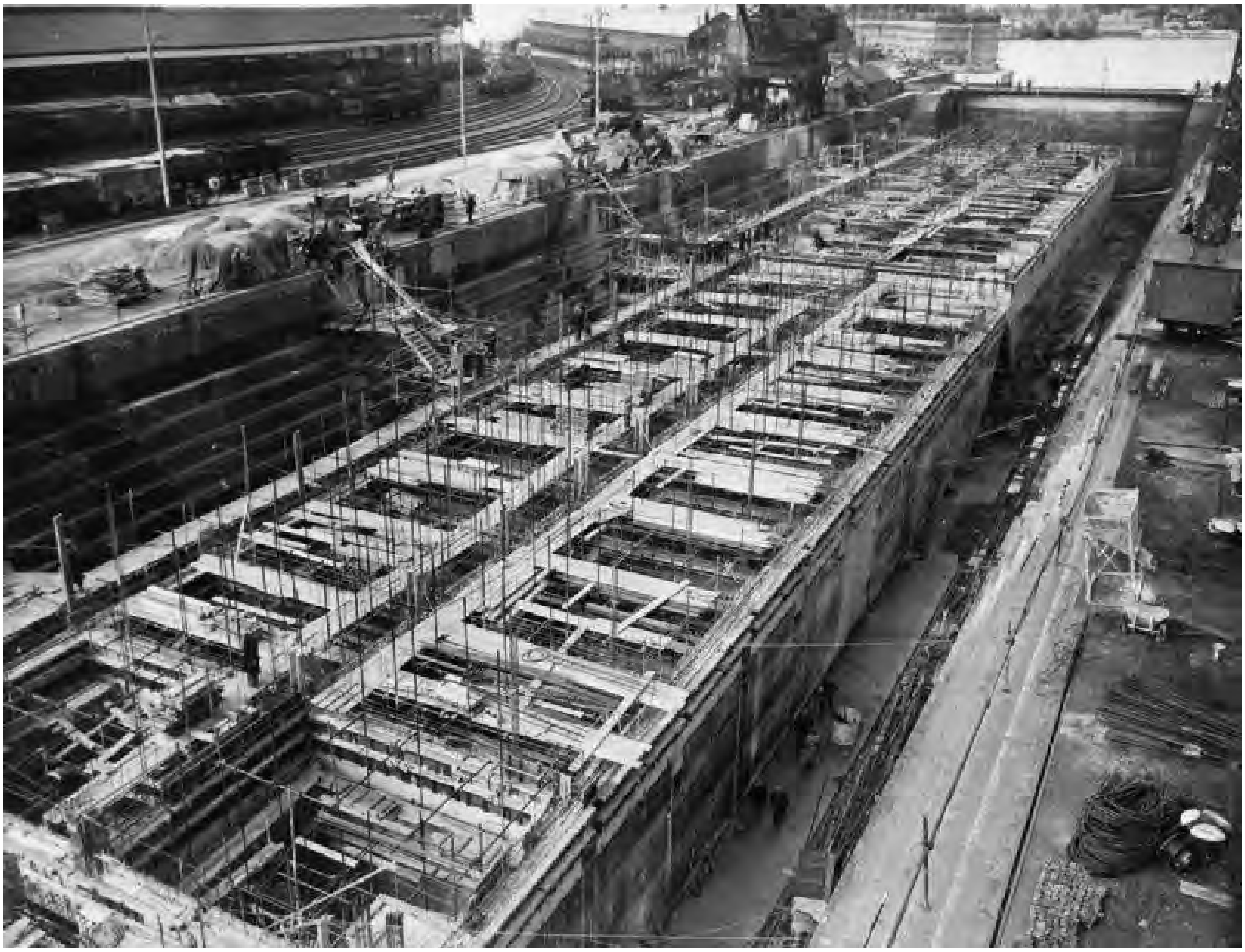


Figure 2.4: Construction of precast concrete boxes used in Mulberry during the Normandy Invasion.

Figure 2.5: Deployment of the Mulberry modules to form a detached breakwater system off Normandy France on D-Day plus 5.

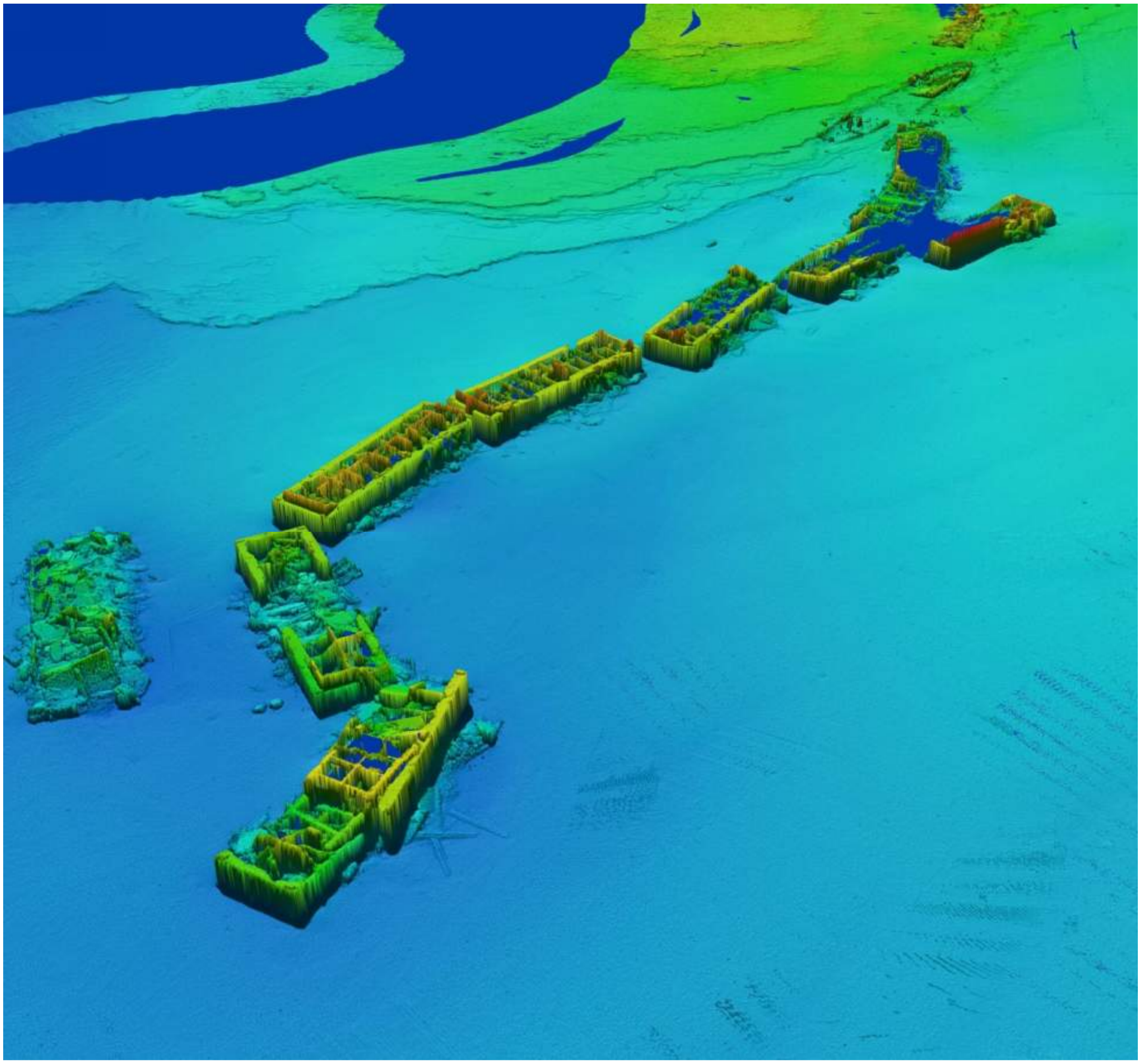


Figure 2.6: Multi-beam 3-dimensional sonar imagery of the Mulberry concrete box modules (upper) sunk off Normandy France in 2004. Figure courtesy of Prof. Larry Meyer, University of New Hampshire.

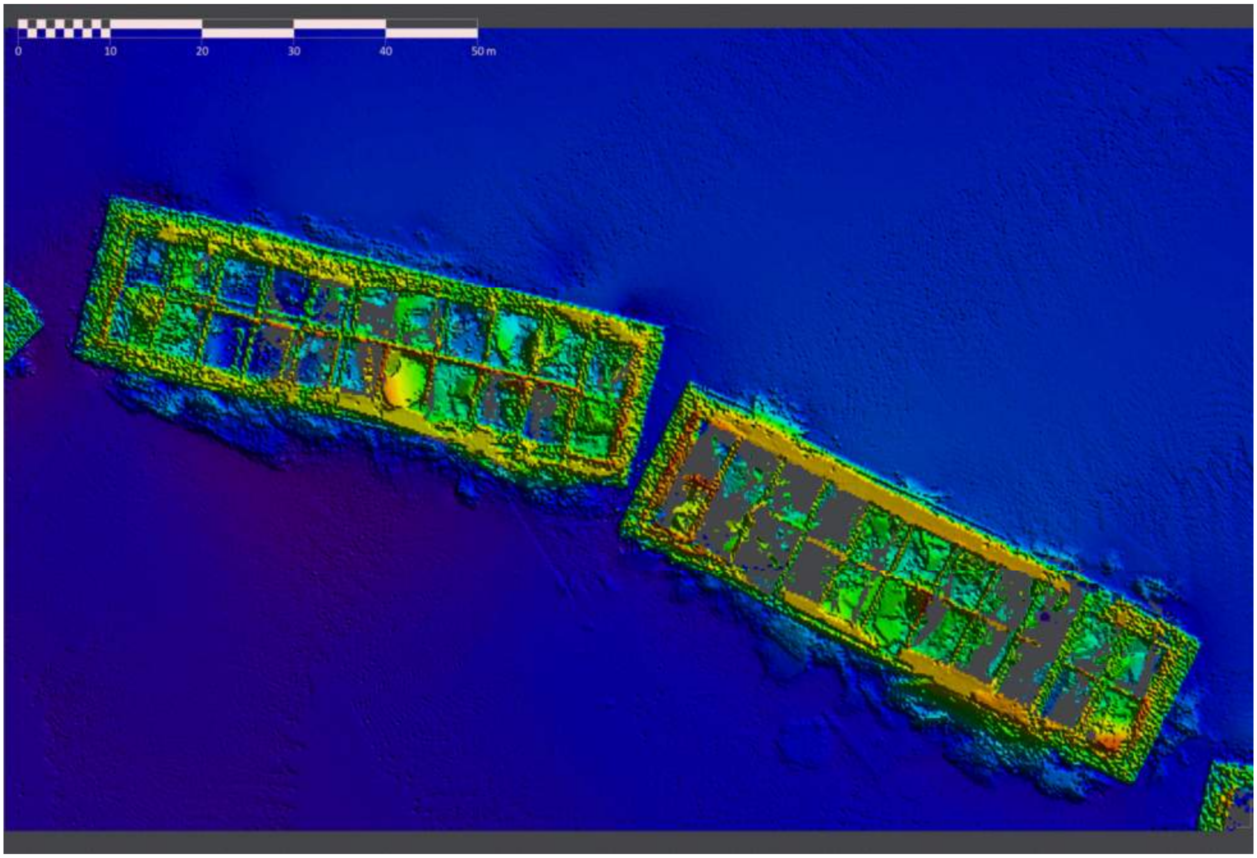


Figure 2.7: High-resolution multi-beam sonar imagery of two of the Mulberry concrete box modules sunk off Normandy France in 2004. Figure courtesy of Prof. Larry Meyer, University of New Hampshire.

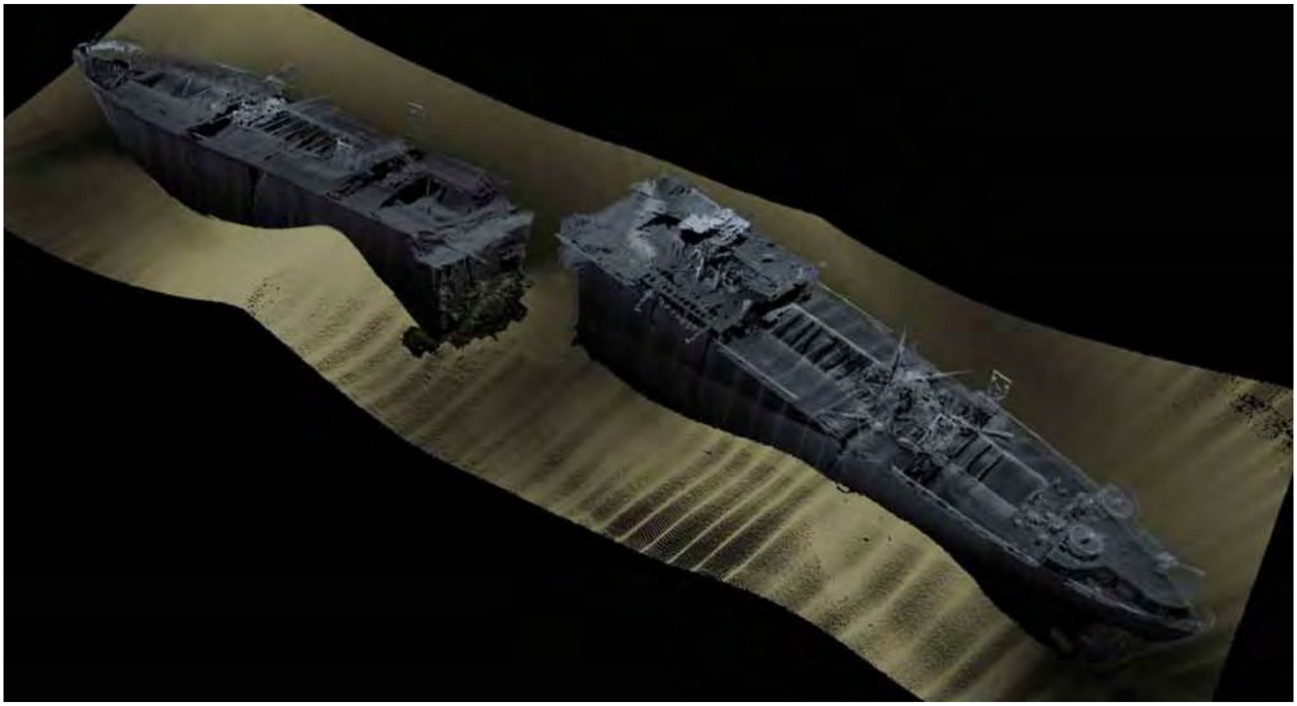


Figure 2.8: High-resolution multi-beam sonar imagery of sand waves around a ship wreck off Normandy France in 2004. Figure courtesy of Prof. Larry Meyer, University of New Hampshire.

down-sides to the deep water solution. First, it will require a longer conveyance pipeline to the shore-side desalination facilities, a cost increase factor. Second, the seabed at water depths of between 70 ft. and 90 ft. is typically comprised of gray or green muds, indicating that the absence of wave motion allows for fine sediment deposition of washload from river floods which could eventually put a capping layer of mud on top of the engineered fill that was placed in the SIG box modules. That would reduce infiltration rates to the branch pipe network and degrade SIG source water production rates. Finally, the attraction of marine life to the SIG box modules by the artificial reef effect will ultimately lead to benthic organisms recruiting to and living in the engineered fill; and because that fill is confined by the boxes, its organic content will increase over time, ultimately reducing infiltration rates and degrading source water quality produced by the SIG. So, while an intriguing idea, it is not clear whether or not the precast concrete box modular SIG will actually reduce construction costs relative to the fully buried SIG concept built off a temporary pier.

Seabed infiltration galleries (SIG) and other shallow subsurface intakes are relatively innocuous. They are favored by environmental and permitting agencies for their perceived benefits in avoiding entrainment/impingement impacts, although no peer-reviewed studies have been done to definitively prove the minimizing effects on marine life (Foster, et. al., 2012) They are also less vulnerable to upsets from sporadic jellyfish runs and red tide occurrences, which could otherwise upset desalination plant operations, (Pankratz, 2014)

In summary, the drawbacks to SIG designs are that their productivity and sustained reliability is highly site specific and determined by seabed sediment characteristics, underlying site geology and the wave and tidal activity. The construction of a SIG can have significant water quality and marine life impacts due to the need to dredge and remove a large section of ocean bottom habitat, obliterating the benthic communities of about 40 acres of seabed in the case of the RBGS & ESGS sites. Operation of the SIG could also result in marine life impacts due to periodic maintenance activities that disrupt benthic habitat and produce turbidity in the water column, (e.g. activities such as seabed raking, spot dredging and fill replacement). And, even when hydrologic conditions are favorable, the costs of a large offshore construction project may prove infeasible for many, especially smaller, projects, (Pankratz, 2014).

Large-scale seabed infiltration galleries can be technically complex to construct. The technical complexity of a SIG is compounded during long-term operation by the difficulty to adequately clean the laterals and distribution piping when they become partially clogged. All well types require periodic maintenance and cleaning which can be easily accomplished in conventional vertical wells, but can be quite complex for a SIG because of its long distance from the shoreline, particularly at RBGS & ESGS where a SIG must be sited far offshore to avoid wave erosion (see Section 6 for more detail). In offshore locations where the bottom sediment is unconsolidated, (as is the case offshore of RBGS & ESGS), construction requires the use of sheet piling. The handling and placement of large sheet pile sections in water depths on the order of 12 m would be extremely challenging in the high energy sea-states which regularly occur offshore of RBGS & ESGS(see Section 6 for more detail).

2.2) Beach Infiltration Gallery (BIG), Long Beach & Huntington Beach:

When a SIG is moved close to shore or inside the surf zone, it is referred to as a B*each Infiltration Gallery* (BIG). A beach infiltration gallery has been designed and constructed by the City of Long Beach, CA, and installed inside the breakwater system of the Long Beach Harbor (Wang, et. al., 2007). This system was in the testing phase for a significant time period with infiltration rates ranging from 2.9 to 5.8 m^3/d (Allen, et. al., 2008). This testing revealed substantial reduction in turbidity, SDI_{15}, total dissolved carbon (TDC), and heterotrophic total plate counts (mHPCs) with initially some reduction in concentrations of DOC and AOC before the system was shut down due to filter clogging (Missimer, et. al.,2013).

Recently, the Independent Science and Technology Advisory Panel (ISTAP) appointed by the California Coastal Commission considered several coastal processes and construction aspects for implementing BIG intake technology at the Huntington Beach Desalination Facility (HBDF). Like the ESGS and the RBGS sites, the HBDF is also sited on an exposed high energy coast with very active beach and shoreline variability. In this regard, the ISTAP addressed several specific questions:

> *"What are the potential shoreline stability impacts on a Beach Infiltration Gallery (BIG)? How much vertical movement of the sand level and horizontal movement of the surfzone could be anticipated as a consequence of seasonal and episodic shifts in the beach profile?"*

Using the Huntington Beach Desalination Facility (HBDF) as a surrogate to answer this question, Figures 2.9 and 2.10 show the measured beach and shore-rise profiles at the SA-180 range line, (located 191 m south of the HBDF), that has been monitored by the U.S. Army Corps of Engineers, Los Angeles District, between October 1918 and January 1994, (USACE, 1994). This historically surveyed range line is in the approximate neighborhood of the optimal SIG site identified in Jenkins and Wasyl, 2014. The envelope of variability defined by these profiles (*critical mass envelope*) reveal the potential range of variability in the beach profiles as a consequence of seasonal and tidal effects and climate cycles such as El Nino Southern Oscillation (ENSO), as well as episodic effects such as accretion/erosion waves propagating through the HBDF area from the beach nourishment activities associated with the *San Gabriel River to Newport Bay Erosion Control Project.* To a certain degree these profiles also reflect the effects of sea level rise over a 76 year period, but certainly not to the degree anticipated by 2050, when sea level is expected to rise another 4 and 24 inches (10.1 to 61 cm) by 2050, according to California State recommended projections. Figures 2.9 and 2.10 are both annotated for the tidal elevations of MHHW and MLLW according to the NOAA tide gage #941-0660 at the Port of Los Angeles. We find that the mean diurnal tidal range overlaid on the historic variability in the beach profiles leads immediately to a 240 m uncertainty in the on/offshore location of the shoreline at any given time. The surf zone begins at the shoreline and extends seaward to the wave breaking point, which from Hunt (1959), is a function of the local water depth: $h_b = H(x) / \gamma$ (1)

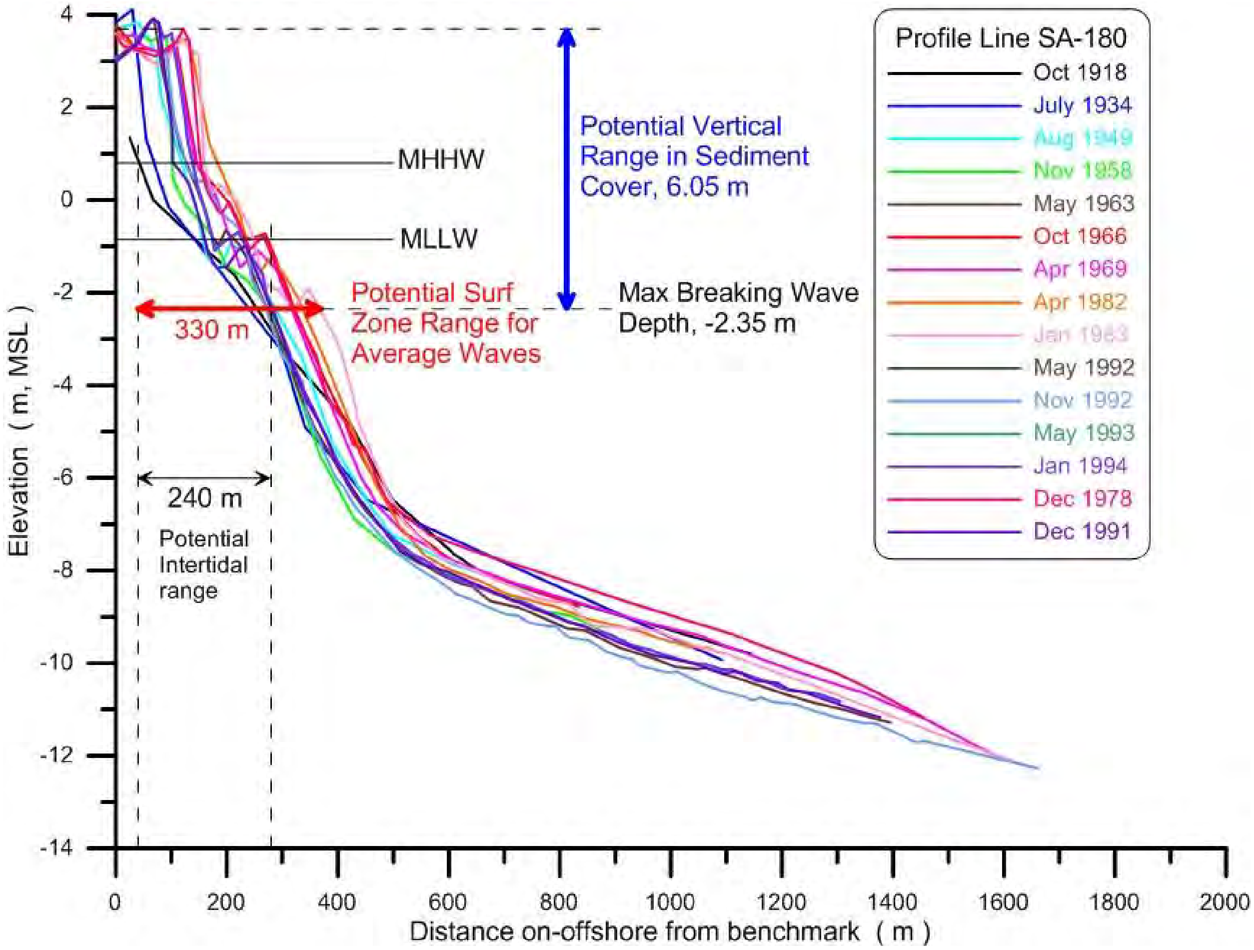


Figure 2.9: Measured beach and shore-rise profiles at the SA-180 range line, (located 191 m south of the HBDF), monitored by the U.S. Army Corps of Engineers, Los Angeles District, between October 1918 and January 1994. Data from USACE, (1994). Annotations are given for average wave climate with deep water incident wave heights in the range of 0.9 m and 1.2 m.

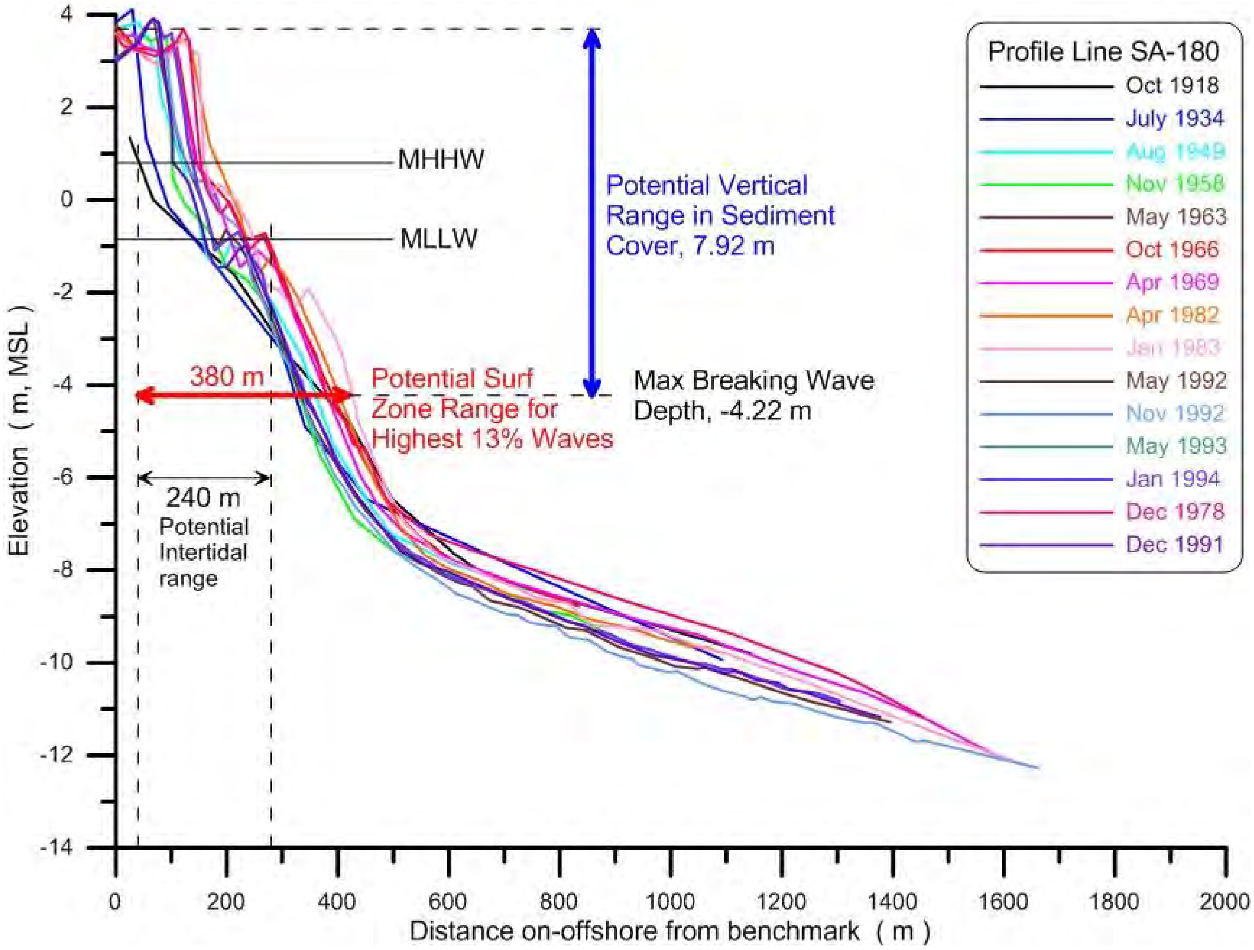


Figure 2.10: Measured beach and shore-rise profiles at the SA-180 range line, (located 191 m south of the HBDF), monitored by the U.S. Army Corps of Engineers, Los Angeles District, between October 1918 and January 1994. Data from USACE, (1994). Annotations are given for the highest 13 % waves with deep water incident wave heights in the range of 2.4 m to 2.7 m, with some waves reaching significant heights as large as 4 m to 6m.

Where h_b is the depth of wave breaking, γ is the breaker factor, and $H(x)$ is the shoaling wave height calculated from the incident wave height H_∞ and period T using Stokes theory:

$$H(x) = \frac{H_\infty}{\sqrt{2\sigma}}\left(\frac{g}{h(x)}\right)^{1/4} \quad and \quad \sigma = \frac{2\pi}{T} \tag{2}$$

For average waves, (with deep water incident wave heights in the range of 0.9 m to 1.2 m) the maximum depth of wave breaking calculates at -2.35 m MSL (Figure 1); and for the highest 13% waves (with deep water incident wave heights in the range of 2.4 m to 2.7 m) the maximum depth of wave breaking is -4.22 m MSL. This means that the on/off shore variability of the surf zone can be as much as 330 m between the most eroded beach profile and the most accreted profile under average wave climate conditions (Figure 2.9), and as much as 380 m for the highest 13% of incident waves (Figure 2.10). If we examine the vertical variation in the beach sand levels across these ranges of surf zone variability, we find as much as 6.05 m of vertical variation under average wave climate (Figure 2.9) and 7.92 m of vertical variation for the highest 13% of incident waves. This means that one would probably have to excavate as much as 8 m of sediment overburden to completely bury and level a Beach Infiltration Gallery in the surf zone. If one merely looks at the profiles in Figures 2.9 and 2.10 from afar, it is apparent that the profile envelope (*critical mass envelope*) is much steeper and thicker in the surf zone than offshore near closure depth where the SIG was optimally sited in Jenkins and Wasyl, (2014), indicating that the challenges of burying and leveling an infiltration gallery diminish as one goes further offshore. Ideally, a Beach Infiltration Gallery should be built when the beach and shore-rise profiles are in their most eroded state. This would lessen the likelihood of exposure of the BIG by future erosion. This opportune construction scheduling would most likely coincide with cessation of winter waves during an El Nino year.

One of the expected advantages of a BIG over a SIG is that construction costs could be reduced by moving closer to shore because a shorter temporary pier would be required for construction. However, mobilization, labor and time on-job are major cost factors. Moving the gallery closer to shore puts the construction work in a regime of higher waves and greater wave induced currents as a consequence of wave shoaling. As waves propagate into shallower water, they shoal and increase in height according to Equation (2); and eventually break once the water depth becomes roughly 5/4 the shoaling wave height. It is difficult to see how construction costs are reduced by moving shoreward into a more difficult construction environment. At offshore locations near closure depth, it is estimated there would be 13% loss in construction time due to high sea states that would cause excessive pendulation to crane operations from the temporary pier, or loss of engineered fill as a consequence of excessive water motion (Jenkins and Wasyl, 2014). That *down-time* number would undoubtedly increase to perhaps 18 % or 20 % if the preponderance of work is performed further inshore where sea states are higher. The reduced materials costs of a shorter construction pier must be weighed against loss of on-job time and perhaps heightened risk of component damage while trying to work in the higher states encountered near shore.

2.3) Applicability of Shallow Sub-Seabed Intakes to RBGS and ESGS Sites

In contrast to the sites where previous sub-surface intakes have been built for small-scale seawater desalination plants, (e.g., Fukuoka Japan, Long Beach Harbor, San Pedro del Pinatar, Aguilas, and Alicante, Spain, and Salina Cruz, Mexico), the RBGS and ESGS sites are located on the exposed open coast of the Southern California Bight, fully open to long period swells from the Gulf of Alaska winter storms; and next to one of the largest most active submarine canyons, the *Redondo Submarine Canyon*. This entire geologic province is an eroding collision coast with a major sediment sink for the Santa Monica Littoral Cell (Figure 2.11) located in the neighborhood of the project (*Redondo Submarine Canyon*). Sediment cover is highly variable due to turbidity current activity in this submarine canyon. The major drainage basins supplying sediment to this littoral cell are Calleguas, Malibu and Ballona Creeks which lie within and between structurally complex folds and thrust faults with appreciable vertical slip and overturned beds. These formations are predominantly Cenozoic sediments of Pliocene through Eocene age that are relatively unconsolidated and easily eroded. While these creeks provide locally marginal sediment cover for a SIG or BIG, that sediment cover is layered with lenses of silts and clays from the river wash loads that have persisted throughout the Holocene up to and including present time (Inman and Jenkins, 1999; Geosyntec, 2013). Although these watersheds are largely influenced by a semi-arid Mediterranean type climate, the periodic occurrence of El Nino floods throughout the last 6000 years of the Holocene have resulted in perpetual formations of new layers of silts and clays in the offshore sediment stratigraphy. This broad-scale and continuing geomorphic process is highly unfavorable for the future maintenance and sustainability of a SIG or BIG at the RBGS and ESGS sites, because each of these technologies rely on a large fraction of source water productivity coming from vertical infiltration through the seabed. Consequently, the potential for local water sheds to produce new deposits of silts and clays on top of post-construction sea beds at RBGS and ESGS is a concern and relevant design consideration.

Seabed Infiltration Galleries (SIG), the Beach Infiltration Galleries (BIG), and the Neodren Seawater Intake System all require three precise geomorphic conditions of the site location for successful operation. These are: 1) adequate sediment cover, 2) the proper grain size distribution within that sediment cover (no lenses of silts and clays), and 3) a stable seabed. All are vulnerable to exposure by erosion; and conversely all are vulnerable to impaired infiltration rates due to new deposition of silts and clays on the seabed following construction. If the sediment cover becomes capped with lenses of newly deposited fine grained silts and clays, the permeability of the sediment cover will be inadequate to provide the required amount of feed water. All three of these subsurface intake technologies must have at least 10 ft. of sediment cover that is predominantly sands and/or gravels to provide adequate seabed permeability and insure high infiltration rates of seawater. While the Obayashi Seabed Infiltration Gallery can be made to provide that type of sediment cover through the use of engineered fill, the Neodren Seawater Intake

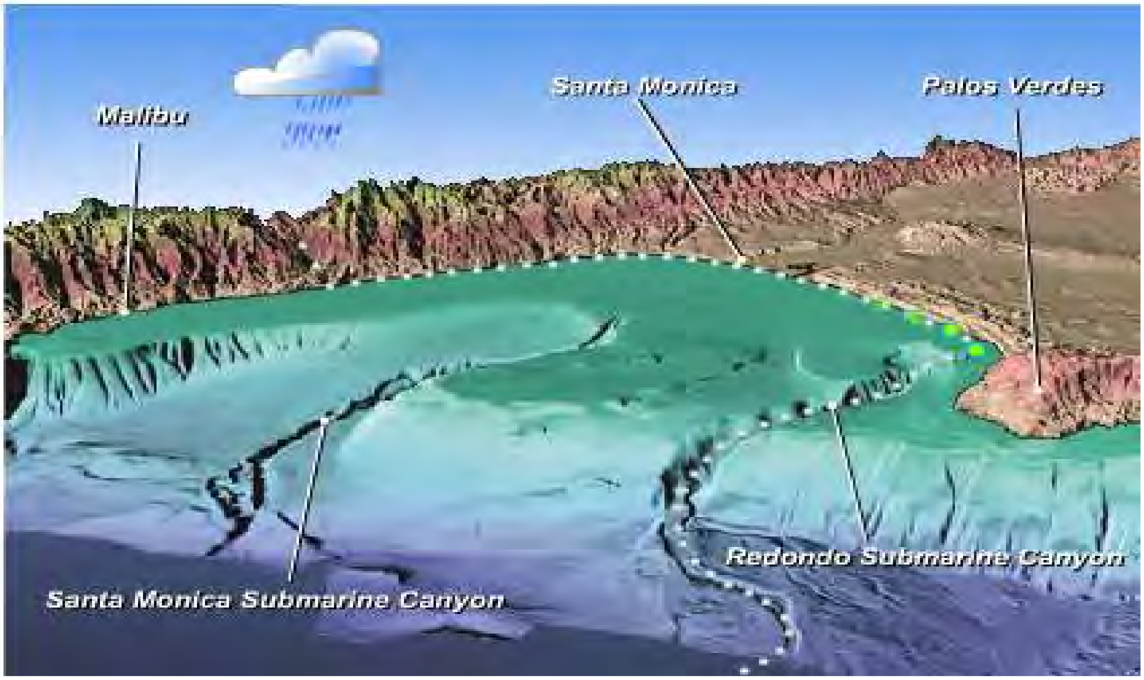


Figure 2.11: Santa Monica Littoral Cell. Dotted line shows littoral drift pathway from natural sediment sources in the Malibu and Santa Monica Hills and from dredging of Marina del Rey.

relies on the existing composition of the native sediment cover for the portion of source water production that comes from vertical infiltration through the seabed.

At the RBGS and ESGS sites, that native sediment cover is highly stratified by lenses of silts and clays found in the borings 20 ft. below existing grade (see Appendix A). These fine are from the wash-load of the Calleguas, Malibu and Ballona Creeks (Inman and Jenkins 1999; Geosyntec, 2013). The constructability of the Obayashi Seabed Infiltration Gallery at RBGS and ESGS is questionable because it requires excavation of a dredged pit to elevations of 10 ft. below ambient seabed in which the infiltration branch pipe segments and engineered fill are subsequently placed, which is surely a time consuming process in high-energy sea states, as are common off RBGS & ESGS (Inman and Jenkins, 1996, 2004c). Therefore it would be exceedingly problematic to get a calm sea state of sufficient length of time to complete this kind of construction, and the dredged pit is likely to collapse before the infiltration pipes and engineered fill can be placed. To avoid this, the Obayashi Seabed Infiltration Gallery must be constructed a considerable distance off shore, beyond closure depth, (the depth beyond which seabed erosion or accretion ceases, typically at about – 15 meters MSL depth). Construction in such deep water is undoubtedly more difficult from a mechanical perspective, and consequently more expensive and problematic (Inman and Jenkins, 1996). For this reason, the only sensible construction option for either a SIG or a BIG is to first build a temporary pier from which the SIG and BIG holes can be dredged and the piping and engineered fill subsequently placed. On the other hand, the Neodren Seawater Intake is insulated from these construction problems (over distances of no more than 2500 ft. from the shore-side drill entry point) due to its horizontal directional drilling techniques. However, it is probably desirable to place the Neodren Seawater Intake close to shore where wave induced bottom stresses are large and capable of re-suspending or even preventing deposition of lenses of fine grained silts and clays. Based on these considerations we proceed with a sediment budget and seafloor stability analysis tailored to the Neodren™ system, as the SIG and BIG alternatives appear more costly and difficult to construct.

3) Technical Approach: To quantitatively evaluate the problems of implementing Neodren™ technology at the RBGS and ESGS sites, we invoke a numerical seabed stability analysis utilizing the ***Coastal Evolution Model*** applied to the Santa Monica Littoral Cell (Figures 2.11 and 3.1). The Coastal Evolution Model was commissioned by the Kavli Foundation to make forecast predictions of the effects of sea level rise on the coastline of California (see Jenkins and Wasyl, 2005).

3.1 General Description: The Coastal Evolution Model (CEM) is a process-based numerical model. It consists of a Littoral Cell Model (LCM) and a Bedrock Cutting Model (BCM), both coupled and operating in varying time and space domains (Figure 3.2) determined by sea level and the coastal boundaries of the littoral cell at that particular sea level and time. At any given sea level and time, the LCM accounts for erosion of uplands by rainfall and the transport of mobile sediment along the coast by waves and currents, while the BCM accounts for the cutting of bedrock by wave action in the absence of a sedimentary cover.

In both the LCM and BCM, the coastline of the Santa Monica Littoral Cell (the region of coastline between Point Dume and Palos Verdes, Figure 3.1) is divided into a series of coupled control cells (Figure 3.3). Each control cell is a small coastal unit of uniform geometry where a balance is obtained between shoreline change and the inputs and outputs of mass and momentum. The model sequentially integrates over the control cells in a down-drift direction so that the shoreline response of each cell is dependent on the exchanges of mass and momentum between cells, giving continuity of coastal form in the down-drift direction. Although the overall computational domain of the littoral cell remains constant throughout time, there is a different coastline position at each time step in sea level. For each coastline position there exists a similar set of coupled control cells that respond to forcing by waves and current. Time and space scales used for wave forcing and shoreline response (applied at 6 hour intervals) and sea level change (applied annually) are very different. To accommodate these different scales, the model uses multiple nesting in space and time, providing small length scales inside large, and short time scales repeated inside of long time scales.

The LCM (Figure 3.2, upper) has been used to predict the change in shoreline width and beach profile resulting from erosion, accretion and longshore transport of sand by wave action where sand source is from river runoff or from tidal exchange at lagoon and bay inlets (e.g., Jenkins and Inman, 1999). More recently it has been used to compute the sand level change (farfield effect) in the prediction of mine burial (Jenkins and Inman, 2002; Inman and Jenkins, 2002). Time-splitting logic and feedback loops for climate cycles and sea level change were added to the LCM together with long run time capability to give numerically stable long term predictions.

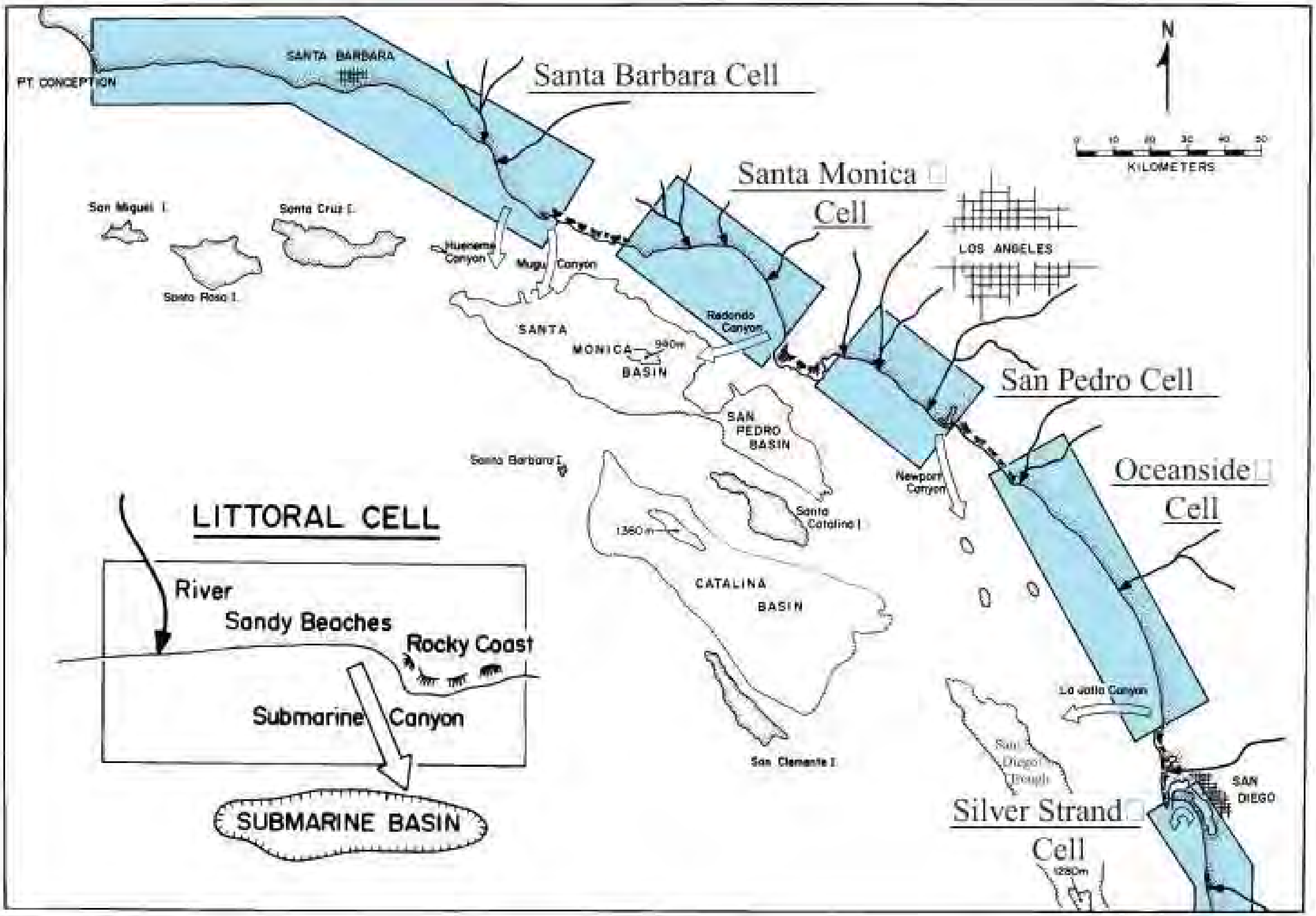


Figure 3.1 The five littoral cells along the southern California coast. Each cell contains a complete sedimentation cycle. Most sand is brought to the coast by streams, carried along the shore by waves and currents, and lost through submarine canyons to offshore basins [after Inman and Frautschy, 1965].

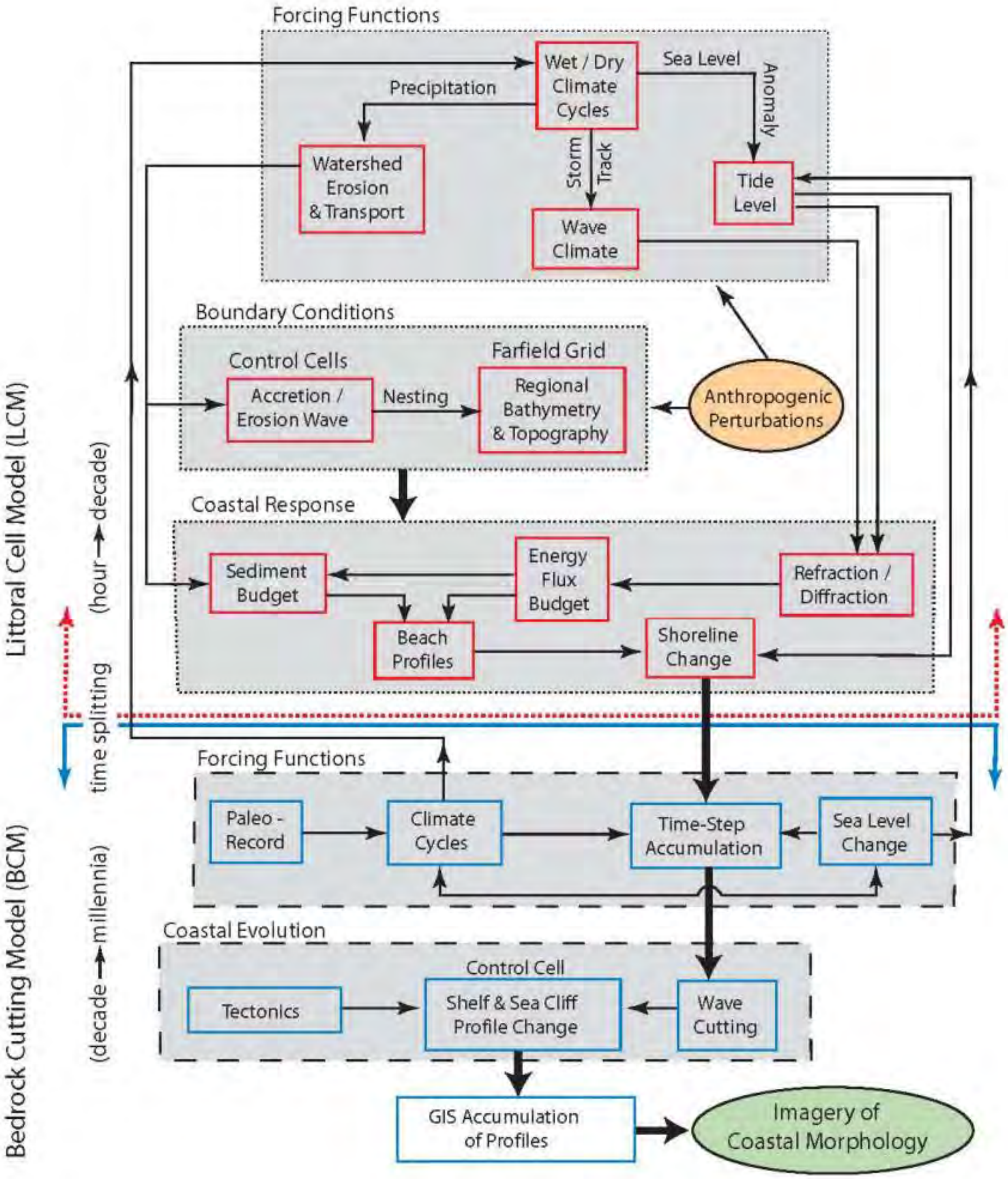
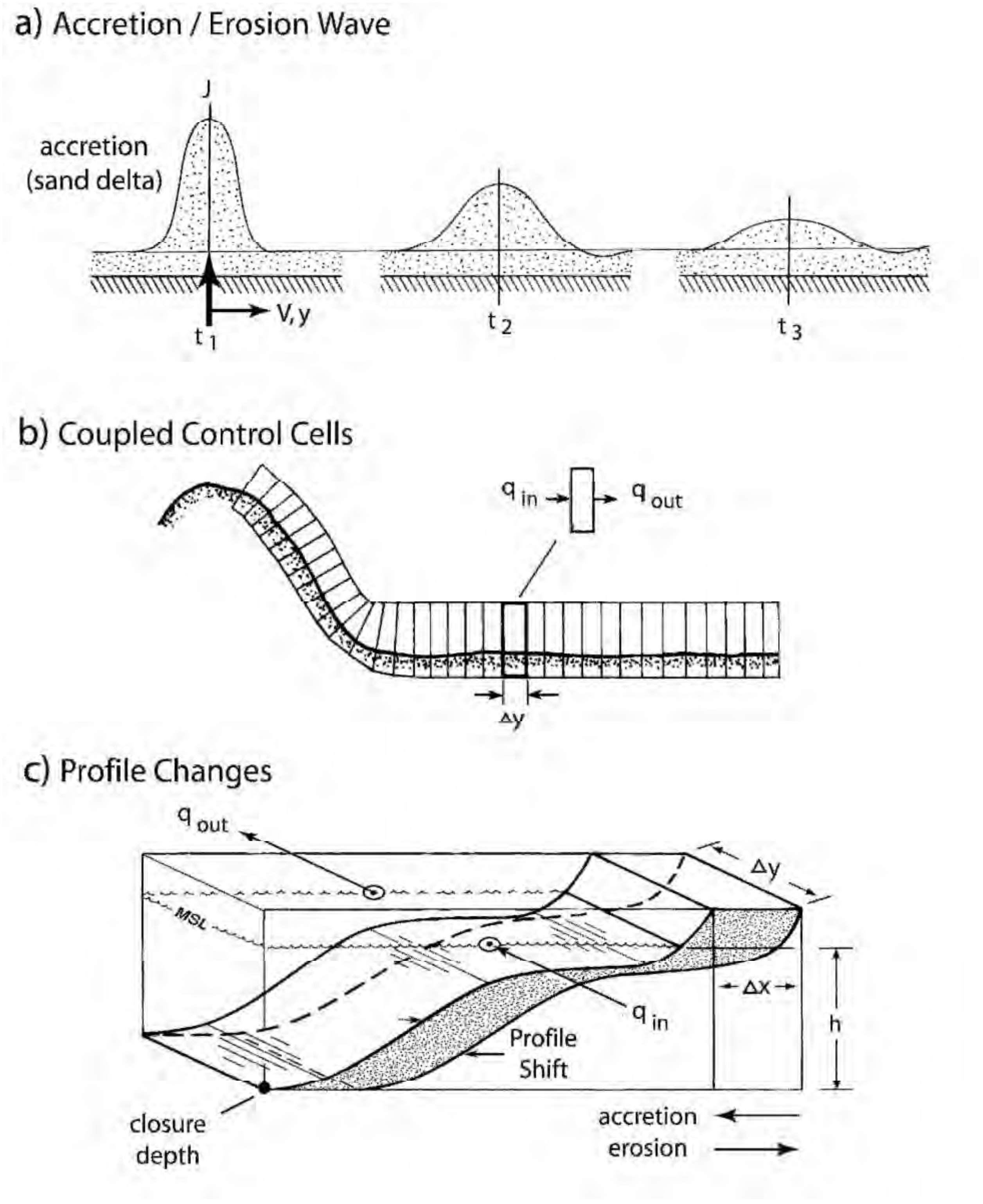


Figure 3.2: Architecture of the Coastal Evolution Model consisting of the Littoral Cell Model (above) and the Bedrock Cutting Model (below). Modules (shaded) are formed of coupled primitive process models. (from Jenkins and Wasyl, 2005).



a) Accretion / Erosion Wave

b) Coupled Control Cells

c) Profile Changes

Figure 3.3: Computational approach for modeling shoreline change after Jenkins, et. al., (2007).

In the LCM, the variation of the sediment cover with time is modeled by time-stepped solutions to the sediment continuity equation (otherwise known as the *sediment budget*) applied to the boundary conditions of the coupled control cell mesh diagramed schematically in Figure 3.3. The sediment continuity equation is written (Jenkins, et al, 2007):

$$\frac{\partial q}{\partial t} = \frac{\partial}{\partial y}\left(\varepsilon \frac{\partial q}{\partial y}\right) - V_l \frac{\partial q}{\partial y} + J(t) - R(t) \tag{3}$$

Where q is the sediment volume per unit length of shoreline (m^3/m) and *dq/dt* is the sediment volume flux ($m^3/m/day$), ε is the mass diffusivity, V_l is the longshore current, *J(t)* is the flux of new sediment into the littoral cell from watersheds or beach disposal of dredge material, and *R(t)* is the flux of sediment lost to sinks , in this case, the Redondo Submarine Canyon. The first term in (3) is the surf diffusion term while the second is the advective term due to the longshore current. For any given control cell inside the reach from Point Dume to the Redondo King Harbor, (3) may be discretized in terms of the rate of change of "beach volume", Λ, in time increment Δt , given by:

$$\frac{d\Lambda}{dt} = J(t) + \frac{q_{in} + q_{out}}{\Delta t} \tag{4}$$

Sediment is supplied to the control cell by the sediment yield from the rivers and beach nourishment, $J(t)$ by the influx of sediment volume due to littoral drift from up-coast sources, q_{in} (beach-fill). Sediment is lost from the control cell due to the action of wave erosion and expelled from the control cell by exiting littoral drift, q_{out}. Here fluxes into the control cell (*J(t)* and $q_{in}/\Delta t$) are positive and fluxes out of the control cell ($q_{out}/\Delta t$) are negative.

The beach and nearshore sand volume change, *dq/dt*, is related to the change in shoreline position, *dX/dt*, according to:

$$\frac{dV}{dt} \cong \frac{d\Lambda}{dt} = \frac{dX}{dt} \cdot Z \cdot l \tag{5}$$

where $$Z = Z_1 + h_c \tag{6}$$

Here, Z is the height of the shoreline flux surface equal to the sum of the closure depth below mean sea level, h_c, and the height of the berm crest, Z_1, above mean sea level; and l is the length of the shoreline flux surface. Hence, beaches and the offshore bottom profile out to closure depth remain stable if a mass balance is maintained such that the flux terms on the right-hand side of equation (4) sum to zero; otherwise the shoreline will move during any time step increment as:

$$\Delta x(t) = \frac{1}{\Delta y(Z_1 + h_c)} \int \left(\frac{\partial}{\partial y} \left(\varepsilon \frac{\partial q}{\partial y} \right) - V \frac{\partial q}{\partial y} + J(t) \right) dt \qquad (7)$$

where ε is the mass diffusivity, V is the longshore drift , J is the flux of sediment from river sources, Δy is the alongshore length of the control cell, and Z_1 is the maximum run-up elevation from Hunt's Formula. River sediment yield, *J*, from is calculated from streamflow, *Q*, based on the power law formulation of that river's sediment rating curve after Inman and Jenkins, (1999), or

$$J = \xi \, Q^{\omega} \qquad (8)$$

where ξ, ω are empirically derived power law coefficients of the sediment rating curve from best fit (regression) analysis (Inman and Jenkins,1999). When river floods produce large episodic increases in *J*, a river delta is initially formed. Over time the delta will widen and reduce in amplitude under the influence of surf diffusion and advect (move) down-coast with the longshore drift, forming an accretion erosion wave (Figure 3a). The local sediment volume varies in response to the net change of the volume fluxes, between any given control cell and its neighbors, referred to as divergence of drift = $q_{in} - q_{out}$, see Figure 3b and 3c. The mass balance of the control cell responds to a non-zero divergence of drift with a compensating shift, Δx , in the position of the equilibrium profile (Jenkins and Inman, 2006). This is equivalent to a net change in the beach entropy of the equilibrium state. The divergence of drift is given by the continuity equation of volume flux, requiring that *dq/dt* is the net of advective and diffusive fluxes of sediment plus the influx of new sediment, *J*. The rate of change of volume flux through the control cell causes the equilibrium profile to shift in time according to (7).

It is well known that beach and nearshore bottom profiles change seasonally in response to seasonal wave climate variations as shown in Figure 3.4, (cf: Inman et al, 1993; Jenkins and Inman 2006); and that seasonal transitions between summer and winter equilibrium states cause seasonal changes in the mean shoreline (Equation 7).

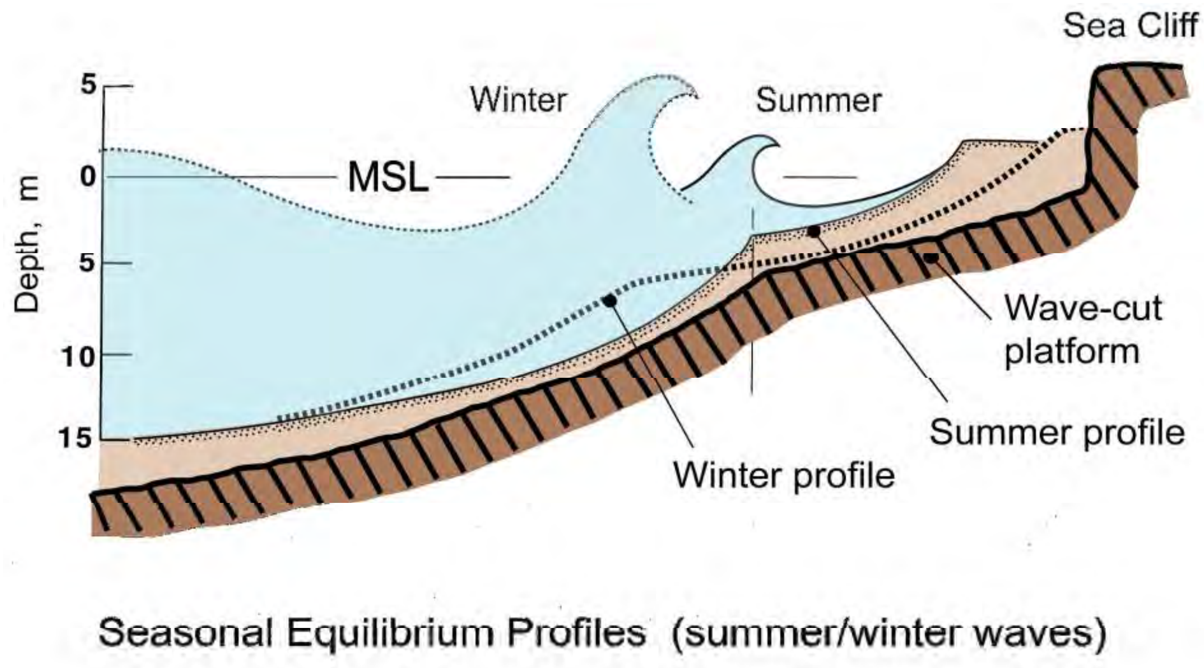


Figure 3.4: Schematic of summer and winter equilibrium beach profiles, from Inman, et al (1993).

Short period waves during summer (from the spin up of winds from the local North Pacific High) cause the inner bar-berm section of the beach profile to build up and steepen; while long period storm swells during winter from the Aleutian low cause the bar-berm profile to flatten, and transfer beach sand to the outer shore-rise profile. These changes between summer and winter equilibrium states are predicted from long-term wave records applied to the well-tested elliptic cycloid solutions published in Jenkins and Inman (2006).

When a long term collection of summer and winter beach equilibrium profiles for a broad range of wave heights, a well-defined envelope of variability becomes apparent as illustrated in Figure 3.5 and 3.6a. Figure 3.5 combines 12 measured bottom profiles over a 37 year period from two adjacent beaches near Oceanside, CA. These beaches have geomorphic similitude with the beaches near Redondo King Harbor, and are shown here to illustrate a fundamental principle. In Figure 3.5, elliptic cycloid solutions for equilibrium profiles are also overlaid as colored traces to further define this envelope of variability.

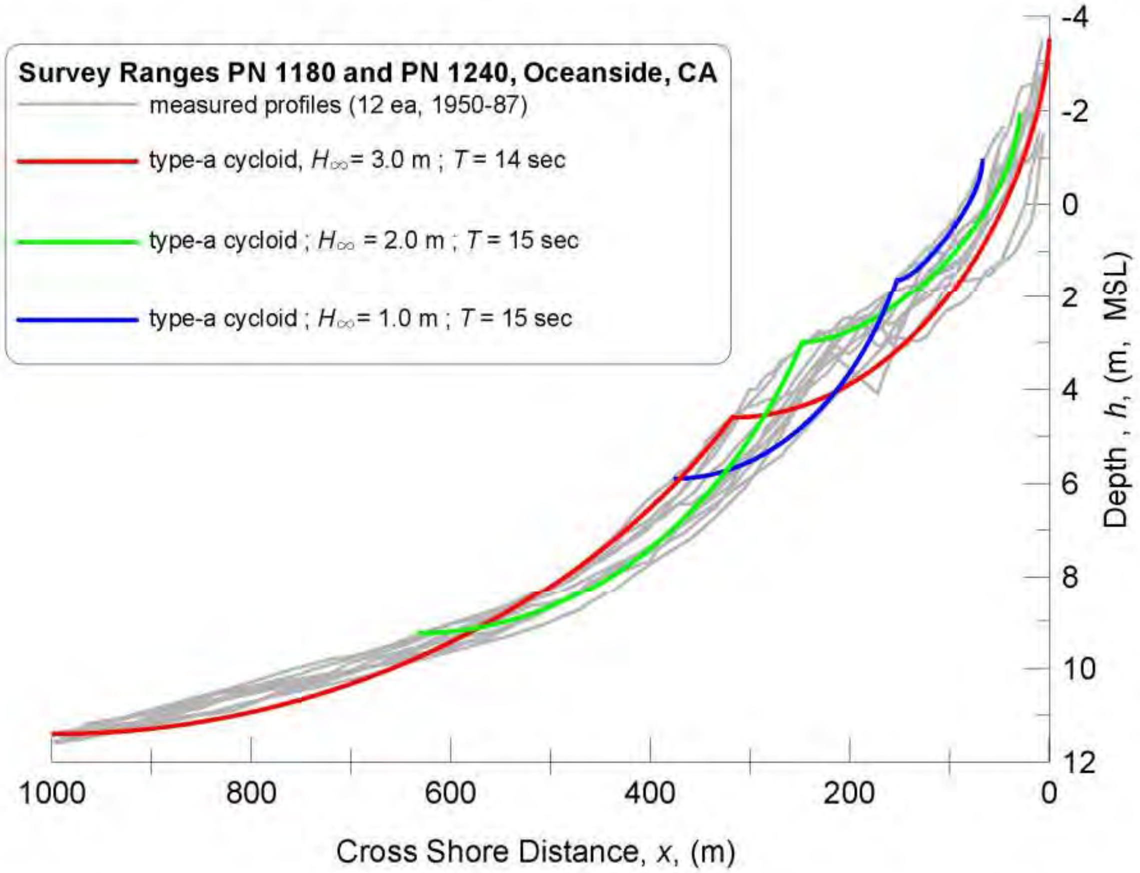


Figure 3.5: Envelope of variability of measured beach profiles (1950- 1987) at Oceanside CA (shown in grey), compared to an ensemble of elliptic cycloid solutions (colored) for selected wave heights and periods for average summer and winter wave climate; (from Jenkins and Inman, 2006)

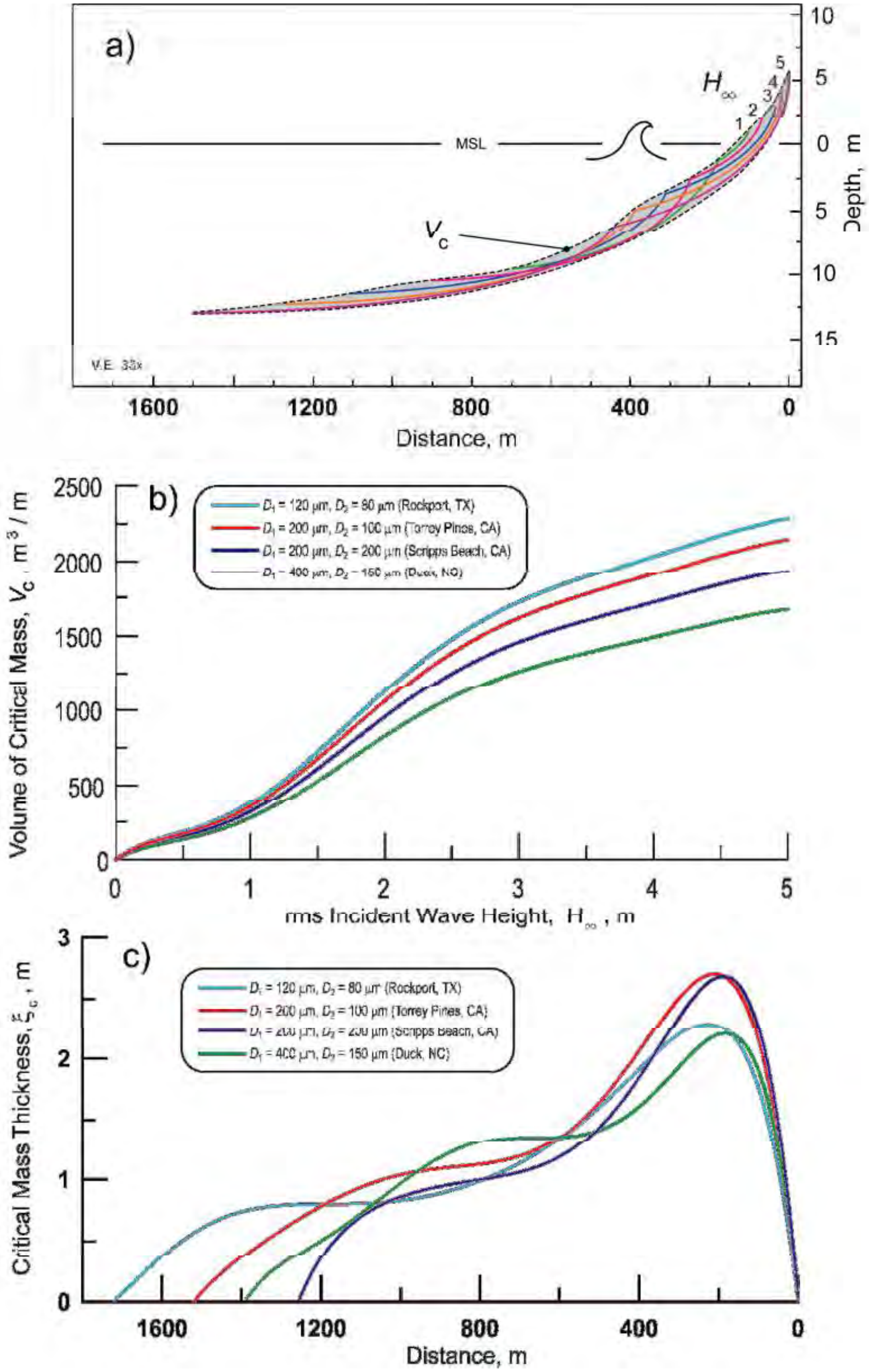


Figure 3.6: Features of the critical mass of sand: a) critical mass envelope for waves of 1m to 5m in height; b) volume of critical mass as a function of wave height and sediment grain size; c) variation in the thickness of the critical mass as a function of distance offshore.

The cycloid solutions are from Jenkins and Inman, 2006, and are based on average summer and winter wave heights and periods. Comparison of the measured profiles in grey with the cycloid solutions indicates that the volume of sand associated with long term beach profile variations are directly calculable by integration of the cycloid solutions between the limits of wave climate. This integration is shown in Figure 3.6b, and the volume of sand is referred to as the ***critical mass***. The critical mass represents the minimum volume of sediment cover required to maintain equilibrium bottom profiles and a stable seabed over the long-term, (where long-term is on the order of decades). Figure 3.6b indicates that the critical mass increases with wave height, and decreases with sediment grain size. Thus, the critical mass requirements become very large for finer-grained sediments in high energy wave climate environments.

Furthermore, the total mass of sand in the littoral cell, (as specified by the sediment budget in Equation 4), must exceed the critical mass in order for the beach and nearshore sediment cover to remain sustainable over time. If the sediment budget declines to less than the critical mass, then the beach and nearshore will denude down to bedrock, and all the sediment cover is quickly lost. This occurred in many places in Southern California during the El Nino winter of 1983 (Inman and Jenkins, 1993, 2004), and would be disastrous for a SIG or BIG intake system if it happened at the RBGS or ESGS sites in the future. Only the Neodren™ technology would be able to survive a repeat of the 1983 El Nino winter conditions due to its ability to be placed below the critical mass envelope by means of horizontal directional drilling (HDD).

4.2) Closure Depth: This is the most important parameter in the optimal siting of shallow sub-seabed intake technology. Closure depth represents the closest point to the shoreline where a stable seabed can be found, because it is the point beyond which all changes in the beach profiles cease. It also represents the outer limit of the critical mass. If a SIG were located inshore of closure depth, the engineered fill would suffer seasonal or episodic erosion, and subsequently be replaced by seasonal or episodic deposition of native sediments whose grain size may or may not be compatible with the fill material.

Hallermeier [1978, 1981] derived a relation for closure depth, by assuming a relationship for the energetics of sediment suspensions based on a critical value of the Froude number, giving:

$$h_{\mathrm{c}} \cong 2.28 H_{\mathrm{ss}} - 6.85 \left(H_{\mathrm{ss}}^{2} / g T^{2} \right) \qquad (9)$$

where H_{ss} is the nearshore storm wave height that is exceeded only 12 hours each year and T is the associated wave period.

Birkemeier [1985] suggested different values of the constants and found that the simple relation $h_{\mathrm{c}} = 1.57\, H_{\mathrm{ss}}$ provided a reasonable fit to his profile measurements at Duck, North Carolina. *Cowell et al.* [1999] reviews the Hallermeier relation for closure depth h_{c} and limiting transport depth h_{i} and extends the previous data worldwide to include Australia. Their calculations indicate that h_{c} ranges from 5 m (Point Mugu California) to 12 m (SE Australia), while h_{i} ranges from 13 m (Netherlands) to 53 m (La Jolla, California). They conclude that discrepancies in data and calculation procedures make it “pointless to quibble over accuracy of prediction” in h_{c} and h_{i}. In the context of planning for beach nourishment, *Dean* [2002] observes that "although closure depth…..is more of a concept than a reality, it does provide an essential basis for calculating equilibrated…beach widths."

While it may be reasonable to apply the Hallermeier relation or its simpler form after *Birkemeier* [1985] to the shorerise boundary condition, comparisons with the *Inman et al.* [1993] beach profile data set show that these relations tend to underestimate closure depth. We propose an alternative closure depth relation. This relation is based on two premises: 1) closure depth is the seaward limit of non-zero net transport in the cross-shore direction; and, 2) closure depth is a vortex ripple regime in which no net granular exchange occurs from ripple to ripple. *Inman* [1957] gives observations of stationary vortex ripples in the field and *Dingler and Inman* [1976] establish a parametric relationship between dimensions of stationary vortex ripples and the Shield's parameter $\widetilde{\Theta}$ in the range $3 < \widetilde{\Theta} < 40$. Using the inverse of that parametric relation to solve for the depth gives (Jenkins and Inman, 2006):

$$h_{\mathrm{c}} = \frac{K_{\mathrm{e}} H_{\infty}}{\sinh k h_{\mathrm{c}}} \left(\frac{D_{\mathrm{o}}}{D_2} \right)^{\psi} \tag{10}$$

where K_{e} and ψ are non-dimensional empirical parameters, D_2 is the shorerise median grain size; and D_{o} is a reference grain size. With $K_{\mathrm{e}} \sim 2.0, \psi \sim 0.33$ and $D_{\mathrm{o}} \sim 100 \mu\mathrm{m}$, the empirical closure depths reported in *Inman et al.* [1993] are reproduced by (10). From (10) we find closure depth increases with increasing wave height and decreasing grain size, as shown in Figure 3.7. Because of the wave number dependence of (10), closure depth also increases with increasing wave period. Using (10), the distance to closure depth X_{c2} can be obtained from (Jenkins and Inman, 2006),

$$X_{\mathrm{c2}} = \frac{h_{\mathrm{c}} I_{\mathrm{e}}^{(2)}}{\varepsilon} \cong \frac{\pi\, h_{\mathrm{c}}}{2\varepsilon} \sqrt{\frac{2 - e^2}{2}} \tag{11}$$

Where X_{c2} is measured from the origin of the shorerise located a distance X_2 from the berm and a distance $X_3 - X_2$ inside the breakpoint (Figure 3.8a), $I_{\mathrm{e}}^{(2)}$ is the elliptic integral of the second kind, and ε is a stretching factor proportional to the Airy wave mild slope factor *N*, and

$$\varepsilon = \frac{\sigma}{N} \left(\frac{H_{\mathrm{b}}}{\gamma g} \right)^{1/2} \cong \frac{\sigma^{4/5}}{2^{1/5} N} \left(\frac{H_{\infty}}{g \gamma} \right)^{2/5} :$$

4.2) Elliptic Cycloid Solutions for the Shore-rise and Beach Profiles: The elliptic cycloid was proven to be the mathematical representation of a shore-rise or bar-berm beach profile by Jenkins and Inman, 2006. This mathematical relation is embedded in the algorithms of the CEM and used to calculate the bottom profile of the beach and seabed offshore of the RBGS & ESGS for any given point in time based on the incident wave height, period, direction and sediment grain size.

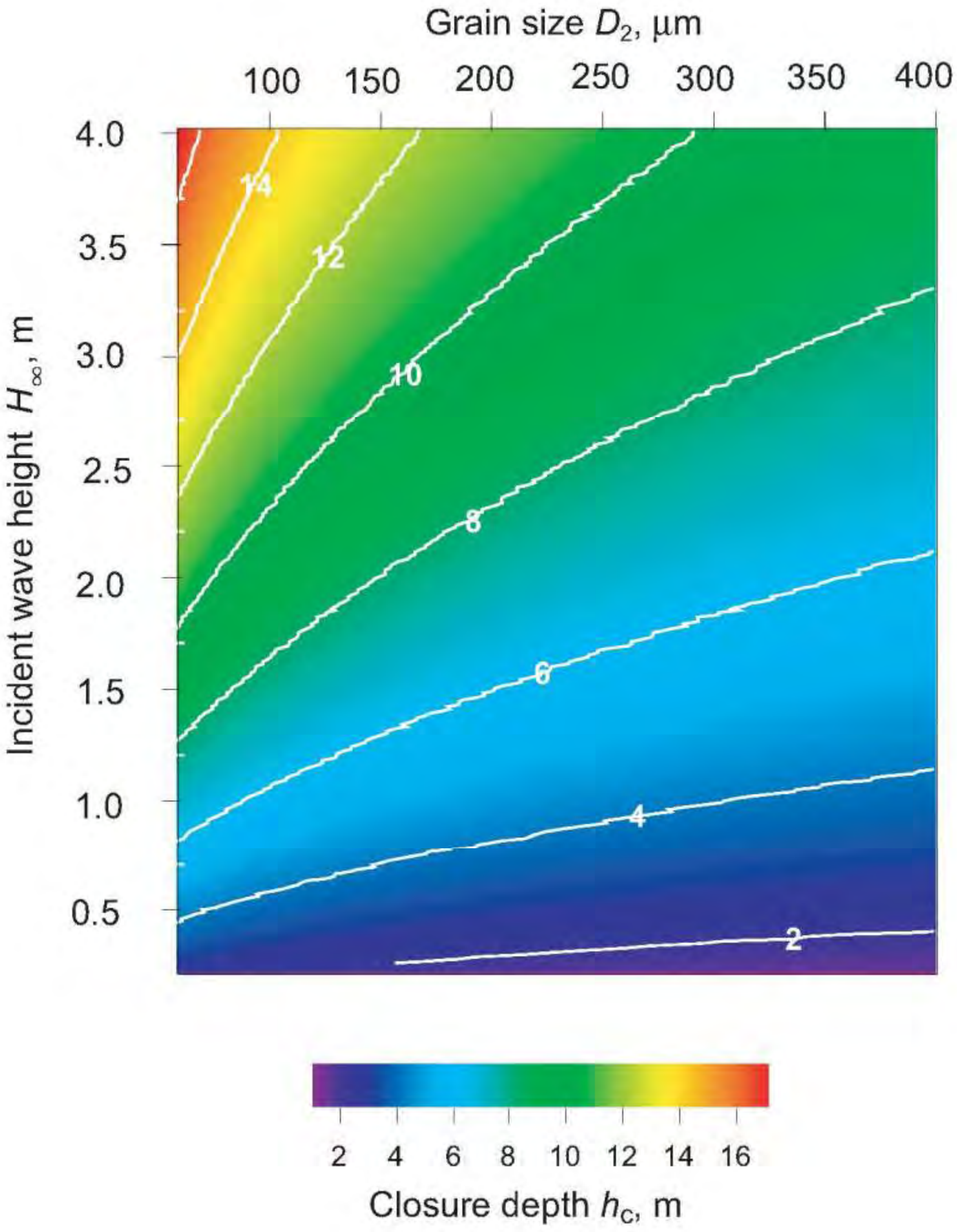


Figure 3.7: Closure depth contoured versus incident wave height and sediment grain size for waves of 15 second period, with $K_e \sim 2.0, \psi \sim 0.33$ and $D_o \sim 100 \mu m$. D_2 is the shorerise median grain size; and D_o is a reference grain size.

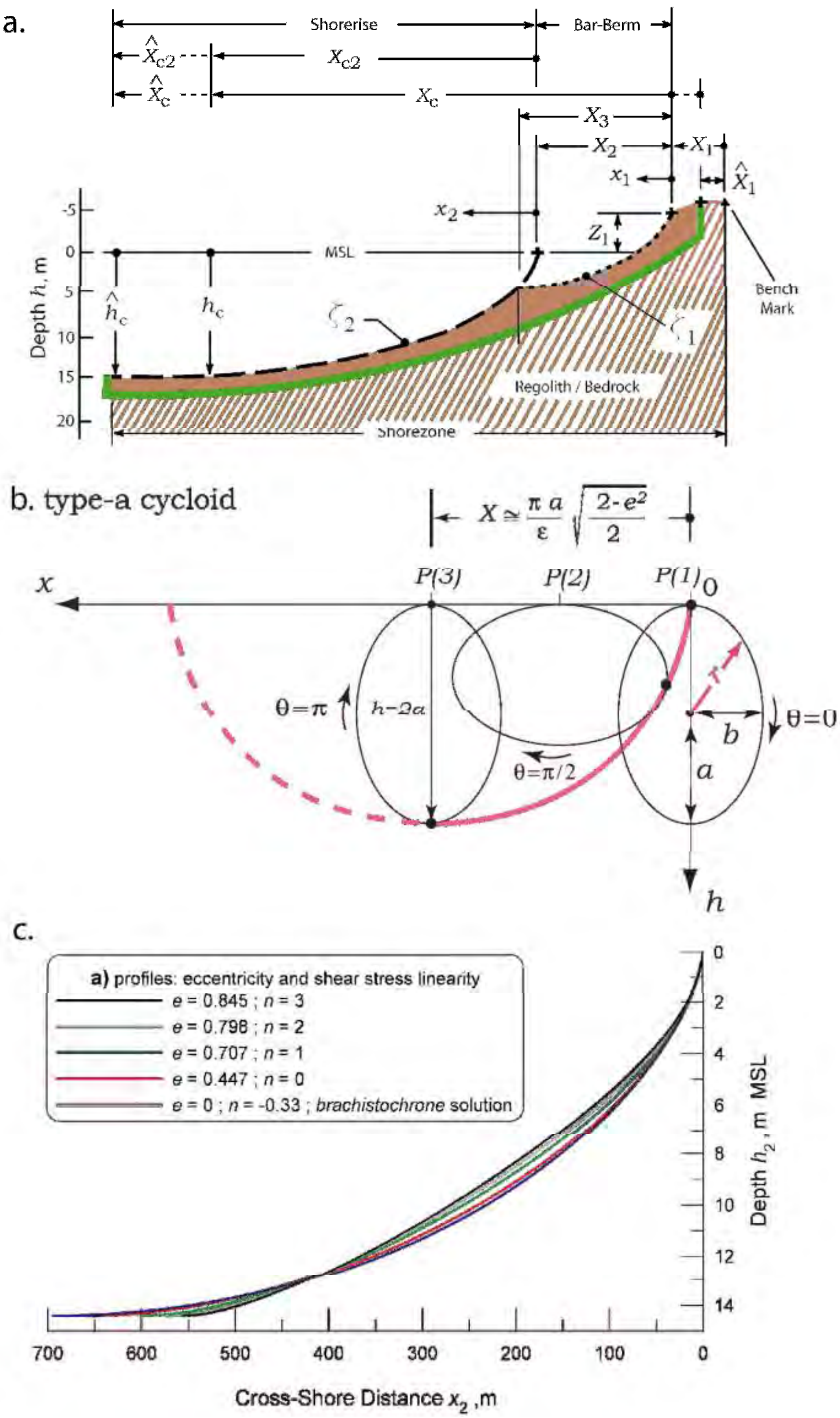


Figure 3.8. Equilibrium beach profile a) nomenclature, b) elliptic cycloid, c) Type-a cycloid solution.

The elliptic cycloid solutions were developed for beach profiles by Jenkins and Inman, (2006) using equilibrium principles of thermodynamics applied to very simply representations of the nearshore fluid dynamics. Equilibrium beaches are posed as isothermal shorezone systems of constant volume that dissipate external work by incident waves into heat given up to the surroundings. By the maximum entropy production formulation of the second law of thermodynamics (the law of entropy increase), the shorezone system achieves equilibrium with profile shapes that maximize the rate of dissipative work performed by wave-induced shear stresses. Dissipative work is assigned to two different shear stress mechanisms prevailing in separate regions of the shorezone system, an outer solution referred to as the *shorerise* and a *bar-berm* inner solution. The equilibrium shorerise solution extends from closure depth (zero profile change) to the breakpoint, and maximizes dissipation due to the rate of working by bottom friction. In contrast, the equilibrium bar-berm solution between the breakpoint and the berm crest maximizes dissipation due to work by internal stresses of a turbulent surf zone. Both shorerise and bar-berm equilibria were found to have an exact general solution belonging to the class of elliptic cycloids.

The elliptic cycloid solution is a curve allows all the significant features of the equilibrium profile to be characterized by the eccentricity and the size of one of the two ellipse axes. These two basic ellipse parameters are related herein to both process-based algorithms and to empirically based parameters for which an extensive literature already exists. The elliptic cycloid solutions reproduce realistic and validated wave height, period and grain size dependence and demonstrated generally good predictive skill in point-by-point comparisons with measured profiles (Jenkins and Inman, 2006 display).

To understand the formulation of the elliptic cycloid representation of the nearshore bottom profile and sensitivity to ocean conditions, we first review the nomenclature of the shorezone as shown schematically in Figure 3.8. The seaward boundary of the shorezone is a vertical plane at the critical closure depth $\hat{h}_c$ (Figure 8a) corresponding to the maximum incident wave [e.g., *Kraus and Harikai*, 1983]. The landward boundary is a vertical plane at the berm crest (cross), a distance $\hat{X}_1$ from a bench mark. The cross-shore length of the system from the berm crest to closure depth is $\hat{X}_c$. The distance from the point of wave breaking to closure depth is $\hat{X}_{c2}$ such that $\hat{X}_c = \hat{X}_{c2} + \hat{X}_2$, where $\hat{X}_2$ is the distance from the berm crest to the origin of the shorerise profile near the wave breakpoint. We consider equilibrium over time scales that are long compared with a tidal cycle and profiles that remain in the wave dominated regime where the relative tidal range (tidal range/*H*) < 3 [*Short*, 1999]. Under these conditions, the curvilinear solution to the bottom profile which satisfies the maximum entropy production formulation of the *Second Law of Thermodynamics* can be expressed in polar coordinates (r, θ) as:

$$x = x_2 = \frac{2r\, I_e^{(k_{1,2})}}{\pi\,\varepsilon}(\theta - \sin\theta) \qquad (12)$$

where r is the radius vector measured from the center of an ellipse whose semi-major and semi-minor axes are a, b and $I_{\mathrm{e}}^{(k)}$ is the elliptic integral of the first or second kind. This curve is what a point on the circumference of an ellipse would trace by rolling through some angle θ , (Figure 3.8b); hence the name elliptic cycloid. The polar equivalent of the type-a cycloid shown in Figure 3.8b has a radius vector whose magnitude is:

$$r = r_{\mathrm{a}} = \left[\frac{a^2 b^2}{a^2 \sin^2 \theta + b^2 \cos^2 \theta} \right]^{1/2} = \frac{a\sqrt{1-e^2}}{\sqrt{\sin^2 \theta + (1-e^2)\cos^2 \theta}} \tag{13}$$

where e is the eccentricity of the ellipse given by $e = \sqrt{1-(b^2/a^2)}$. The polar form of the type-a cycloid in Figure 3.8b is based on the elliptic integral of the second kind that has an analytic approximation, $I_{\mathrm{e}}^{(2)} = (\pi/2)\sqrt{(2-e^2)/2}$, see *Hodgman* [1947]. The inverse of (13) for the type-a elliptic cycloid gives the companion solution in terms of local water depth, h, as:

$$h = h_2 = \frac{\pi\varepsilon\, x_2}{2I_e^{(k_{1,2})}} \left(\frac{1-\cos\theta}{\theta - \sin\theta} \right) = r\left(1-\cos\theta\right) \tag{14}$$

The depth of water at the seaward end of the profile ($\theta = \pi$) is $h = 2a$ in the case of the type-a cycloid. The length of the profile X is equal to the semi-circumference of the ellipse,

$$X = \frac{2aI_{\mathrm{e}}^{(2)}}{\varepsilon} \cong \frac{\pi\, a}{\varepsilon}\sqrt{\frac{2-e^2}{2}} \qquad \text{at} \quad \theta = \pi \quad \text{(type-a cycloid)} \tag{15}$$

4.3) Critical Mass: The critical mass determines the volume of sediment that can be potentially eroded, and the depth below existing grade that erosion might extend, due to extreme storms and seasonal change or shoreline recession. The critical mass of sand on a beach is that required to maintain equilibrium beach shapes over a specified time, usually ranging from seasons to decades. The critical mass for a seasonal beach is determined from the volume of the envelope of sand necessary to maintain continuous beach forms during the many changes in shape from one equilibrium state to another over a period of seasons (Jenkins and Inman, 2003). Generally, changes in profile shape between equilibrium states involve transitional shapes that are non-equilibrium in form. However, as a first order approximation, we assume the critical mass envelope consists of a set of incremented equilibrium profiles, and the associated set of transitional profiles occurring between successive equilibrium states. Each profile in this set corresponds to a particular rms breaker height H_{b} that varies between some seasonal minimum H_{bo} and the critical wave height $\hat{H}_{\mathrm{b}}$, the highest wave condition for which the existing sand supply can accommodate equilibrium and transitional profile adjustments. The equilibrium profiles are incremented by infinitesimal changes in wave height, $H_{\mathrm{bo}} \leq H_{\mathrm{b}} + \mathrm{d}H_{\mathrm{b}} \leq \hat{H}_{\mathrm{b}}$, giving a continuous envelope of beach profile change. The volume of this envelope can be calculated from the thermodynamic solutions for the bar-berm profile, ζ_1, and the shorerise profile ζ_2 to solve for the volume of critical mass V_{c} per meter of shoreline (m^3/m):

$$V_c = \int_{H_\infty}^{\hat{H}_b} \int_{X_1}^{X_3} \frac{\partial \zeta_1}{\partial H_b} dx dH_b + \int_{H_\infty}^{\hat{H}_b} \int_{X_3}^{X_c} \frac{\partial \zeta_2}{\partial H_b} dx dH_b \qquad (16)$$

Analytic solutions to V_c are difficult because the thermodynamic solutions for the curvilinear coordinates (ζ_1, ζ_2) using elliptic cycloids are transcendental. Therefore solutions for the V_c envelope are obtained by numerical integration of (16) based on long term wave climate (cf. Section 5). We use the number crunching capabilities of the CEM for this purpose. Figure 3.9 gives the critical mass solution resulting from numerical integrations of (16). Because equilibrium and transitional profiles are grain size dependent through the closure depth condition, the volume of critical mass has a certain degree of sensitivity to grain size. Sensitivity analyses of (16) based on numerical integration show that finer grain sizes, particularly in the shorerise, tend to result in larger volumes of critical mass. This is shown in in Figure 3.10 with the wave period fixed. Longer curvilinear length ζ_1, ζ_2 and deeper closure depths h_c arise from finer grained sediment, thus resulting in physically larger critical mass envelops. However, the sensitivity of the volume of critical mass to grain size is second order relative to the dependence on wave height and period. A polynomial fit to the wave height dependence averaged over all grain sizes gives the following analytic approximation:

$$V_c \cong 500 H_b^{0.9} \qquad (17)$$

where H_b is in meters, giving V_c in m^3 per meter of beach length.

4.0) Model Initialization and Calibration:

Implementation of the CEM to evaluate the SIG or Neodren™ siting feasibility questions requires comprehensive data bases to populate the input files and arrays. Those data bases were harvested from the existing literature and include bathymetry, beach and shorerise profiles, sediment grain size, river sediment flux, and nearshore, tides, waves, and currents.

Long-term monitoring of ocean properties in the coastal waters surrounding RBGS and ESGS has been on going for about 30 years as required for compliance with NPDES permits for the AES Redondo Beach Generating Station thermal discharges (CRWQCB, 1999, 2000; MBC, 2002-2006). These data were accessed from the NPDES monitoring reports that are periodically released and filed with the Regional Water Quality Control Board. In attempting to reconstruct 24-year long, continuous, unbroken records of all eight controlling variables for the dilution and dispersion modeling problem, certain gaps were found in some of the data bases. These gaps were filled by using ocean data measured at CDIP monitoring sites in Santa Monica Bay, San Pedro, Sunset Beach, Huntington Beach, Begg Rock and San Clemente, CA, see CDIP (2004). Any remaining gaps that could not be filled by these most immediate neighbors were filled by monitoring data from the Scripps Pier in La Jolla, about 90 miles to the southeast of RBGS and King Harbor.

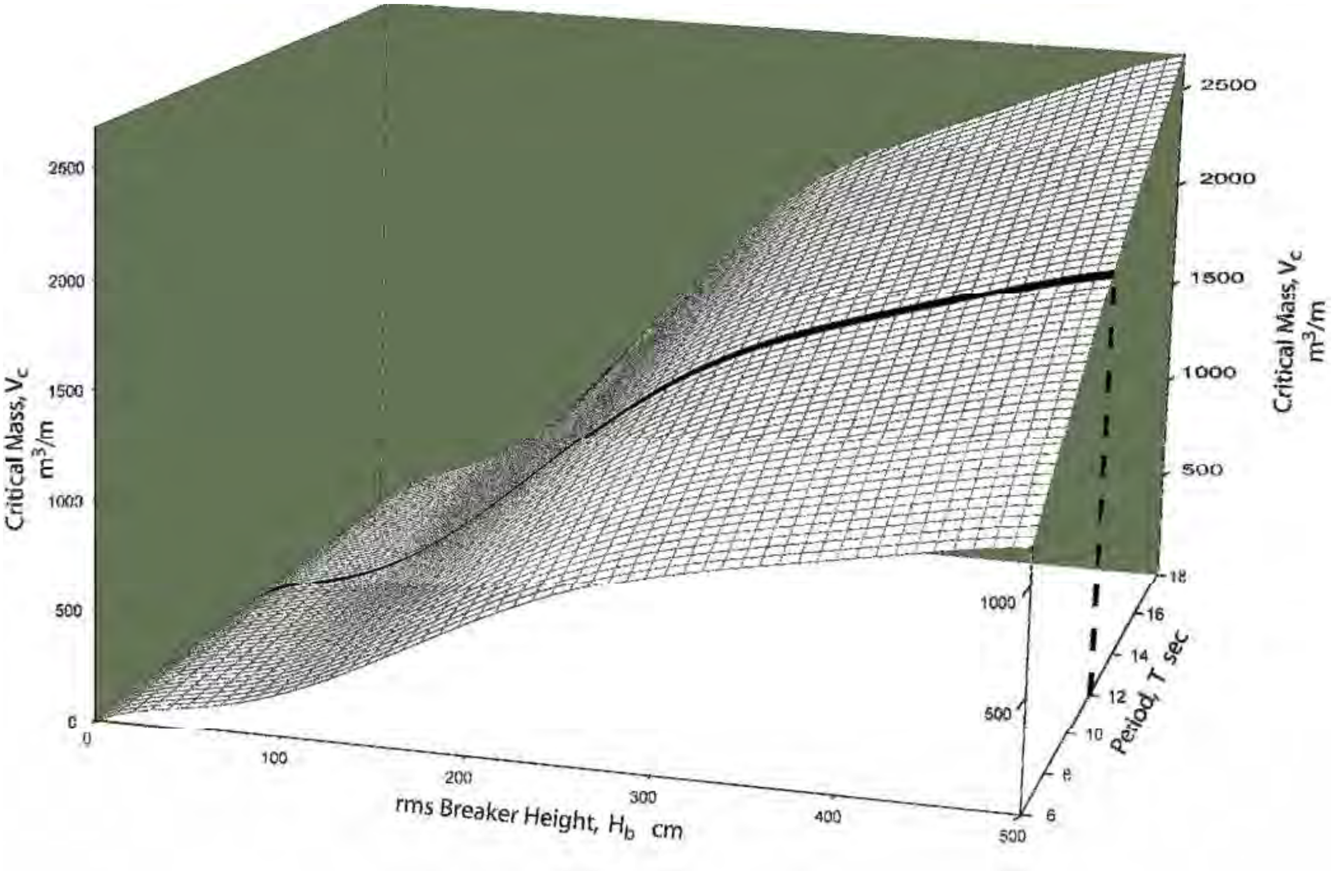


Figure 3.9: Three dimensional rendering of the total solution space of the critical mass. Black line corresponds to the solution in Figure 10 for D_1 = 225 microns and D_2 = 125 microns

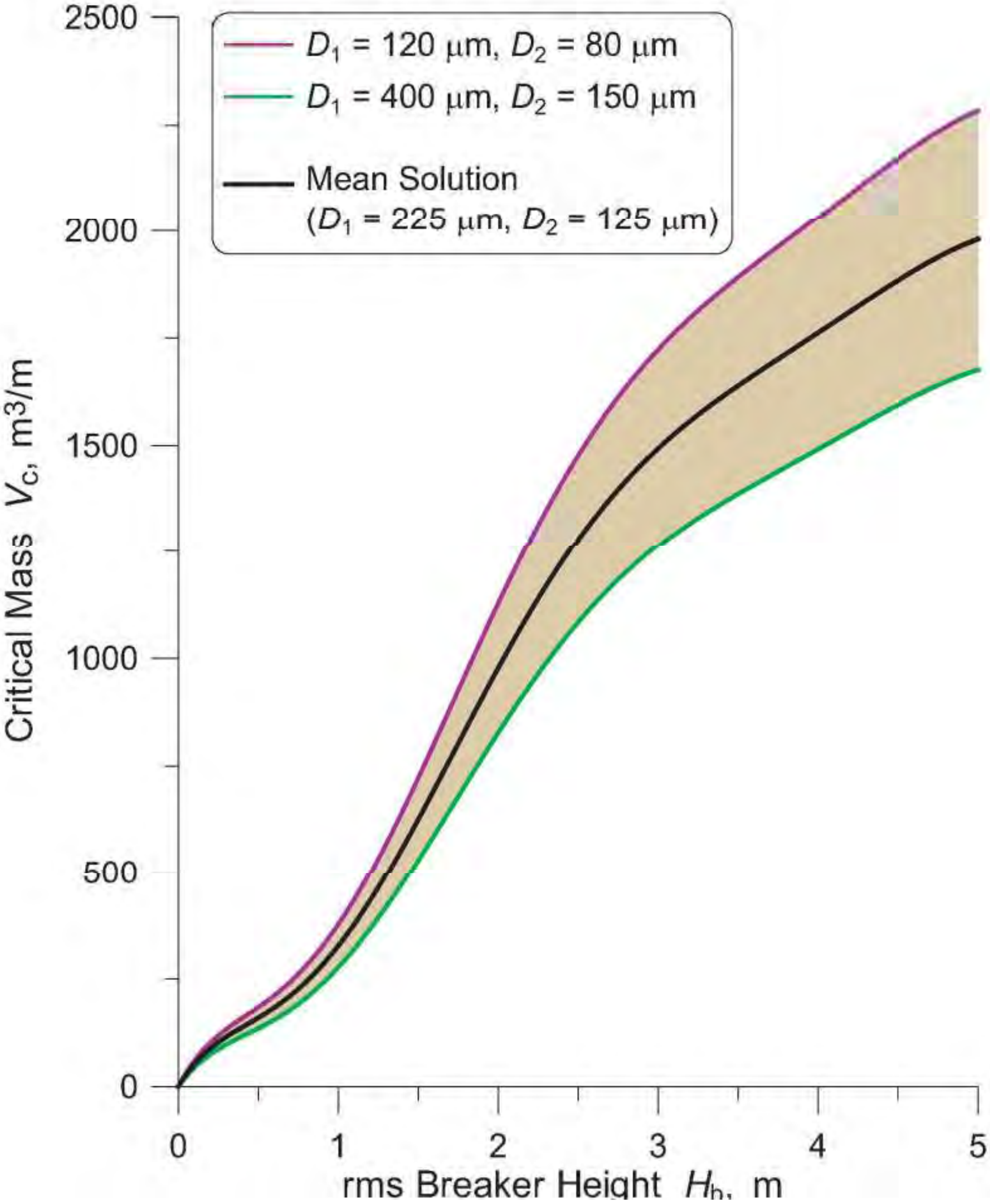


Figure 3.10: Critical mass solution as a function of rms breaker height for 12 sec waves breaking on variable sediment grain size in the bar-berm D1 and shore-rise D2 portions of the seabed profile. Curves generated from numerical integration of elliptic cycloid solutions.

Only about 1% of the total record length contained gaps filled by the Scripps Pier proxy records. None the less, the Scripps Pier site has many physical features in common with the nearshore area around RBGS and King Harbor. Both sites have a submarine canyon nearby. Consequently internal waves are an active mechanism at both sites in causing daily (diurnal) variations in salinity, temperature, and other ocean properties. The longer period variations at seasonal and multiple year time scales are the same at both sites due to their proximity. Consequently the Scripps Pier Shore Station data (SIO, 2005) and the Coastal Data Information Program monitoring at Santa Monica Bay, San Pedro, Sunset Beach and Huntington Beach, (CDIP, 2004) are reasonable surrogates to fill gaps in the NPDES data for the RBGS and King Harbor and Hyperion outfalls. These properties will be shown to exhibit considerable natural variability over the period of record from 1980 to mid-2004 due to daily and seasonal changes, but most especially due to climate changes of global scale.

4.1) Bathymetry: Bathymetry provides a controlling influence on all of the coastal processes that affect sediment transport. The bathymetry consists of two parts: 1) a stationary component in the offshore where depths are roughly invariant over time; and 2) a non-stationary component in the nearshore where depth variations do occur over time. The stationary bathymetry generally prevails at depths that exceed closure depth which is the depth at which net on/offshore transport vanishes. Closure depth is typically -12 m to -15 m MSL in the Santa Monica Littoral Cell, [Inman et al. 1993]. The stationary bathymetry was derived from the National Ocean Survey (NOS) digital database. Gridding is by latitude and longitude with a 1 x 1 arc second grid cell resolution yielding a computational domain of 30.9 km x 18.5 km. Grid cell dimensions along the x-axis (longitude) are 25.7 meters and 30.9 meters along the y-axis (latitude).

For the non-stationary bathymetry data inshore of closure depth (less than -15 m MSL) nearshore and beach surveys were conducted by the US Army Corps of Engineers in 1985, 1990, 1996 and have been compiled in Everts, 1997. These nearshore and beach survey data were used to update the NOS database for contemporary nearshore and shoreline changes that have occurred following the most recent NOS surveys. In the very nearfield of the RBGS an ESGS intakes and discharge, Tenera (2007) performed high resolution bathymetric survey on 5 m grid cell resolution. These data were incorporated in the nearfield grid and co-registered with the NOS data along the deep water boundary (Figures 4.1 – 4.3).

To perform both the required wave shoaling and transport computations in the farfield of RBGS and ESGS, resolution of the bottom bathymetry must be sufficient to provide at least two grid points per wavelength of the highest frequency wave to be shoaled. The farfield grid computes the effects of island sheltering and regional scale refraction and circulation due to the shallow banks of the continental margin (Figure 4.4). Nearfield grids (Figures 4.1 - 4.3) are nested inside the farfield grid and is used to calculate the broad scale littoral sediment transport in the Santa Monica Littoral Cell between Marina Del Rey and Redondo King Harbor.

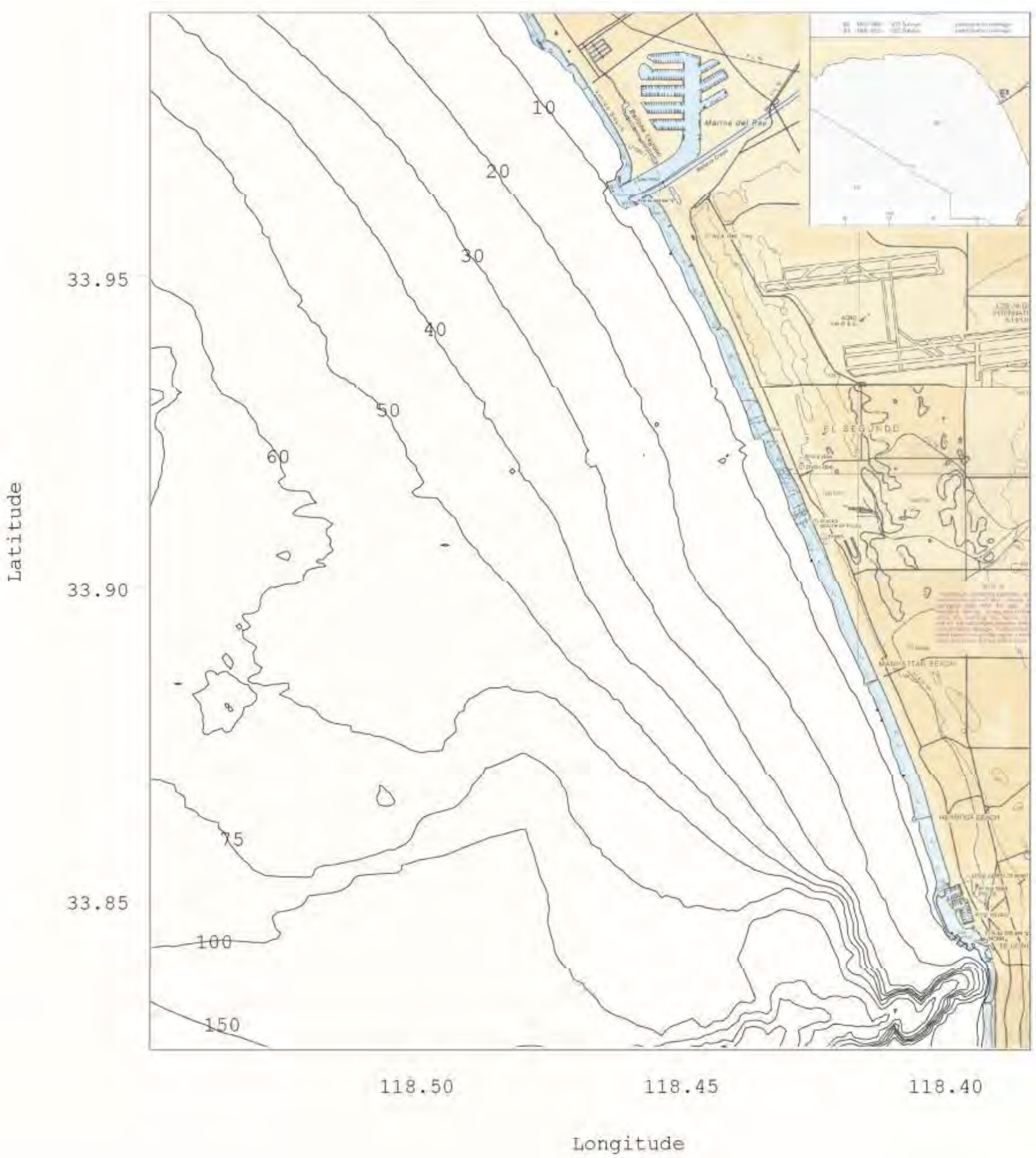


Figure 4.1 Nearfield grid derived from NOS bathymetry used for divergence of littoral drift, erosion/accretion and critical mass computations. Depth contours in meters MSL. Note *Redondo Submarine Canyon* in the bottom right hand corner of the figure.

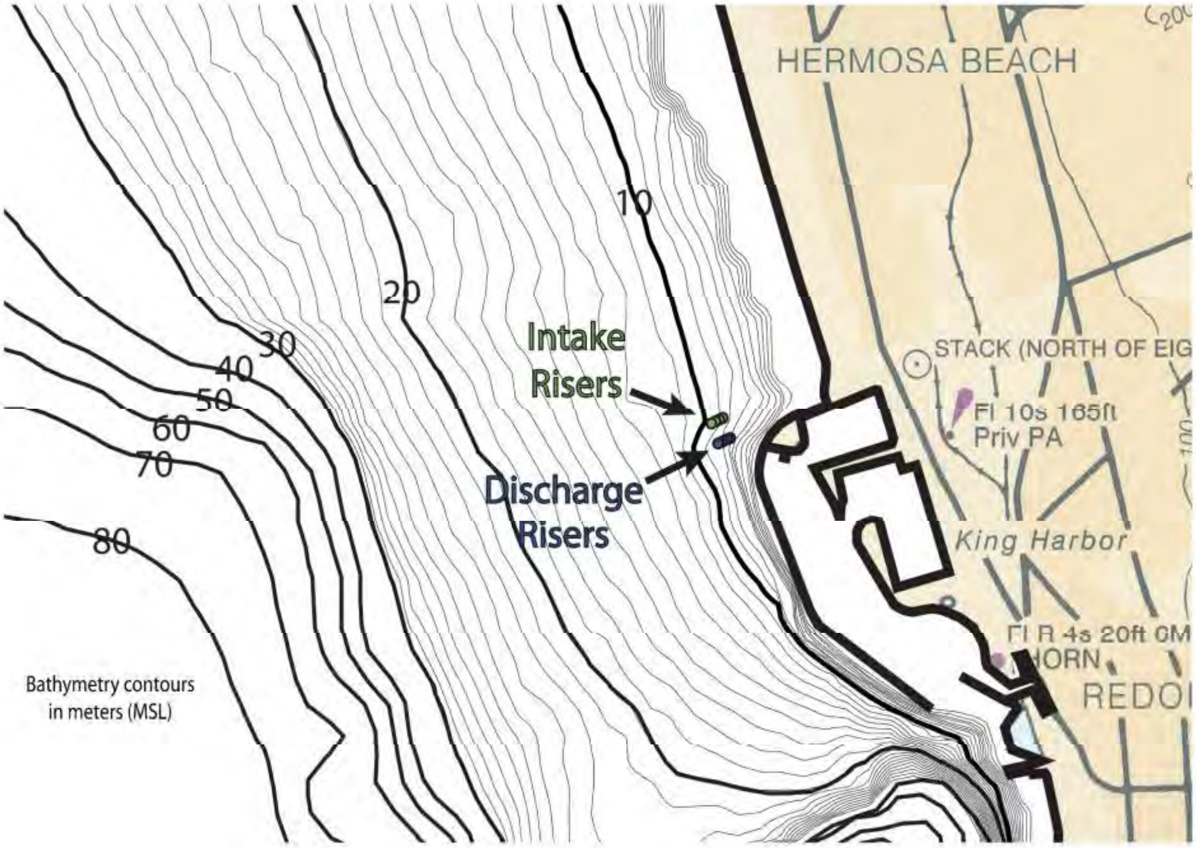


Figure 4.2 Nearfield bathymetric grid centered on the RBGS site for the West Basin Municipal Water District's proposed sea water desalination. Bathymetry from NOS with survey corrections by Tenera (2007).

Redondo Beach end of tunnel coordinates in UTM (m) are:

Intake tunnel: 11S 370,140 m E - 3,746,387 m N
Discharge tunnel: 11S 370,193 m E - 3,746,362 m N

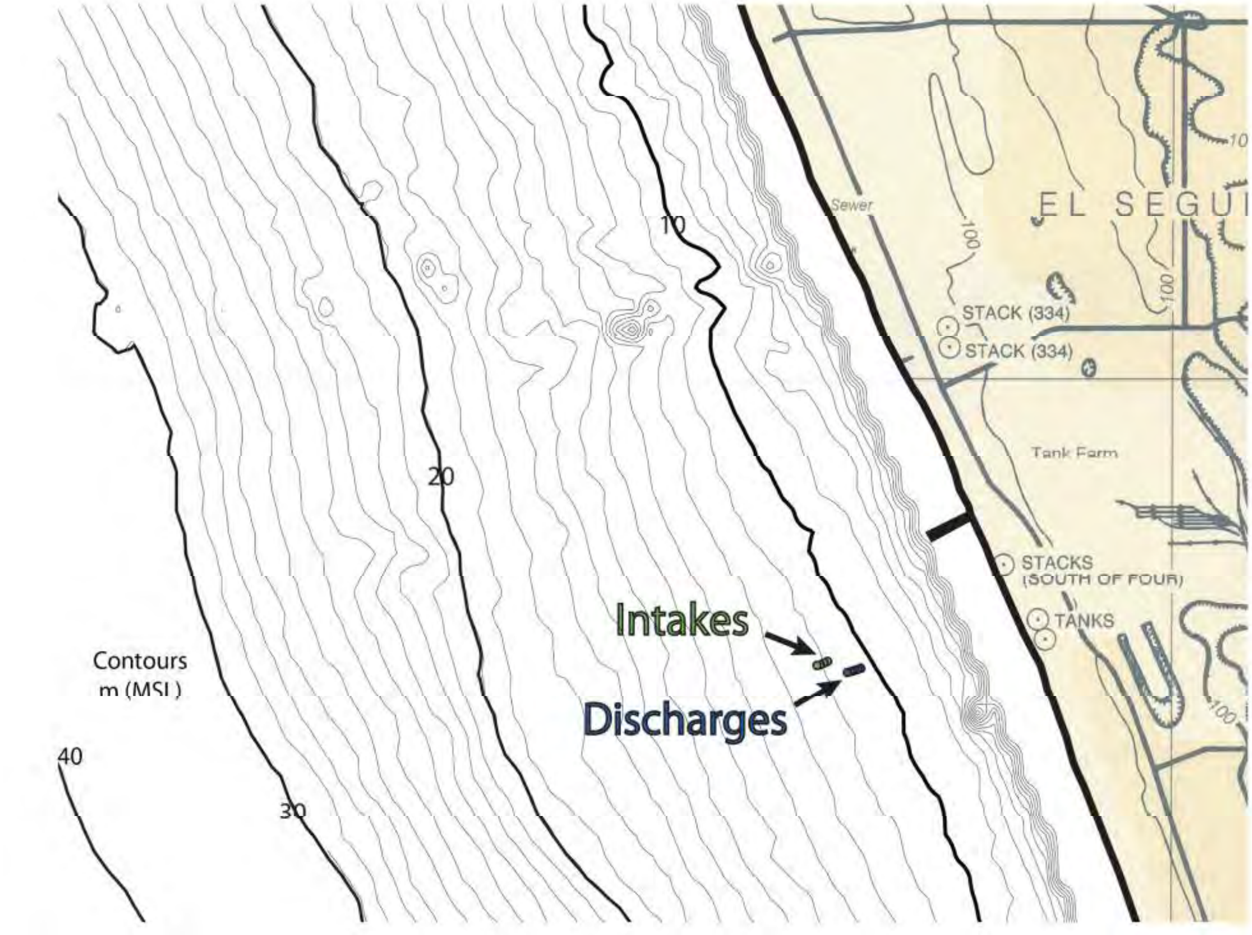


Figure 4.3 Nearfield bathymetric grid centered on the ESGS site for the West Basin Municipal Water District's proposed sea water desalination. Bathymetry from NOS with survey corrections by Tenera (2007).

El Segundo end of tunnel coordinates in UTM (m) are:

Intake tunnel: 11S 367,576 m E - 3,752,769 m N
Discharge tunnel: 11S 367,720 m E – 3,752,820 m N

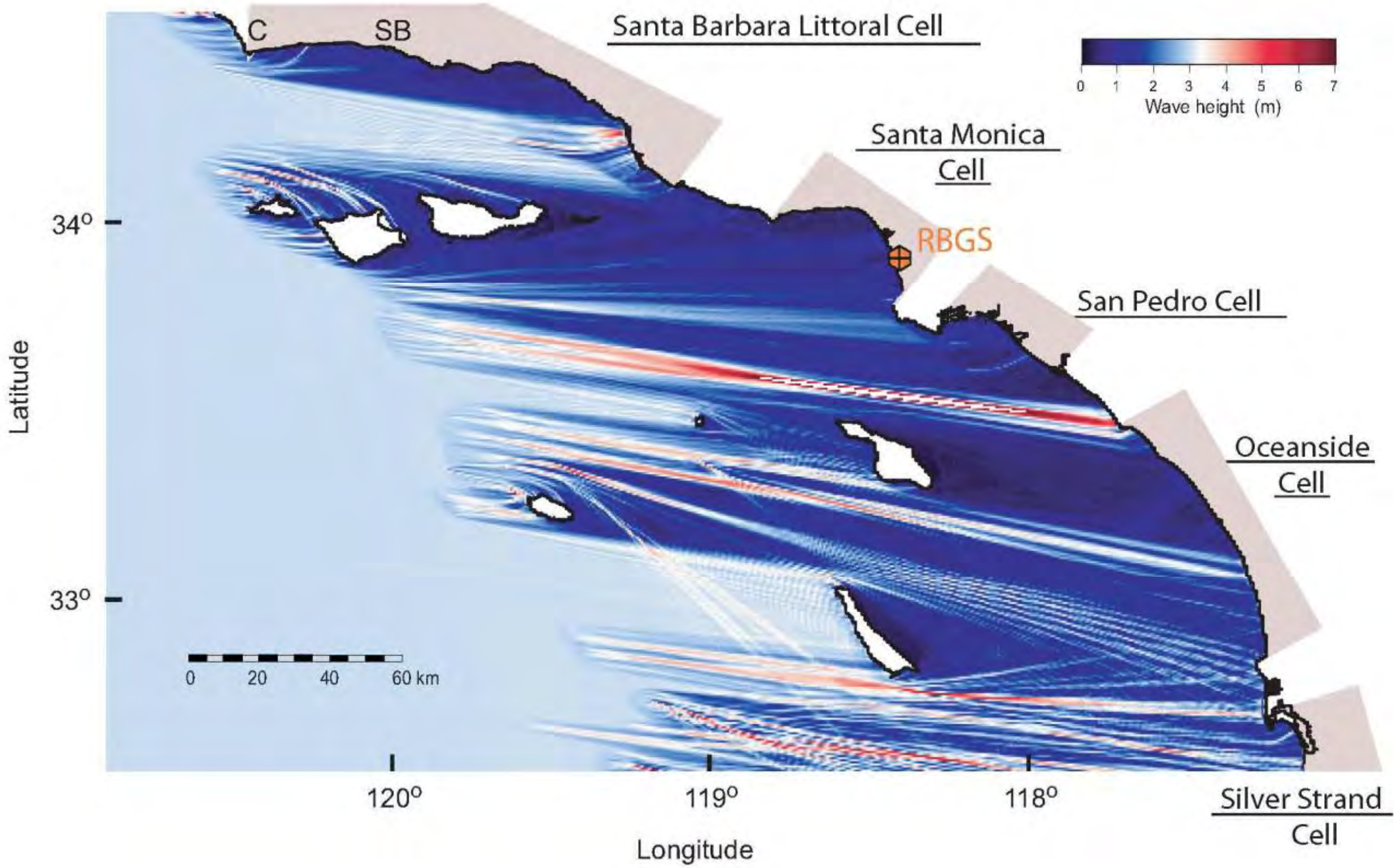


Figure 4.4: Farfield refraction/diffraction for broad-scale littoral sediment transport calculations in the Santa Monica Littoral Cell based on NOS digital bathymetry. Refraction/diffraction based on storm of 13 January 1993 with 3m deep-water significant wave heights and 15 sec periods approaching Southern California Bight from 285^0

4.2) Discharge Structures. Another concern over beach and shorerise profile variation and critical mass is the possibility of burial of the offshore discharge diffusers at the ESGS and RBGS sites. Figure 4.5 provides engineering drawings of the Phase-2 (60 mgd) discharge riser/diffuser structure designed by ARCADIS for the West Basin Sea Desalination Project at both the RBGS and ESGS sites. At the RBGS site, five such discharge riser/diffuser structures will be place at the end of the discharge tunnel at UTM coordinates 11S 370,193 m E - 3,746,362 mN, at a depth of -6 m to -9 m MSL. The upper panel of Table 3.1 gives the exact location of each of the five discharge riser/diffuser ports in UTM coordinates at the RBGS site. At the ESGS site, the discharge riser/diffuser structures will be place at the end of the discharge tunnel at UTM coordinates 11S 367,720 m E – 3,752,820 m N, also at a depth of -10 m to -11 m MSL. The lower panel of Table 4.1 gives the exact location of each of the five discharge riser/diffuser ports in UTM coordinates at the ESGS site. The discharge riser/diffuser structure consists of a 54 inch diameter feeder pipe buried below the seafloor that delivers the brine discharge to 5 diffuser risers. Each of the 5 risers for the 20 mgd design is 10 inches in diameter, while the riser diameters for the 60 mgd are 16 inches in diameter. For both designs, each riser is fitted with a Tideflex duckbill nozzle angled upward at a 60 degree angle. The duckbill nozzles are self-adjusting to variable flow rate to maintain optimal jet nozzle diameter, and each duckbill stands 7 ft. above the seafloor atop its riser.

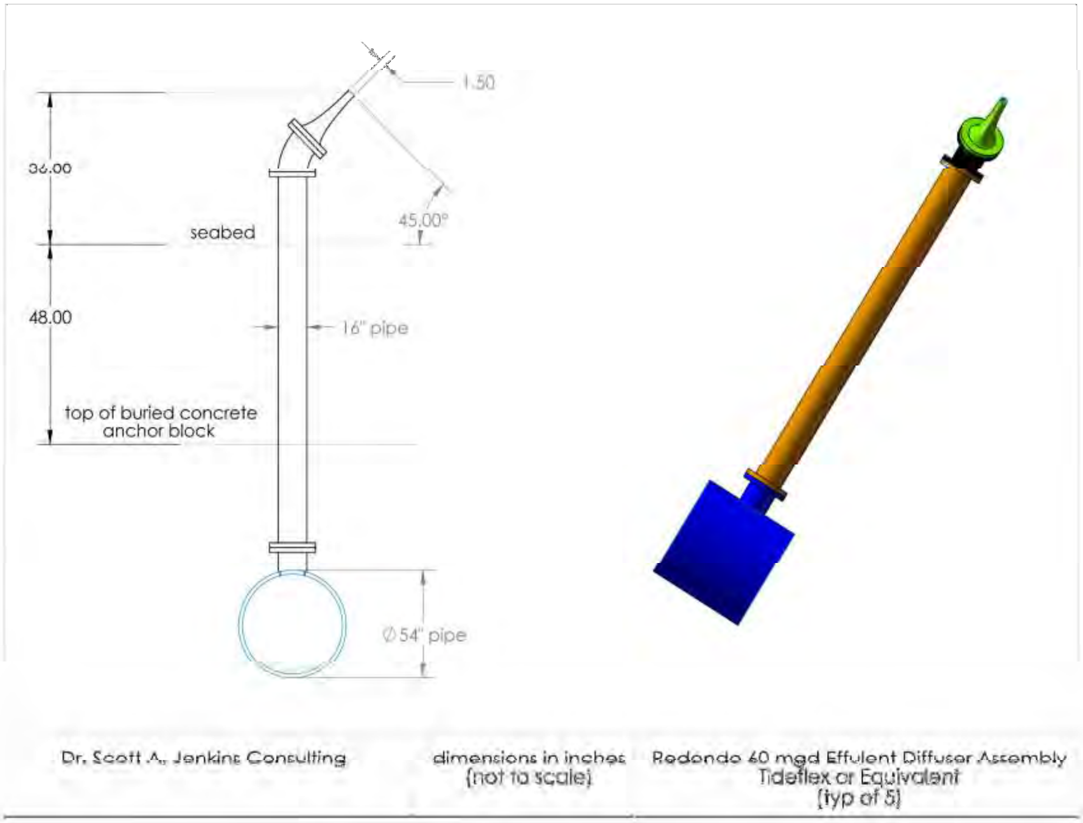


Figure 4.5. Dimensional drawing and 3-d SolidWorks model of discharge riser/diffuser structure to be used in the Phase-2 (60 mgd) by the West Basin Municipal Water District Sea Water Desalination Project. Dimensions based on ARCADIS engineering drawing.

Table 4.1: Discharge Riser/Diffuser Specifications:

Redondo Beach

	Discharge Pipe Center			20 MGD ALTERNATIVE			60 MGD ALTERNATIVE		
	NAD_1983_StatePlane California_V_FIPS_0405_Feet				Discharge			Discharge	
Discharge	Easting (X)	Northing (Y)	UTM (m)	Diameter in	Flow MGD	Velocity ft/s	Diameter in	Flow MGD	Velocity ft/s
Port 1	6,439,220.410	1,767,792.630	11S 370175mE 3746333mN	10	4.03	11.49	16	12.11	14.03
Port 2	6,439,193.040	1,767,780.340	11S 370166mE 3746330mN	10	4.01	11.42	16	12.02	13.94
Port 3	6,439,165.670	1,767,768.050	11S 370158mE 3746326mN	10	3.99	11.37	16	11.97	13.88
Port 4	6,439,138.310	1,767,755.760	11S 370150mE 3746322mN	10	3.99	11.35	16	11.95	13.86
Port 5	6,439,110.940	1,767,743.470	11S 370141mE 3746319mN	10	3.98	11.35	16	11.95	13.85
Total					20.00			60.00	

Depth of discharges at Redondo Beach: -6 m to -9m MSL
Discharge flow rates (low flow case (20 MGD) and high flow case (60 MGD))

El Segundo

	Discharge Pipe Center			20 MGD ALTERNATIVE			60 MGD ALTERNATIVE		
	NAD_1983_StatePlane California_V_FIPS_0405_Feet				Discharge			Discharge	
Discharge Port	Easting (X)	Northing (Y)	UTM (m)	Diameter in	Flow MGD	Velocity ft/s	Diameter in	Flow MGD	Velocity ft/s
Port 1	6,430,947.370	1,788,801.040	11S 367716mE 3752759mN	10	4.03	11.47	16	12.09	14.02
Port 2	6,430,919.810	1,788,789.180	11S 367707mE 3752756mN	10	4.01	11.41	16	12.02	13.94
Port 3	6,430,892.260	1,788,777.320	11S 367699mE 3752752mN	10	3.99	11.38	16	11.98	13.89
Port 4	6,430,864.700	1,788,765.460	11S 367690mE 3752749mN	10	3.99	11.36	16	11.96	13.86
Port 5	6,430,837.150	1,788,753.600	11S 367682mE 3752745mN	10	3.98	11.36	16	11.95	13.86
Total					20.00			60.00	

Depth of discharges at El Segundo: -10 m to -11m MSL
Discharge flow rates (low flow case (20 MGD) and high flow case (60 MGD))

4.3) Sediment Grain Size and Stratigraphy: Grain size of the sediments in the nearshore domain, and their variability with depth in the seabed (stratigraphy) is a leading order variable in both the closure depth and beach/shorerise profile algorithms of the Coastal Evolution Model. The model is initialized using 7 seafloor cores taken at in the nearfield of the RBGS & ESGS, see APPENDIX-A. The closure depth solutions and elliptic cycloid profile solutions that determine the burial and erosion potential of the intake and discharge end-works are functions of the seabed sediment grain size (Jenkins and Inman, 2006). There is a unique solution for the volume of critical mass for any arbitrary selection of grain size in the bar-berm, D_1, and the shorerise, D_2. Regional seafloor sediment characterization by USACE, (2006) for region around ESGS and RBGS has produced the grain size distribution shown in Figure 4.6. According to the boring logs in Appendix-A, the upper 20 ft. of sediment cover can be characterized by this grain size distribution. Accordingly, the top 20 ft. of seabed sediments are comprised of 82% sand sized sediment and 18% fines consisting of very fine sand, silts and clays. Below 20 ft. from existing grade lens of brown, blue a gray clays are found, believed to be derived from ancient lagoonal deposits that underlie the King Harbor breakwaters and adjacent potions of the shelf. In the top 20ft of sediment, median grain size is about 220microns, fairly typical of fine sand beaches found throughout the lower Southern California Bight. The wet bulk density of these seafloor sediments is 1.63 g/cm^3 with a water content of 47.4%. The sediments also contain about 3.38% organics, again associated with ancient lagoonal deposits. These grain size values are inputs to the elliptic cycloid solutions (12) – (15) after Jenkins and Inman (2006).

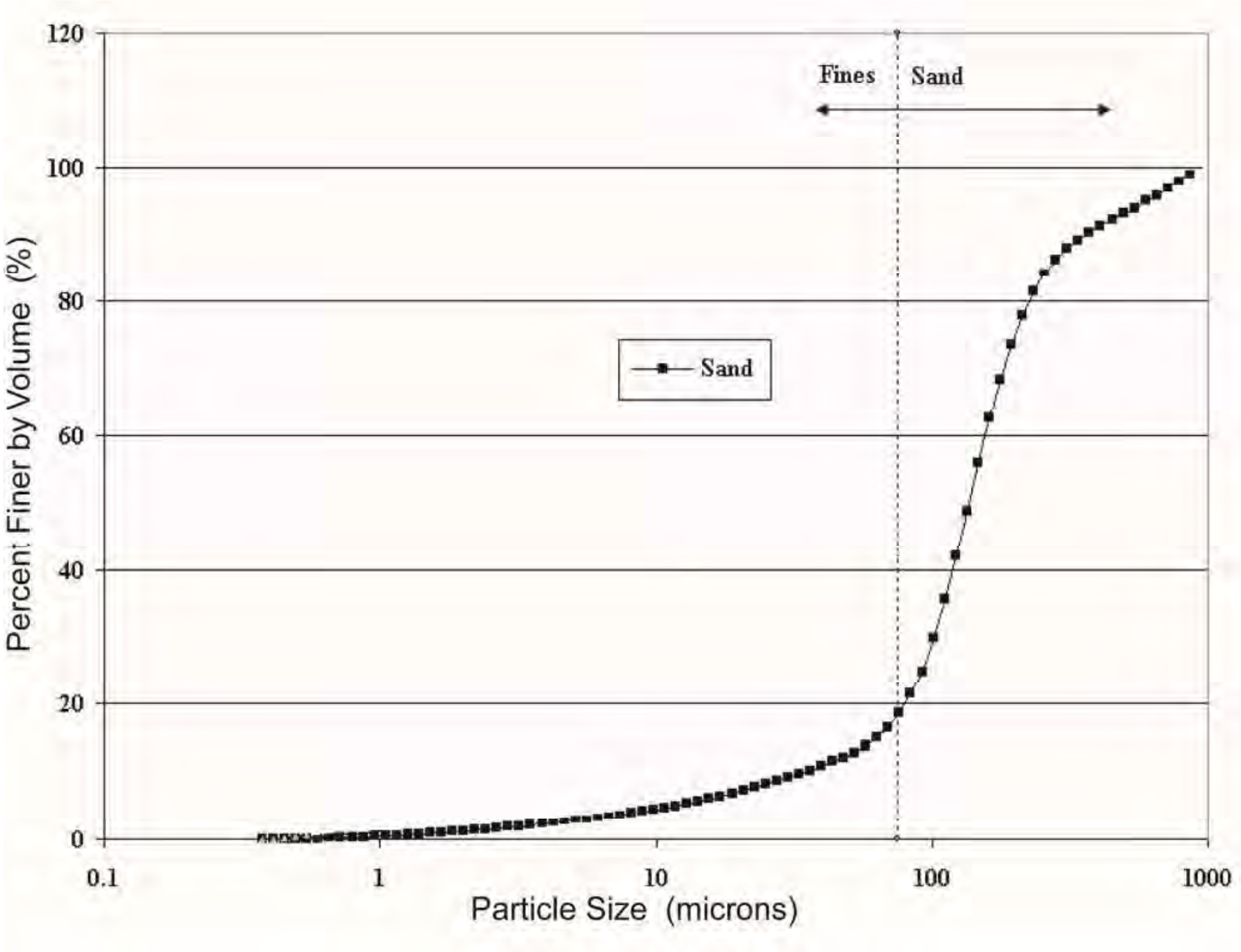


Figure 4.6: Sediment grain size distribution as measured by Coulter-Counter for Santa Monica Bay near the El Segundo and Redondo Beach project sites. (From USACE, 2006, APPENDIX-A).

4.4) Beach and Shorerise Profiles: Non-Stationary bathymetry is the domain of seafloor inshore of closure depth that varies over time in response to beach erosion and accretion. It is measured periodically with beach and shorerise profiling conducted by the US Army Corps of Engineers (USACE) in the neighborhood of the Chevron Groin and the Redondo King Harbor. These measurements are archived in the reports USACE, (1999 and 2001), and the profiles for the ranges relevant to the seabed stability around the ESGS and RBGS sites are plotted Figures 4.7 and 4.8, respectively. These measurements are used to calibrate the beach and shorerise profile algorithms in the Coastal Evolution Model. Measured beach and shore-rise profiles across the south fillet beach at the Chevron Groin near the ESGS site are plotted in Figure 4.7 between June 1991 and September 1997. This is the down-drift beach at the groin and typically represents the most eroded profiles in the nearfield of the ESGS site; thereby capturing the worst case scenario at this site. Figure 4.8 shows the measured beach and shore-rise profiles across the fillet beach at the north breakwater of the Redondo King Harbor near the RBGS site, monitored by the U.S. Army Corps of Engineers, Los Angeles District, between April 1980 and July 1994. These measurements are used to calibrate the beach and shorerise profile algorithms in the Coastal Evolution Model.

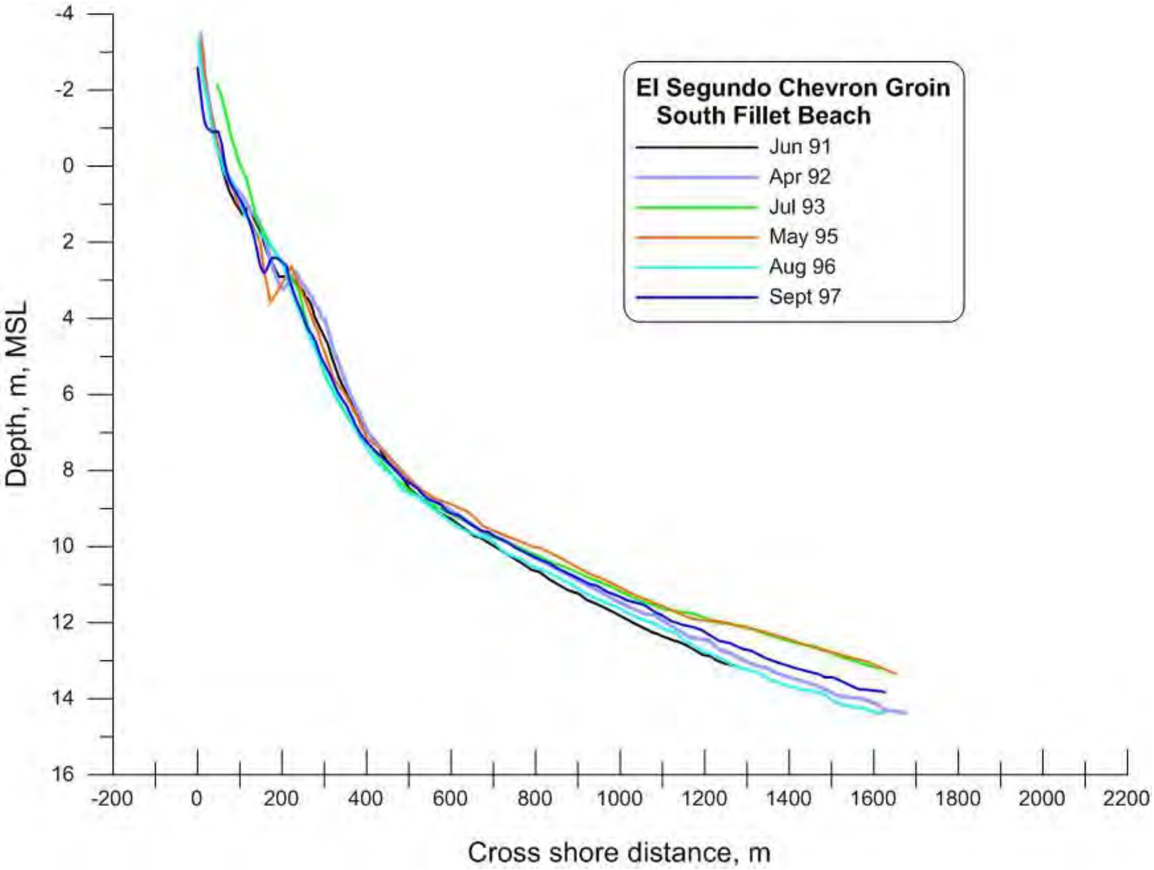


Figure 4.7: Measured beach and shore-rise profiles at the Chevron Groin near the ESGS site, (cf. Figure 4.1), monitored by the U.S. Army Corps of Engineers, Los Angeles District, between June 1991 and September 1997. Data from USACE, (1999 and 2001).

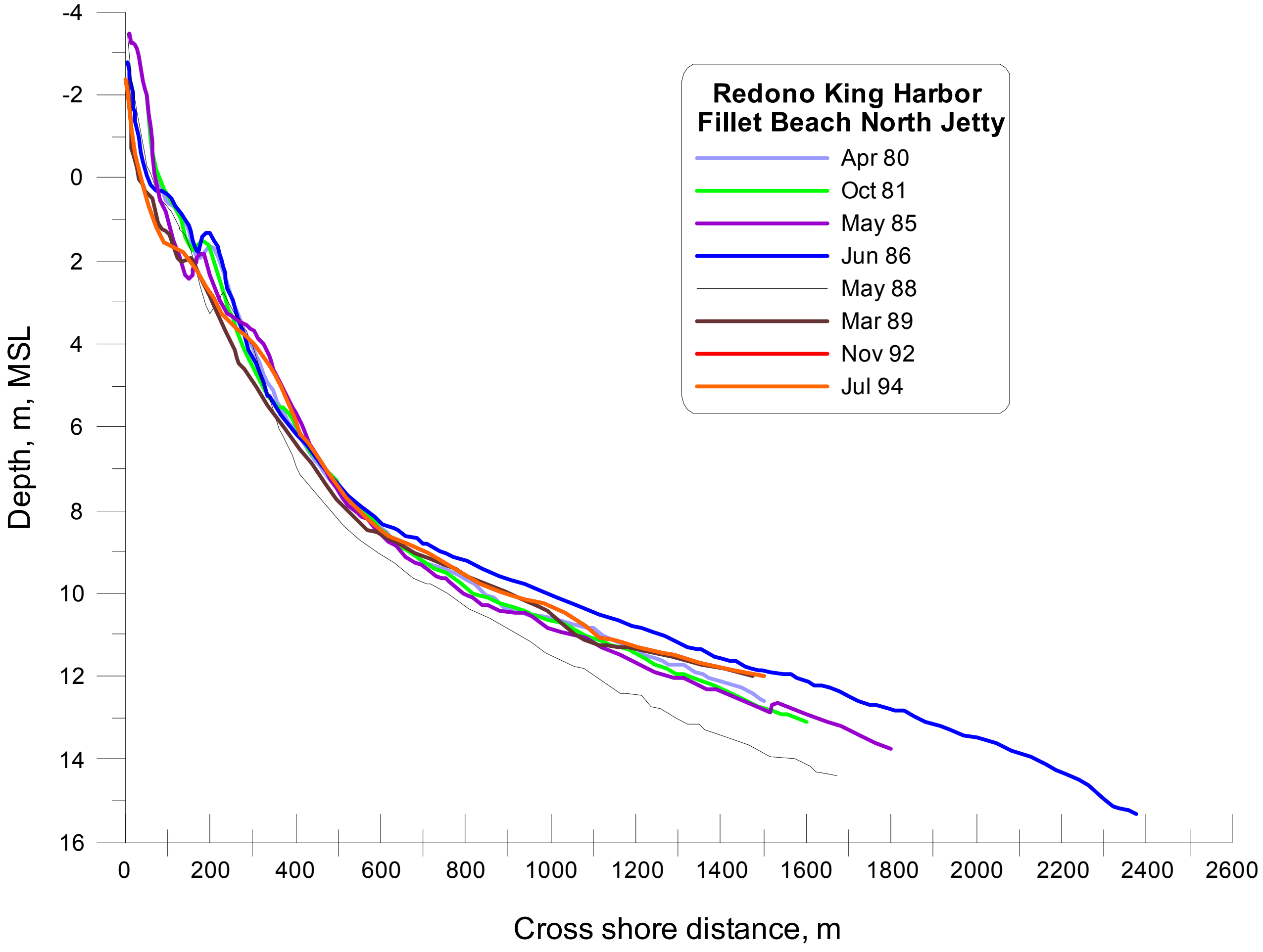


Figure 4.8: Measured beach and shore-rise profiles at the north breakwater of the Redondo King Harbor near the RBGS site, (cf. Figure 4.2), monitored by the U.S. Army Corps of Engineers, Los Angeles District, between April 1980 and July 1994. Data from USACE, (1999 and 2001).

4.5) Sediment Flux from River Floods: River sediment flux is the most persistent source term in the sediment budget of the Santa Monica Littoral, and is due to the discharges from three major creeks: Calleguas Creek, Malibu Creek, and Ballona Creek, represented by the *J(t)* term in equation (3). The USGS has published annual mean flow volumes since 1940 and daily event based runoff volumes for these creeks during water years 1997-98 and 1998-99 (USGS, 2000). The upstream drainage of these creeks has a combined area of 1,146 square kilometers. The annual mean flow volumes at the USGS gage stations on these creeks for the period of record of 1940-99 are listed in Inman and Jenkins, 1999. The peak flow event was in 1983, and no comparable floods have occurred since 1998.

The sediment yield data induced by rainfall variation is derived by applying sediment rating curves to the annual mean stream flow of the three major creeks of the Santa Monica Littoral Cell. The rating curves were derived in a two-step procedure [e.g., Brownlie and Taylor, 1981a&b]. This procedure utilized a limited amount of daily sediment flux measurements available under two separate USGS monitoring programs, namely: 1) the Hydrologic Benchmark Network; and 2) the National Stream Quality Accounting Network (USGS, 1997). Rather than seeking rating curves between annual flow volume and annual sediment flux per Brownlie and Taylor (1981a), better correlations are obtained between daily cumulative flow volume, (V_i, m^3/day) and daily sediment yield (J_i, tons/day), see Inman and Jenkins, (1999). These data were fitted to a power function $J_i = \xi Q^{\omega}$, where (ξ, ω) are statistically derived constants (per equation 9) that give daily estimates of sediment flux from the Calleguas Creek, Malibu Creek, and Ballona Creek over the period of record of the CEM simulations. For the Calleguas Creek, $\xi = 4.13 \times 10^{-9}$ and $\omega = 1.892$; for the Malibu Creek, $\xi = 5.04 \times 10^{-9}$ and $\omega = 1.872$; while for the Ballona Creek $\xi = 2.14 \times 10^{-9}$ and $\omega = 1.996$. Sediment flux data for these three creeks are plotted in Figures 4.9 through 4.11. There it is shown that sediment flux from the Calleguas Creek and Malibu Creek, is an order of magnitude greater than that of the Ballona Creek, where annual mean sediment flux from the Calleguas Creek is $J = 0.62 \times 10^6$ metric tons per year; and the Malibu Creek is $J = 0.72 \times 10^6$ metric tons per year as compared to only $J = 0.014 \times 10^6$ metric tons per year for the Ballona Creek. These values are used as sediment source inputs to the CEM sediment budget analysis for the Santa Monica Littoral Cell.

4.6) Sediment from Beach Disposal of Dredge Material: Another important input to the sediment source term *J(t)* in the CEM sediment budget (equation 1) is beach disposal of dredge material, otherwise referred to as *beach nourishment*. Beach nourishment has been especially active in the Santa Monica Littoral Cell for many years, principally due to beach disposal of dredge material from Marina Del Rey. With over 4,700 boat slips and a design depth of 20 feet, it is the largest man-made harbor in the United States. By law, the United States Army Corps of Engineers (Corps) is responsible for keeping the Marina's entrance and main channels navigable and safe for all users.

As such, the Corps dredges sediment from the main channel an average of every three to five years and places on average 150,000 cubic yards (CY) on neighboring beaches (Figure 4.12). In 1999-2000, the Corps dredged 480,000 CY from the Marina to remove clean and contaminated sediment and restore, its design depth (of 20 feet) in many locations and fully opening both entrances. Although an additional 350,000 CY of dredging occurred in both 2007 and 2009, the Marina had not been fully dredged thereafter to eliminate the vast quantity of contaminated sediment. By fall 2011, both of the Marina's entrances, as well as a portion of the main channel were suffering from the buildup of approximately 1 million CY of sediment from the adjacent Ballona Creek and neighboring beaches. Over 760,000 CY of this sediment was contaminated with toxic chemicals, insecticides, chlordane, and heavy metals, such as arsenic and lead, due to waste and runoff from the Ballona Creek flood control channel. Though only 62% of this contaminated sediment was eventually removed, estimates to dispose of even this smaller amount at a hazardous waste landfill varied between $70.6 and $94.2 million.

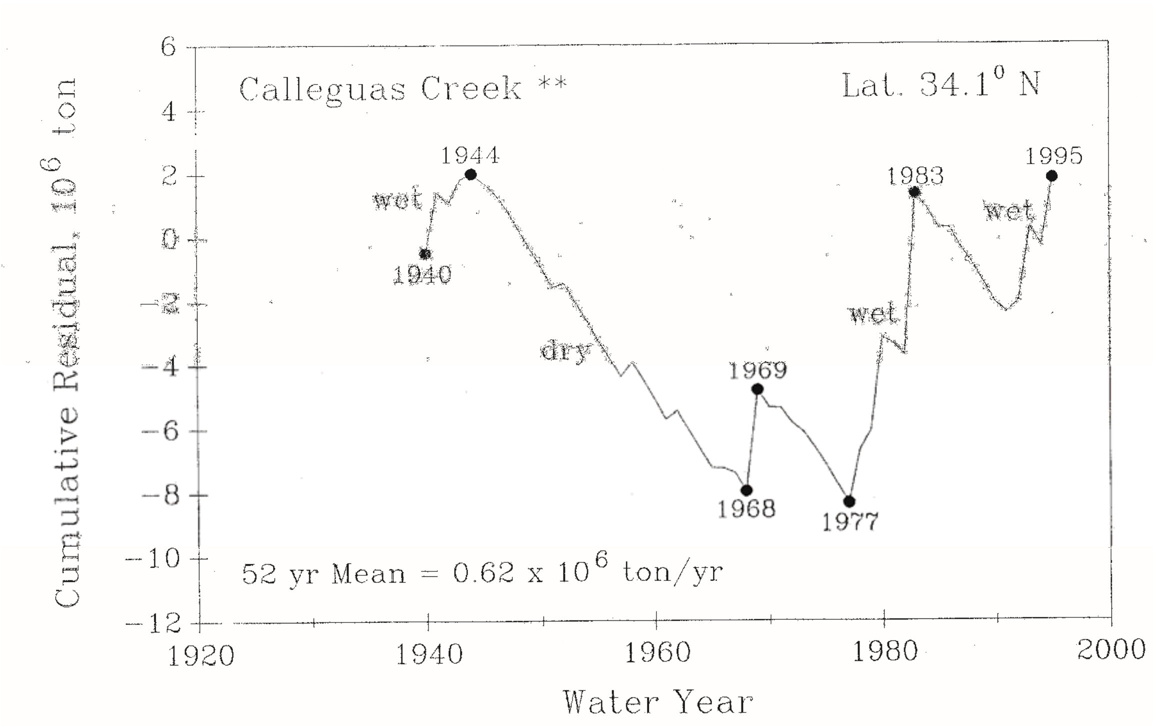


Figure 4.9: Cumulative Residual time series of sediment flux from the Calleguas Creek calculated using data from Inman and Jenkins, (1999) with a 52 year mean, 1945-1995.

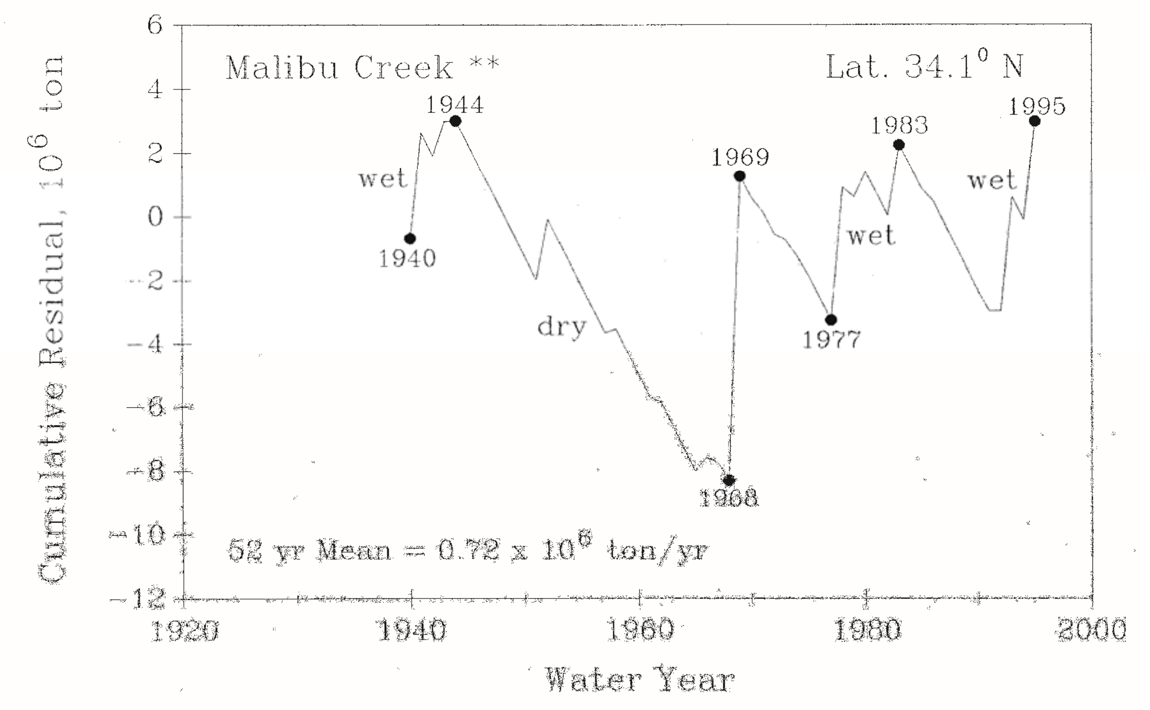


Figure 4.10: Cumulative Residual time series of sediment flux from the Malibu Creek calculated using data from Inman and Jenkins, (1999) with a 52 year mean, 1945-1995.

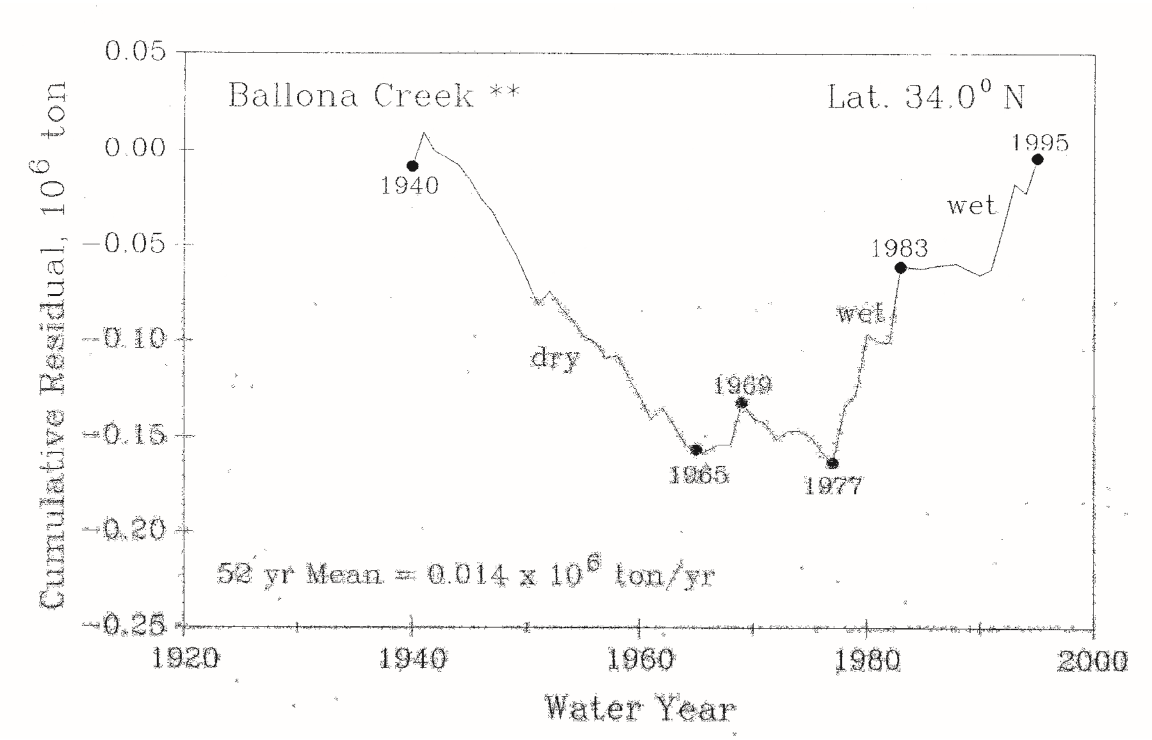


Figure 4.11: Cumulative Residual time series of sediment flux from the Ballona Creek calculated using data from Inman and Jenkins, (1999) with a 52 year mean, 1945-1995.

In October 2011, the Department of Beaches and Harbors and the U.S. Army Corps of Engineers began developing a Maintenance Dredging Project that eventually cleared the entrances of 777,000 total CY, with 471,000 CY of MDR contaminated sediment encapsulated in a pier construction project at the Port of Long Beach and 306,000 CY of clean sediment placed at both Redondo and Dockweiler beaches, as well as offshore at Redondo Beach for use in a future nourishment project. These dredge and beach disposal quantities are used as sediment source inputs to the CEM sediment budget analysis for the Santa Monica Littoral Cell.

4.7) Tides and Ocean Water Levels: The nearest ocean tide gage station is at Santa Monica Pier (NOAA # 941-0840). However, continuous ocean water level measurements are only available at this station after 1995. To fill the period of record prior to 1995 we use the tide gage records at Los Angeles (NOAA #941-0660). For the pre-1995 period we choose the Los Angeles tide gage in preference to the King Harbor tide gage due to the uncertainties associated with gage subsidence at King Harbor. The Los Angeles tide gage (NOAA #941-0660) was last leveled using the 1983-2001 tidal epoch. Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in **METERS** are as follows:

HIGHEST OBSERVED WATER LEVEL (11/13/1997) = 2.332 m
MEAN HIGHER HIGH WATER (MHHW) = 1.624 m
MEAN HIGH WATER (MHW) = 1.402 m
MEAN TIDE LEVEL (MTL) = 0.839 m

MEAN SEA LEVEL (MSL) = 0.833 m
MEAN LOW WATER (MLW) = 0.276 m
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD) = 0.058 m
NGVD29 = 0.700 m
MEAN LOWER LOW WATER (MLLW) = 0.000 m
LOWEST OBSERVED WATER LEVEL (12/17/1933) = -0.874 m

4.8) Waves: Waves are the principle driving mechanism of mixing and current ventilation in the very nearshore region off the RBGS and ESGS sites. This wave dominated region consists primarily of the surfzone but extends seaward into the wave shoaling zone a few surf zone widths beyond the point of wave breaking. Waves are also the most difficult of the 8 controlling variables to get long unbroken records. The availability of wave data in the lower Southern California Bight is what limited the period of record for this long term model analysis to 1980-2004. Waves have been routinely monitored at several locations in the lower Southern California Bight since 1980 by the Coastal Data Information Program, (CDIP, 2004).

In considering the wave climate of the Santa Monica Bay and Redondo Beach/El Segundo area, the sheltering effects of the Channel Island System must be taken into account. Figure 4.4 shows that only certain gaps or “wave windows” between the islands and intervening land masses will allow the high energy, long period swells of distant storms to reach RBGS and ESGS area. Because these island sheltering effects are directionally dependent, it is not sufficient to use wave monitoring data that does not include wave direction. Wave energy and direction have been routinely monitored at several locations in the lower Southern California Bight since 1980 by the Coastal Data Information Program, (CDIP, 2004). The nearest CDIP directional wave monitoring sites are:

a) Huntington Beach Array

Station ID: 072
Location: 33 37.9 North, 117 58.7 West
Approximately 1 mile west of lifeguard headquarters at Huntington Beach, CA
Water Depth (m): 10
Instrument Description: Underwater Directional Array
Measured Parameters:

- ○ Wave Energy
- ○ Wave Period
- ○ Wave Direction

b) San Clemente

Station ID: 052
Location: 33 25.2 North, 117 37.8 West1000 ft. NW of San Clemente Pier
Water Depth (MLLW): 10 m
Instrument Description: Underwater Directional Array
Measured Parameters:

- Wave Energy
- Wave Period
- Wave Direction

c) San Pedro

Station ID: 092
Location:
33 37.07 North, 118 19.02 West
Water Depth (MLLW): 457 m
Instrument Description: Datawell directional buoy
Measured Parameters:

- Wave Energy
- Wave Period
- Wave Direction

d) Santa Monica Bay

Station ID: 028
Location:
33 51.27 North, 118 37.98 West
Water Depth (MLLW): 365 m
Instrument Description: Datawell directional buoy
Measured Parameters:

- Wave Energy
- Wave Period
- Wave Direction

e) Sunset Beach

Station ID: 027
Location: 33 42.30 North, 118 4.20 West
Water Depth (MLLW): 8 m
Instrument Description: directional array
Measured Parameters:

- Wave Energy
- Wave Period
- Wave Direction

e) Begg Rock

Station ID: 138
Location: 33 22.80 North, 119 39.80 West
Water Depth (MLLW): 110 m
Instrument Description: buoy
Measured Parameters:

- ○ Wave Energy
- ○ Wave Period
- ○ Wave Direction

These data sets possessed gaps at various times due to system failure and a variety of startups and shut downs due to program funding and maintenance. The undivided data sets were pieced together into a continuous record from 1980-2004 and entered into a structured preliminary data file. The data in the preliminary file represent partially shoaled wave data specific to the local bathymetry around each monitoring site. To correct these data to the nearshore of RBGS and ESGS, they are entered into a refraction/diffraction numerical code, back-refracted out into deep water to correct for local refraction and island sheltering, and subsequently forward refracted into the immediate neighborhood of RBGS and King ESGS. Hence, wave data off each monitoring site was used to hindcast the waves at RBGS and King Harbor.

The backward and forward refractions of CDIP data to correct it to RBGS and King Harbor were done using the numerical refraction-diffraction computer code, OCEANRDS. The primitive equations for this code are lengthy, so a listing of the FORTRAN codes of OCEANRDS appear in Jenkins and Wasyl (2005). These codes calculate the simultaneous refraction and diffraction patterns propagating over a Cartesian depth grid. A large outer grid (Figure 4.4) was used in the back refraction calculations to correct for island sheltering effects, while a high resolution inner grid (Figure 4.12) was used for the forward refraction over the local bathymetry around the Palos Verdes Peninsula and the RBGS and ESGS. OCEANRDS uses the parabolic equation method (PEM), Radder (1979), applied to the mild-slope equation, Berkhoff (1972). To account for very wide-angle refraction and diffraction relative to the principle wave direction, OCEANRDS also incorporates the high order PEM Pade approximate corrections modified from those developed by Kirby (1986a-c). Unlike the recently developed REF/DIF model due to Dalrymple, et al. (1984), the Pade approximates in "OCEANRDS" are written in tesseral harmonics, per Jenkins and Inman (1985); in some instances improving resolution of diffraction patterns associated with steep, highly variable bathymetry such as found near the Redondo Submarine Canyon. These refinements allow calculation of the evolution and propagation of directional modes from a single incident wave direction; which is a distinct advantage over the more conventional directionally integrated ray methods which are prone to caustics

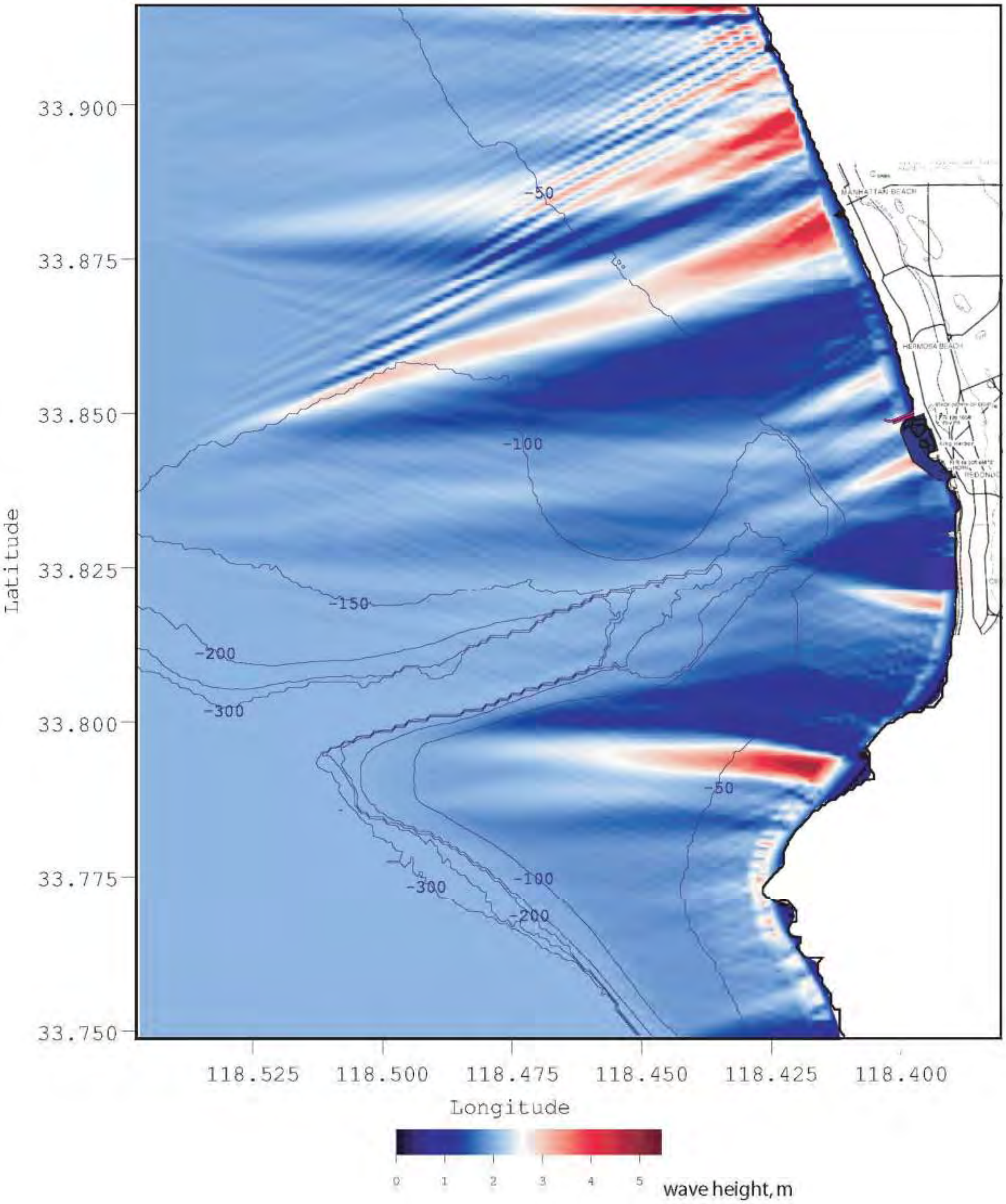


Figure 4.12: Refraction/diffraction pattern in the neighborhood of the RBGS and ESGS sites for the proposed West Basin Municipal Water District Sea Water Desalination Project. Note the large wave shadow in the region between the Redondo King Harbor and the Chevron Groin. Refraction/diffraction calculations based on deep water wave heights = 2.0 m and periods of 15 sec during the 13 January 1993 storm.

(crossing wave rays) and other singularities in the solution domain where bathymetry varies rapidly over several wavelengths.

An example of a reconstruction of the wave field throughout the Bight is shown in Figure 4.4 using the back refraction calculation of the CDIP data from the San Clemente array. Wave heights are contoured in meters according to the color bar scale and represent 6 hour averages, not an instantaneous snapshot of the sea surface elevation. Note how the sheltering effects of Catalina and San Clemente Islands have induced longshore variations in wave height throughout the Southern California Bight. Figure 4.13a shows the significant wave heights inside Santa Monica Bay, with corresponding periods and directions, resulting from the series of back-refraction calculations for the complete CDIP data set at $\Delta t = 6$ hour intervals over the 1980-2004 period of record. The data in Figure 4.13a are values used as the deep water boundary conditions on the nearfield grid (Figure 4.1) for the forward refraction computations into the RBGS and ESGS region (like those in Figure 4.12). The deep water wave angles in Figure 4.13c are plotted with respect to the direction (relative to true north) from which the waves are propagating at the deep water boundary of the nearfield grid (Figures 1.1). Inspection of Figure 4.13a reveals that a number of large swells lined up with the wave windows open to RBGS and ESGS during the El Niño's of 1980-83, 1986-88, 1992-95, and 1997-98. The largest of these swell events was the 1 March 1983 storm, producing 3.5 m deep water swells seaward of the Redondo Submarine Canyon.

Figure 4.12 gives an example of the forward refraction calculation over the nearfield grid of the RBGS and ESGS region for the El Niño storm of 13 January 1993. Although the swells in deep water from this storm were 2 m high, we find in Figure 4.12 that the refraction effects over local bay bathymetry create areas to the south of the King Harbor and to the north of the Chevron Groin where heights increase to 4 m. In these areas, the bay and submarine canyon bathymetry has focused the incident wave energy and these regions of intensified wave energy are referred to as "bright spots." In this case the bright spot is caused by the narrowing of the shelf in the vicinity of the Redondo Submarine Canyon. The increased wave heights in these bright spots increase the mixing and turbulence generated over the seabed boundary layer and by oscillatory wakes of the intake and discharge riser structures. This increases the mixing and dilution rates of the heavy brine that disperses along the seabed into the bright spots. Conversely, the dark areas in Figure 4.12 between the Chevron Groin and the north breakwater of King Harbor where wave heights have been diminished are termed "shadows," and represent areas of reduced mixing and retarded dilution rates. For the 13 January 1993 storm, the area around the RBGS Unit 5-6 discharge is indeed in a shadow zone, while the ESGS site is a "bright spot". In shadow zones adjacent to bright spots, wave-driven currents (sometimes referred to as mass transport) flow away from the bright spots and towards the shadow zones; thereby causing offshore flow in the form of rip currents.

Refraction patterns of the type shown in Figure 4.12 were generated for each of the 8,920 deep water wave events in Figure 4.13 between 1980 and the middle of 2004. The resulting arrays of local wave heights, periods and directions were throughput to CEM for continuous littoral cell analysis (divergence of drift).

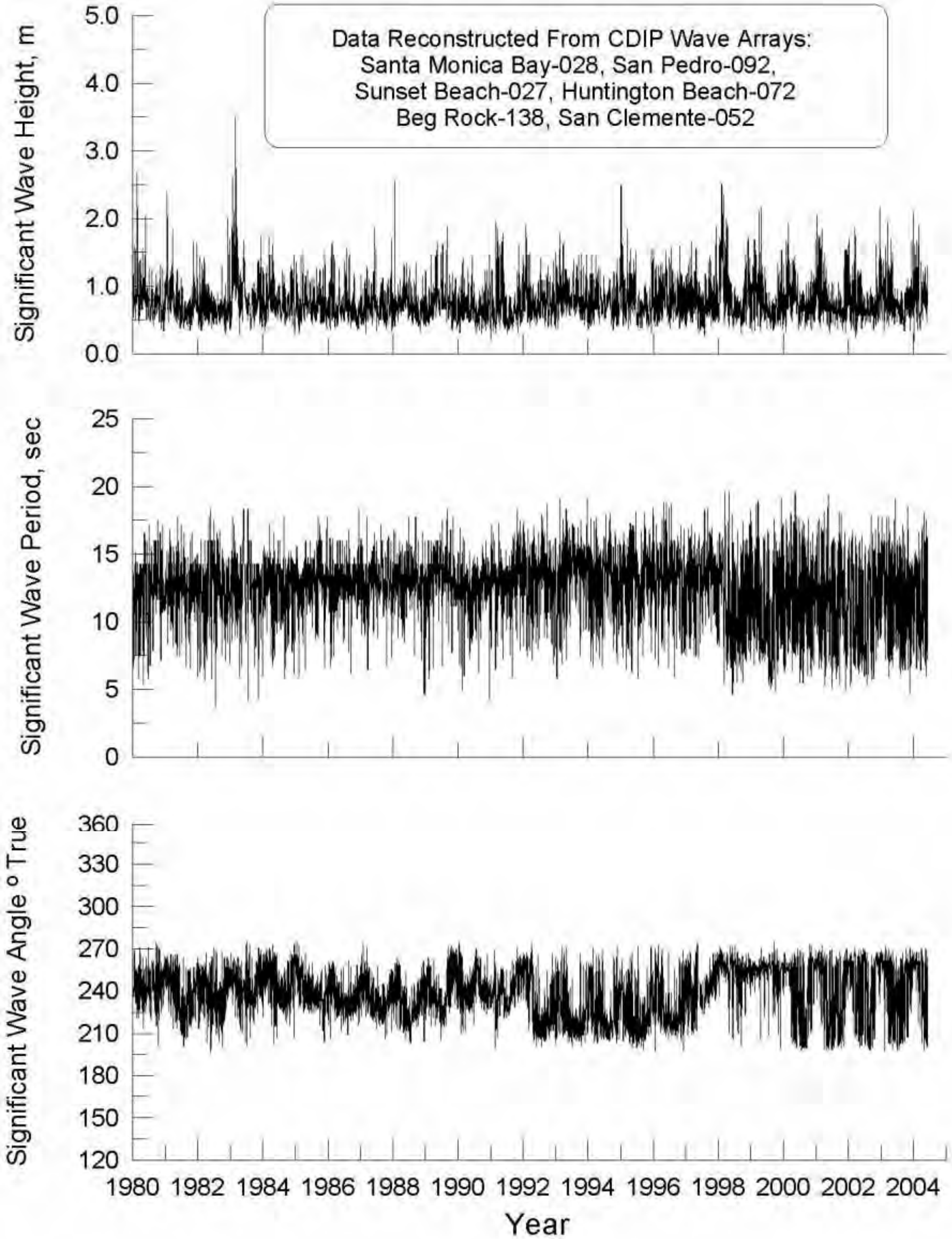


Figure 4.13: Wave data reconstructed from the farfield refraction/diffraction analysis of CDIP measurements. These data used as deep water boundary conditions on the nearfield sediment budget and divergence of drift calculations (see Section 5)

4.9 Currents: While waves dominate the initial dilution and dispersion of heat and concentrated seawater discharge in the inshore domain, the tidal currents control dilution and dispersion in the offshore domain, particularly in the immediate neighborhood of the ESGS and RBGS discharges. Tidal currents were calculated using the tidal constituents from the tide gage station at Los Angeles (NOAA #941-0660). Current forcing is predominantly tidal in the offshore domain of Palos Verdes and Santa Monica Bay, and is a combination of tidal and wave-induced currents in the nearshore domain.

Tidal currents are mixed semi-diurnal with both progressive and standing components in the mid to inner shelf. Tidal currents flow parallel to the shore in a northwestward direction on flood tide and southeastward on an ebb tide as shown in Figure 4.14. The tidal current speed diminishes towards shore due to friction in the shallow coastal boundary layer, and the phase of the tidal motion varies in the cross-shore direction such that during tidal reversals from ebb to flood, the phase of the inshore motion is lagging the offshore motion (see shore zone in Figure 4.14). The maximum currents in the deep water regions seaward of the Redondo Submarine Canyon are typically 60 cm/sec, and 20 cm/sec in the neighborhood of the ESGS and RBGS discharges. Along the Santa Monica/ El Segundo/Redondo Beach coast, the tidal currents are ebb dominated such that over one tidal day (24 hr 50 min) the net current flows down-coast to the southeast as shown in Figure 4.14. The progressive vector plot in Figures 4.14 is composed of self-scaling vectors in units of cm/sec proportional to the vector length in the lower left hand corner, which represents the largest current vector found anywhere on the plot. Wave induced currents predominate in the nearshore where wave shoaling effects are maximum. Wave induced currents increase with increasing wave height and remain significant over a nearshore domain extending 4 to 5 surf zone widths seaward of the shoreline. They flow longshore generally in the direction of longshore wave energy flux (down-drift). These longshore currents increase with increasing wave height and obliquity and flow away from bright spots in the local refraction pattern (Figure 4.14) and converge on shadows. This convergence results in a compensating seaward flowing current within the shadow known as a "rip current." Even though the dilution of brine by mixing may be less in a shadow, dilution by rip current advection (ventilated dilution) will be increased. As a net result, shadows can sometimes be areas of enhanced overall dilution.

Progressive vector arrays of the type shown in Figure 4.14 were generated for 8,920 tidal days 1980-2004, and the resulting current vectors were throughput to the CEM for continuous divergence of drift modeling.

4.10) Model Calibration: We use the same calibration of the of the elliptic cycloid algorithms of the CEM that was used in Jenkins (2014) and peer reviewed by the Independent Science and Technology Advisory Panel (ISTAP) appointed by the California Coastal Commission to evaluate sub-seabed intake alternatives for the Huntington Beach Desalination Project. To calibrate the wave and current algorithms that drive the CEM for the site specific conditions at ESGS and RBGS, we utilize Acoustic Doppler Current Profiler (ADCP) current data measured by Tenera Environmental between 3 February 2006 and 9 January 2007, (Figures 4.15 – 4.17). In order to calibrate

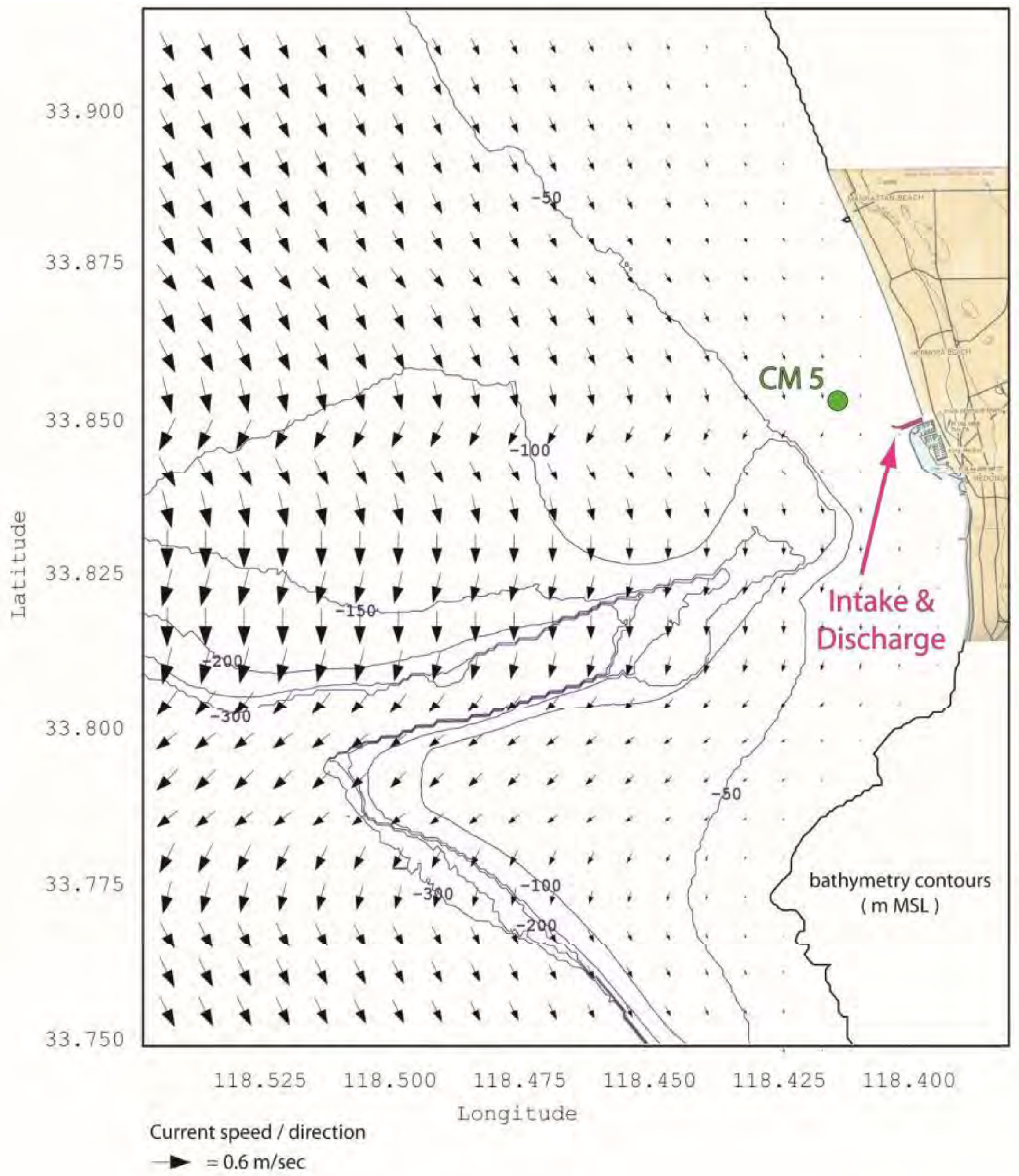


Figure 4.14: Progressive vector plot of net wave and tidal drift in the lower end of the Santa Monica Littoral Cell, 16 March 2016. Current vectors scaled to largest arrow = 0.6 m/s.

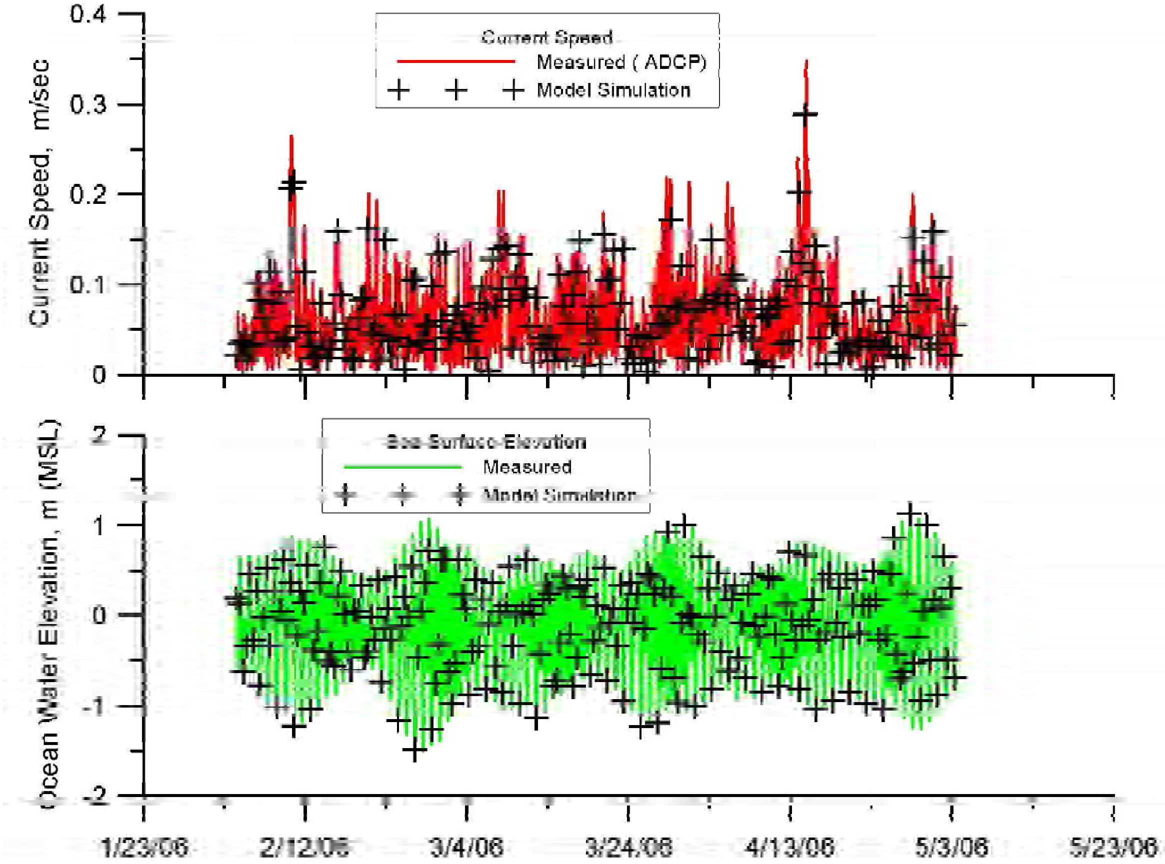


Figure 4.15: Acoustic Doppler Current Profiler data at current meter CM-5 in Santa Monica Bay, 3 February – 3 May 2006. (Data from Tenera Environmental, 2007).

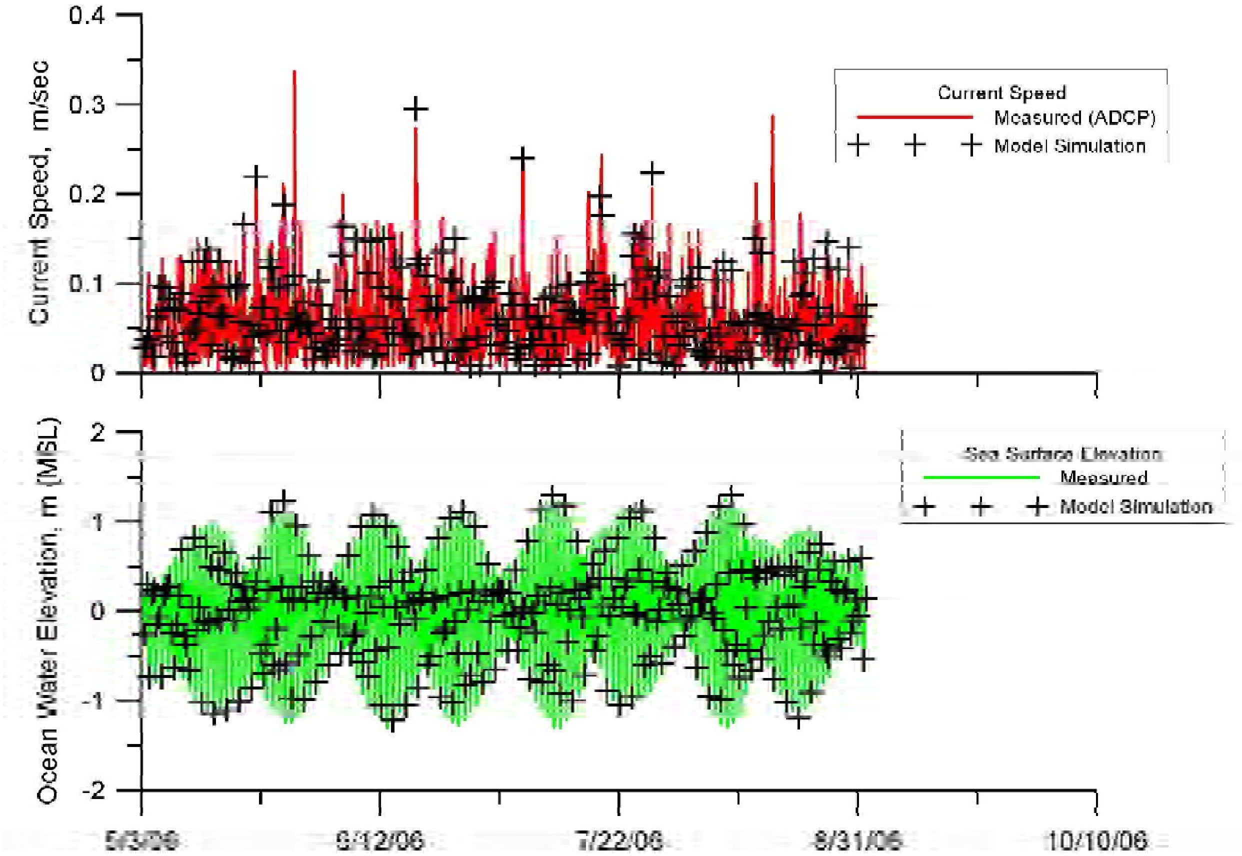


Figure 4.16: Acoustic Doppler Current Profiler data at current meter CM-5 in Santa Monica Bay, 3 May – 1 September 2006. (Data from Tenera Environmental, 2007).

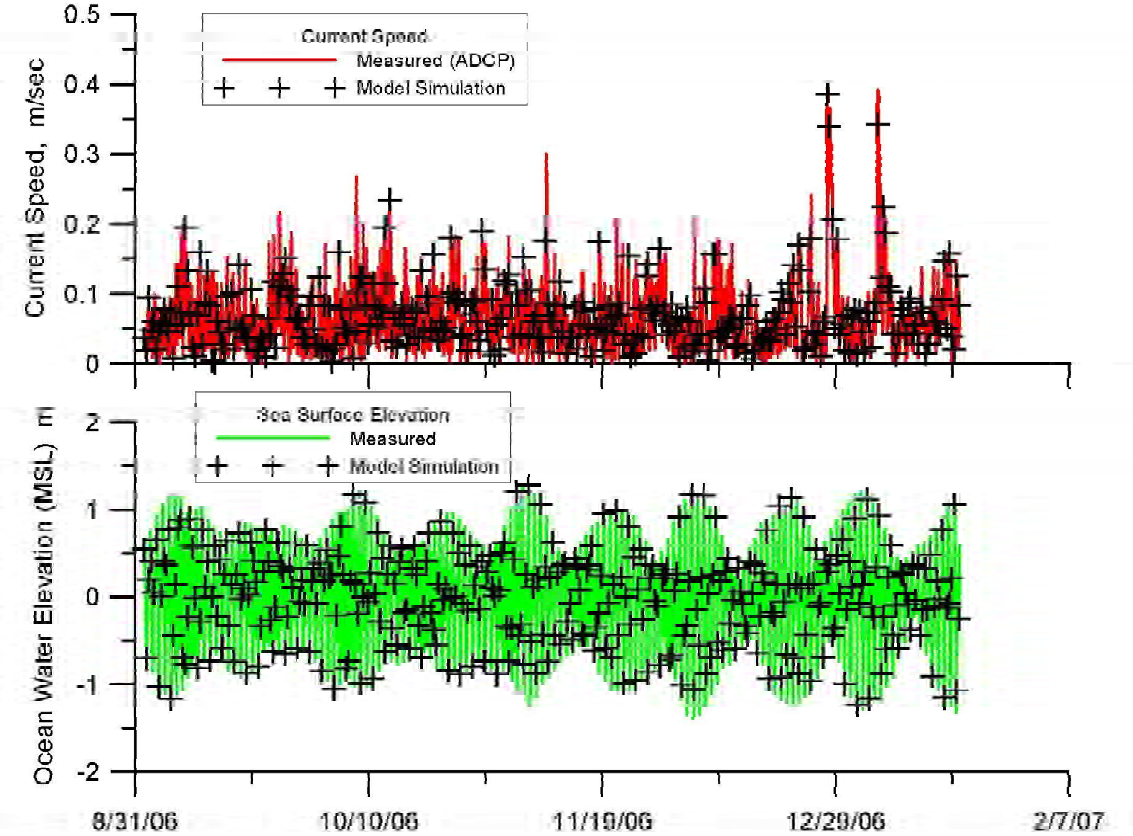


Figure 4.17: Acoustic Doppler Current Profiler data at current meter CM-5 in Santa Monica Bay, 1 September 2006 – 9 January 2007. (Data from Tenera Environmental, 2007).

the CEM current models against the CM-5 ADCP data, the free parameters of the model were adjusted iteratively until the mean square error in the model current prediction was minimized. Comparisons were made between model simulation and current meter measurements at Station CM-5 at the lower end of the Santa Monica Littoral Cell near the ESGS and RBGS sites, as shown in Figure 4.14. The CM-5 velocity measurements were made using an Acoustic Doppler Current Profiler (ADCP) during 316(b) monitoring studies for the RBGS and ESGS facilities performed during the period of 3 February 06 – 19 January 07, (see Tenera Environmental, 2007). In Figure 4.15-4.17, we compare the simulated time series of current speed and water elevations (crosses) at Station CM-5 with the measured time series of current speed (red) and water elevation (green). Inspection of these figures reveals that the model successfully predicts nearly all major current episodes during the year-long monitoring period, as well as the current evolution between times of calm and relatively strong flow. Most of the largest current episodes are due to currents induced by large swells concurrent with spring tides. To quantify the model predictive skill, we perform a regression analysis in Figure 4.18 of the simulated current speed at Station CM-5 against the measured current speed. The coefficient of determination (r-squared) produced by this analysis is $r^2 = 0.87$, which is an excellent calibration result for 2,135 modeled outcomes during the predictive skill test.

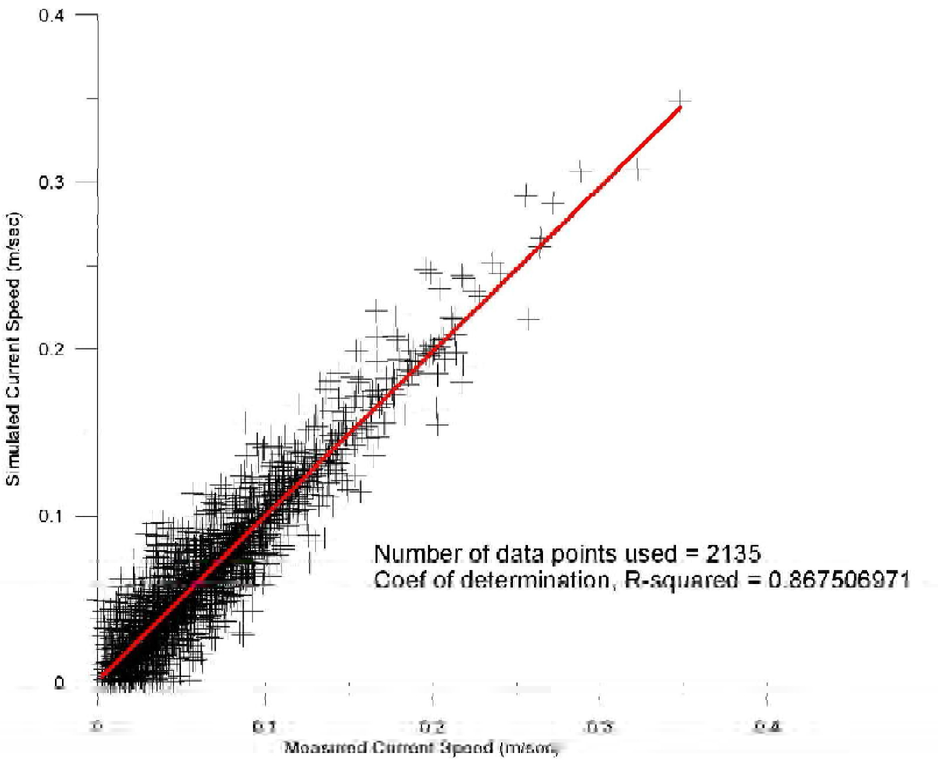


Figure 4.18: Predictive skill of the CEM current calibration using ADCP data from current meter mooring CM-5, February 2006 – January 2007.

5.0 Coastal Evolution Analysis of the Santa Monica Littoral Cell:

The Coastal Evolution Model (CEM) was time-stepped through the 24 year period of record of input variables as detailed in Section 5, (January 1980 through July 2004); producing 8,920 daily solutions at 220 coupled control cells (cf. Figure 3.3 b) along a 19.8 km reach of coast between the Santa Monica Pier and the Redondo King Harbor. In the nearfield of the RBGS & ESGS, computational precision was increased by using the nested inner nearfield grid with 1 arc-second resolution among 238 coupled control cells along a 7.2 km reach of coast between Redondo King Harbor and the Chevron Groin. In the coarse outer grid, the control cells are assigned 90 m spacing along the coastline, and 30 m spacing in the high resolution inner grid. The keystone solutions in each control cell are: 1) the sediment volume flux, *dq/dt,* per unit length of shoreline (m^3/m/day), also referred to as the erosion-deposition flux; 2) the closure depth; and, 3) the critical mass envelope. The sediment volume flux, *dq/dt,* tells us whether the section of coast represented by a particular control cell is eroding ($dq/dt < 0$), or accreting through sediment deposition ($dq/dt > 0$). We use the sediment volume flux to assess the long-term seafloor stability of a particular Neodren^{TM} or other sub-seabed intake site. Ideally an optimal sub-seabed intake site will neither erode nor accrete; and so, we look for the closest places to the RBGS & ESGS where, $dq/dt \to 0$.

The sediment volume flux is calculated by the CEM in each control cell using equation (1). The predominant term is the source term $J(t)$, and the largest sources are the average annual 1.3 million metric tons of deposition from the Calleguas and Malibu Creeks, and the beach-fill that has been placed on Santa Monica and Redondo beaches from dredging of Marina del Rey. However, beach fill sediments do not stay where they were initially deposited, and will propagate down-drift over time as a lump of sediment known as an *accretion/erosion wave*, see Figure 3.3a and Inman and Jenkins (2004c). The formulation of this down-drift migration of the accretion/erosion wave is given by the second term in equation (3), the $V_l\,(dq/dy)$ term, known as *the advective term*. As the accretion/erosion wave migrates down-drift, it also spreads out laterally along the shore line and is reduced in amplitude by the action of the first term in equation (3), referred to as the surf-diffusion term, $\varepsilon(\partial^2 q/dy^2)$. The initial placement of a large amount of sediment in a relatively small area, (whether that be a river delta after a flood or a receiver beach after placement of beach-fill), creates a large along-shore gradient in sediment volume, *dq/dy.* That gradient renders the sediment mass to be highly mobile under the influence of longshore currents, V_l, with additional spreading by surf diffusion. Longshore currents are generated when waves break at an angle to the shoreline, or when there is an along shore variation in wave height; where longshore currents flow down-coast in the direction of wave breaking and flow away from areas of high waves and towards areas of low waves. The formulation for the longshore transport rate of sediment, Q_L, due to the action of the longshore current, V_l, is taken from the work of Komar and Inman (1970) according to:

$$Q_L = K\left(C_n\, S_{yx}\right)_b \qquad (18)$$

where Cn is the phase velocity of the waves; $S_{xy} = E \sin\alpha_b \cos\alpha_b$ is the along shore component of the onshore component of the radiation stress tensor; α_b is the breaker angle relative to the shoreline normal; $E = 1/8\rho g H_b^2$ is the wave energy density; ρ is the density of water; g is the acceleration of gravity; H_b is the breaking wave height; and, K is the transport efficiency equal to:

$$K = 2.2\sqrt{c_{rb}} \tag{19}$$

$$c_{rb} = \frac{2g\tan^2\beta_0}{H_b\sigma^2} \tag{20}$$

Here c_{rb} is the reflection coefficient which is calculated from the nearshore bottom slope, β_0 of the stationary bathymetry as determined from the break point coordinates and the position of the 0 MSL contour; and, σ is the radian frequency = 2π/T, where T is the wave period. The longshore transport velocity, $V_l = \overline{V_l(x)}$ is determined from the longshore current theories of Longuet-Higgins (1970), according to:

$$\overline{V_l}(x) = v_0\left(\frac{10x}{49X_b} - \frac{5}{7}\log\frac{x}{X_b}\right) \qquad \text{if} \qquad 0 \le x \le X_b$$

$$\overline{V_l}(x) = v_0\frac{10}{49}\left(\frac{x}{X_b}\right)^{5/2} \qquad \text{if} \qquad x > X_b \tag{21}$$

$$\text{where: } v_0 = \frac{0.256\pi\beta}{C_D}\sqrt{gh_b}\,\sin\alpha_b$$

Here, X_b is the width of the surf zone derived from the coordinates of the break points (x_b, y_b) that were computed from the CEM refraction analysis. Solutions from equations (18) - (21) give the highest rates of sediment flux in the neighborhood of the break point, $x = X_b$, where the longshore currents approach a maximum value of $\overline{V_l}(x) = v_0$. When the longshore transport rate is averaged over some extended length of time, t_0, the resultant is referred to as littoral drift $\overline{Q}_L$, where :

$$\overline{Q}_L = \frac{1}{t_0}\int_{t_0} KC_nS_{yx}\,dt \tag{22}$$

The net sediment volume flux out of or into a control cell (erosion or deposition, respectively) that results from the action of the advective term in equation (3) is related to the longshore transport rate Q_L by a functional known as the *divergence of drift*, $\nabla \bullet Q_L$, written as:

$$V_l \frac{dq}{dy} = \nabla \bullet Q_L \cong \int \frac{\partial Q_L}{\partial y} dy = KC_n \int \frac{\partial S_{yx}}{\partial y} dy \tag{23}$$

Therefore, the net erosion or deposition of sediment in a control cell due to advective transport by longshore currents (divergence of drift) is proportional to the along shore gradient of the radiation stress tensor component, $S_{xy} = E \sin \alpha_b \cos \alpha_b$. Positive values of radiation stress gradient indicate depositional tendencies, while negative values indicate erosion. Ideally, for a sub-seabed intake site we seek sections of coast where the radiation stress gradient is small and trending to zero. These equations (18-23) relate divergence of drift to the longshore flux of energy at the break point which can be obtained directly from the refraction/diffraction solutions of the CEM, (e.g., Figures 4.12); and is proportional to the square of the near breaking wave height and breaker angle. By this formulation, the CEM calculates a local sediment volume fluxes for control cells in the far-field grid, and in the nearfield grid that are separated by great distances from the primary sources of sediment in the Santa Monica Littoral Cell, in particular beach fill sites at Marina Del Rey and Redondo Beach..

The advective (divergence of drift) term of equation (3) is decisive to the sub-seabed intake siting analysis because it is the mechanism that spreads out the large volumes of river deposition and beach-fill over many kilometers of coastline in southern portion of the Santa Monica Littoral Cell between Santa Monica Pier and the Redondo King Harbor. Divergence of drift and surf diffusion are wave driven, and their magnitudes and variations from place to place in the Santa Monica Littoral Cell depend on the wave refraction/diffraction pattern of the general region, beginning with the initial approach of waves into the Southern California Bight from distant storms. Figure 4.4 shows CEM computations of the refraction/diffraction patterns of the 5 largest storms to enter the Southern California Bight during the 1998 El Nino winter. Many areas of the Bight are sheltered from these waves by the break-water effect of the offshore islands (referred to as *island sheltering*); but there is a significant gap between Catalina Island and the Channel Islands that leaves the southern portion of the Santa Monica Littoral Cell open to waves from the west and north west, while waves approaching from southern hemisphere storms and Mexican hurricanes can freely travel inside of Catalina and San Clemente Islands to arrive at ESGS and RBGS.

Zooming in on local wave shoaling tendencies in the lower Santa Monica Littoral Cell, Figure 4.12 reveals that an abrupt narrowing of the continental shelf seaward of the near the Redondo Submarine Canyon, (creating a large dog-leg in the -40 m to – 250 m depth contours), gives rise to an inner beam of intensified wave energy (red bright spot), that doubles shoaling wave heights immediately north of the Chevron Groin. Immediately south of this bright spot, there is an area of greatly diminished wave energy (blue shadow zone) extending about a kilometer to the south of the ESGS property boundary. Additional bright spots in Figure 4.12 are found at numerous places north of the Chevron

Groin and south of the Redondo King Harbor. These bright spots are consistent with the legacy surfing reputation of Redondo Beach.

The CEM ran 8.920 daily refraction calculations over the January 1980- July 2004 period of record, from which the littoral drift parameters of long-shore current, radiation stress, and radiation stress gradients were obtained for 220 coupled control cells along a 19.8 km reach of coast between Santa Monica Pier and the Redondo King Harbor. Model inputs for these calculations included CDIP monitored waves (cf Figure 4.13), grain size distributions after Figures 4.6 and APPENDIX-A, Calleguas Creek, Malibu Creek, and Ballona Creek sediment flux from, and beach disposal of dredge material from the Marina Del Rey Dredging Project (USACE, 1994; Shad and Ryan, 1996; Weigel, 2009; Gadd et al., 2009). These littoral drift parameters were averaged over the 24 year period of record and their variation along the coast is plotted in Figure 5.1 in terms of distance from the Redondo King Harbor. Dashed trend lines are also overlaid on these plots. Several striking trends are revealed. The variation of the longshore current is plotted in the upper panel of Figure 5.1. The dashed trend line indicates the long-term average longshore current is on the order of 25 cm/s to 35 cm/s, and is directed toward the south everywhere from the sediment sources of Calleguas Creek, Malibu Creek, and Ballona Creek and Marina Del Rey. The longshore current will move (advect) sediment (primarily beach sands) by two transport mechanisms: suspended load transport where sand moves in suspension in the water column; and bedload transport where sand moves in traction along the seabed. Abrupt decelerations in the longshore current indicate locations of chronic rip currents. This southerly persistence and the down-drift intensification indicates that, over time, the longshore current will induce potential transport of beach fill down-coast from Marina Del Rey receiver beaches, dispersing it across other portions of shore zone to the south. This is confirmed by the long-term average of the radiation stress in the middle panel of Figure 5.1. The radiation stress is proportional to the littoral drift, and its trend line is positive, indicating southward-directed transport everywhere between the receiver beaches to the north, down-coast to Redondo King Harbor to the south. The dashed trend line indicates the long-term average radiation stress on the order of 250 N/m to 300 N/m. The alongshore continuity of the long-term average radiation stress indicates that the net littoral drift is a one-way, unidirectional transport stream, a *river of sand* so to speak, flowing away from sediment sources of the creeks and receiver beaches to the north, and flowing toward the Redondo King Harbor and the regional sediment sink a short distance offshore that is the Redondo Submarine Canyon.

The gradient of the radiation stress in the lower panel of Figure 5.1 adds another wrinkle to this transport mechanism. The radiation stress gradient is the dominant factor in determining the magnitude and sign of the divergence of drift. The trend line of the radiation stress gradient has a similar form as that for the longshore current, and is strongly negative immediately south of Marina Del Rey due to the capture of littoral drift sands by the marina’s detached breakwater and groin system, causing the beaches south of the marina to be erosional (with negative radiation stress gradient). This underscores the need for the continuance of the Marina Del Rey Dredging Project; because without

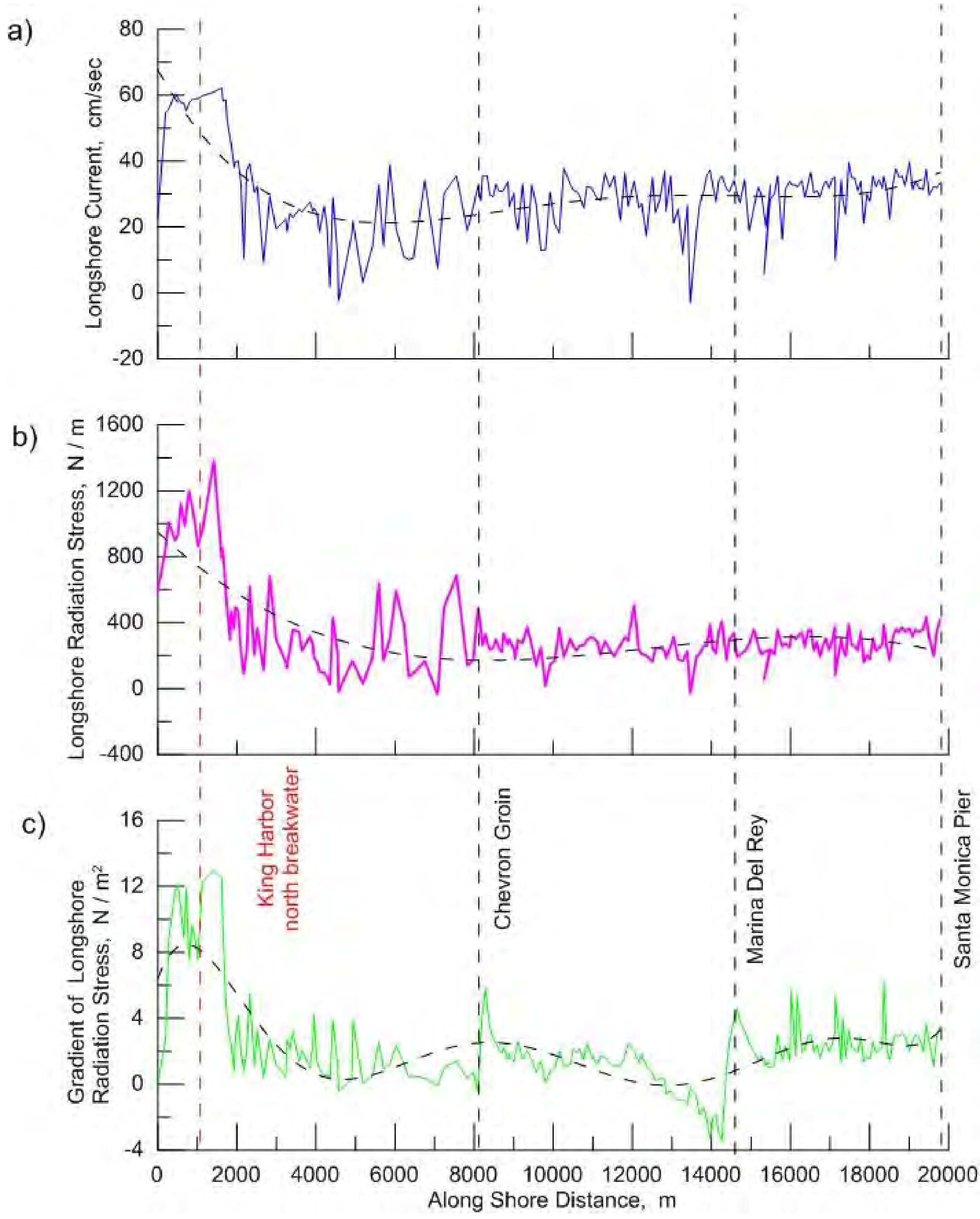


Figure 5.1: Littoral drift parameters at 220 locations between the Santa Monica Pier and Redondo King Harbor, calculated by the calibrated CEM and averaged over the 24-year period of record (1980-2004). Upper panel: longshore current (positive toward the south, negative toward the north). Middle panel: Radiation stress (positive toward the south, negative toward the north). Lower panel: gradient of longshore radiation stress (positive values are depositional and negative values are erosional).

the beach re-nourishment cycles under this program, the strong negative gradient of radiation stress south of the marina assures these beaches will lost. The condition for *loss* of these beaches occurs after they erode to the point to where the no longer retain enough sediment to meet the required critical mass, whence they can no longer support a profile at equilibrium (Jenkins and Inman, 2006). If that happens an *erosion wave* will develop and propagate southward, destabilizing other beaches of the Manhattan and Redondo Beach community (Inman and Jenkins, 2004c).

Of particular interest to the problem at hand is the feature in the long-term gradient in radiation stress (Figure 5.1) to trend weakly negative to neutral south of the Chevron Groin. It is here that the RBGS & ESGS facilities are located. In the lower panel of Figure 5.1, the gradient in radiation stress approaches zero along a 4,000 m section of coast near the RBGS & ESGS facilities. This condition is referred to as *non-divergent littoral drift* and indicates a stable, steady-state condition that is neither erosional nor depositional, an optimal condition of sub-seabed intake site. To the south of this area, the gradient in radiation stress turns positive at the Redondo King Harbor breakwater system while the longshore current is turned offshore by the deflection action of the breakwater, resulting in offshore deposition in and around the harbor entrance.

With this insight, we now turn to CEM solutions using the high-resolution inner grid with 238 coupled control cells along a 7.2 km reach of coast between the Chevron Groin and Redondo King Harbor. In this inner grid we perform the more complex calculations for sediment volume flux solutions to equation (3) for the complete sediment budget. Divergence of drift with its radiation stress gradient factor is only one of 4 terms contributing to sediment volume flux solution. Figure 5.2 gives the solution for the daily sediment volume flux between the Chevron Groin and Redondo King Harbor averaged over the 24-year period of record (1980-2004). Inspection of Figure 5.2 reveals the sediment volume flux trends to zero over a 4000 m reach of coast in the neighborhood of the AES and RBGS & ESGS facilities, indicating this section of coast is stable with minimal erosional or depositional tendencies. Among other lesser factors, this condition arising at this particular location because the divergence of drift is almost nil, i.e., the same amount of littoral drift that arrives at the northern edge of this region also exits this region at the southern edge. Nowhere else is this stable condition found within 7 km to the north or to the south of the RBGS & ESGS facilities. Figure 5.3 shows a potential Neodren^{TM} installation at this optimal site. North or south of this potential Neodren^{TM} site, there are erosional and depositional regions, interspersed at the cross-over points by very short segments of coastline with zero sediment volume flux. However, these cross-over coastal segments between depositional and erosional areas do not embrace sufficient coastline length for a usable sub-seabed intake site. Also, the magnitudes of the non-zero sediment volume fluxes in these neighboring erosional or depositional areas are significant. When factored over 20 years, these non-zero sediment volume fluxes accumulate to 2,000 m^3 to 4000 m^3 per meter of coast, on the order of all the total sediment volume in a critical mass envelope.

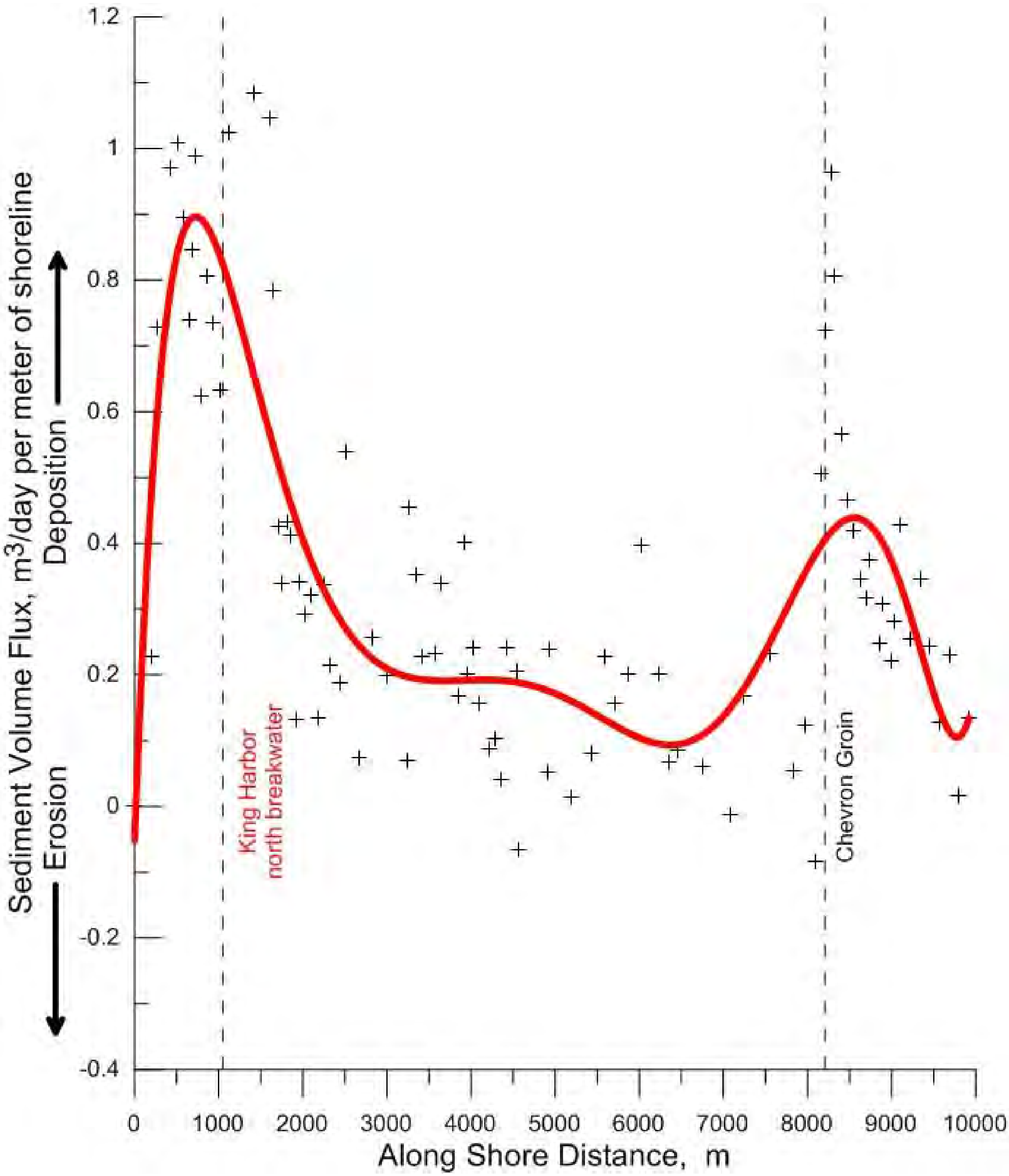


Figure 5.2: Daily sediment volume flux, *dq/dt,* calculated by the calibrated CEM from equation (3) and averaged over the 24-year period of record (1980-2004) for the reach between the Chevron Groin and Redondo King Harbor in the southern end of the Santa Monica Littoral Cell.

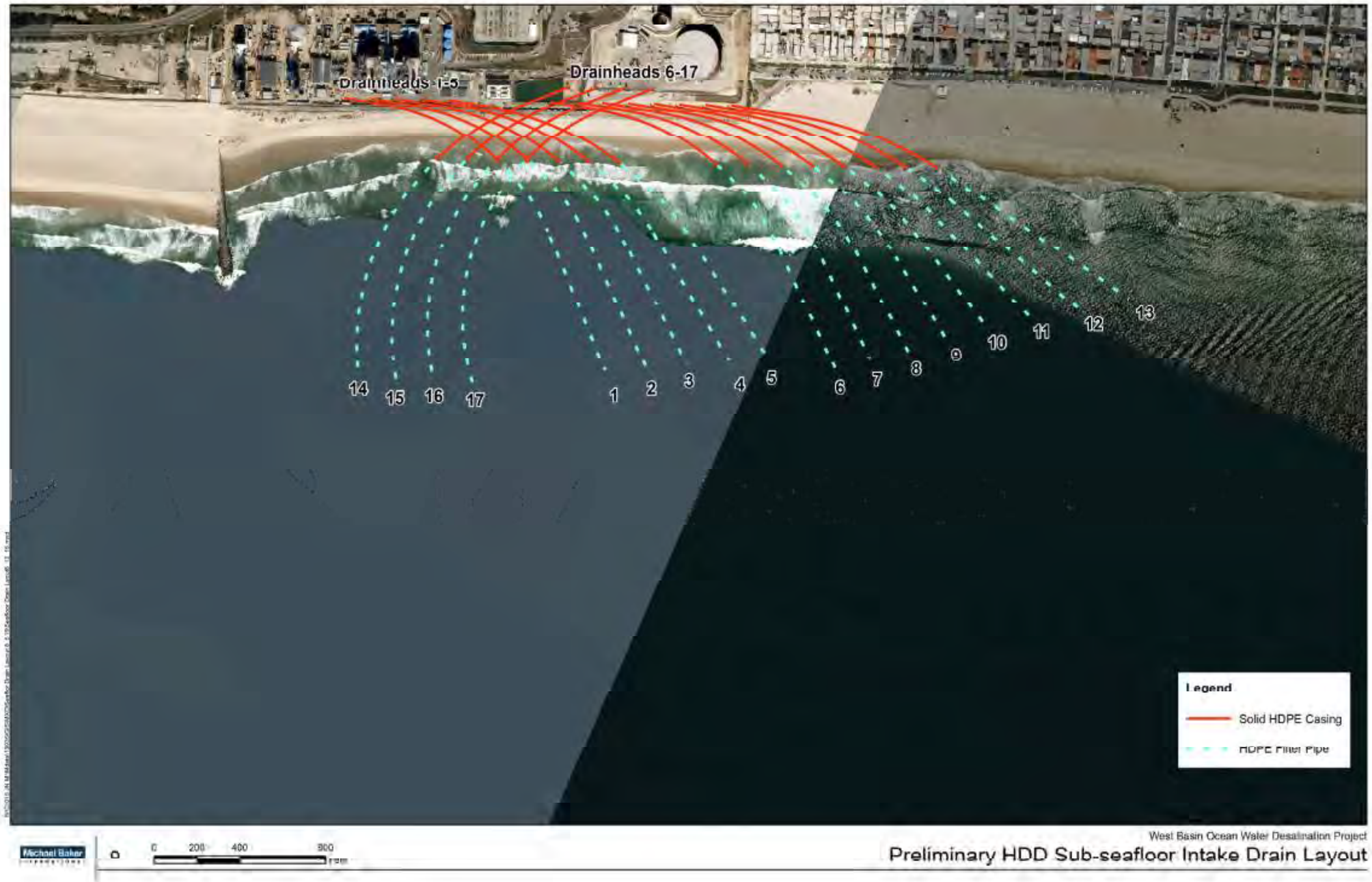


Figure 5.3: Potential Neodren^{TM} installation where the gradient in radiation stress and littoral sediment volume flux approaches zero along a 4,000 m section of coast near the RBGS & ESGS facilities. This condition is referred to as *non-divergent littoral drift* and indicates a stable, steady-state condition that is neither erosional nor depositional, an optimal condition of sub-seabed intake site.

The CEM results in Figures 5.1 and 5.2 identify the location of a potential Neodren^{TM} or sub-seabed intake site along the coastline, but do not provide guidance on how far offshore that site must be for a stable seabed. For that guidance we turn to the CEM solutions for closure depth and critical mass envelope. Fortuitously, the potential site is approximately bracketed by two of the historic US Army Corps of Engineers survey ranges, cf. Figures 4.7 and 4.8. These surveys provide very high confidence to the CEM solutions for closure depth and critical mass at the potential Neodren^{TM} sites. Based on 8,290 solutions over the 1980-2004 simulation period, the CEM calculates in Figure 5.4 that bottom profile perturbations caused by shoaling waves at the ESGS site near the Chevron Groin were found to cease seaward of the -15 m MSL depth contour, referred to as *closure depth*. In addition, the critical mass envelope is relatively thin at the Chevron Groin (Figure 5.5) due to the stabilization action of the groin.

The critical mass determines the volume of sediment cover above the Neodren™ intakes that can be potentially eroded by the action of seasonal and episodic profile change or shoreline recession. The critical mass of sand on a beach is that required to maintain equilibrium beach shapes over a specified time, usually ranging from seasons to decades. The critical mass envelope in Figure 5.5 indicates that sand level variations due to beach profile changes are no more than 3.3 m across the bar-berm beach profile a the ESGS site, and no more than 1.5 m across the shore rise profile off shore. This fortuitous sediment transport behavior was linked to an offshore feature in the continental shelf bathymetry that created a *shadow zone* (area of diminished wave height) in the refraction pattern of the large waves from distant storms (Figure 4.12). Based on the critical mass and closure depth calculations over a 20 year period, we conclude that the HDD pipeline routes posed for Neodren™ intakes provide at least a four-fold margin of safety against exposure by extreme event waves. The ESGS diffuser site as specified in the Master Plan is inside closure depth, but the 7 ft. tall riser pipe/nozzle assemblies on the ARCADIS designed diffusers should provide adequate free-board to prevent burial of the duckbill nozzles at the proposed depths of -10 to -11 m MSL at the proposed ESGS discharge site.

Sand level variations over a Neodren™ system placed off the RBGS site were found to be greater owing to positive divergence of littoral drift and episodic turbidity current activity in the *Redondo Submarine Canyon*. Figure 5.6 shows that historic beach and shorerise profile variations at a survey range on the north side of Redondo King Harbor show significantly greater vertical excursions in sand elevations, and those vertical elevation changes occur further offshore than at the Chevron Groin in Figure 5.4.Comensurate with these empirical data, Figure 5.6 shows a greatly expanded critical mass envelope and deeper closure depths than found at the ESGS site, both based on long term CEM sediment budget calculations. The critical mass envelope in Figure 5.7 indicates that sand level variations due to beach profile changes are 3.6 m across the bar-berm beach profile at the RBGS site, but are also 2 m to 2.4 m across the shore rise profile off shore, while closure depth increases to -15.7 m.

Based on the critical mass and closure depth calculations in Figure 5.6, we conclude that the HDD pipeline routes posed for Neodren™ intakes at the RBGS provide a three-fold margin of safety against exposure by extreme event waves, slightly less than found for the ESGS site but still adequate. The RBGS diffuser site as specified in the Master Plan is inside closure depth, (at a depth of between -6 m and -9 m MSL), but extending the riser pipes on the ARCADIS design

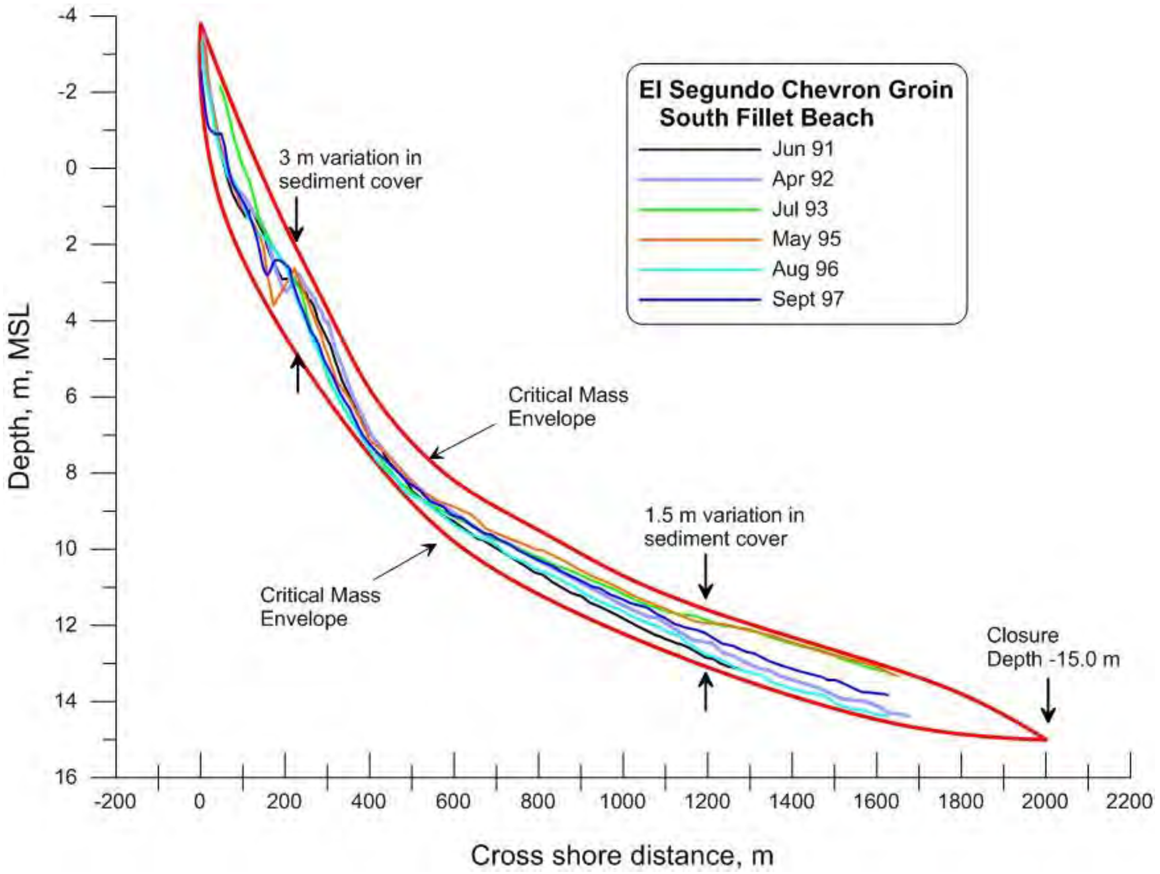


Figure 5.4: Critical mass envelope at historic Chevron Groin survey range, El Segundo, calculated by the calibrated CEM sediment budget based on the 24-year period of record CDIP monitored waves, Calleguas, Balona and Malibu Creek sediment flux APPNEDIX-A, and beach disposal of dredge material from the Marina Del Rey Dredging Project, (USACE, 1994 Measured beach profiles from Gadd et al., 2009. Closure depth = -15 m MSL calculated from equation (7). Critical mass volume = 2,941 m^3 per meter of shoreline calculated from equation (13).

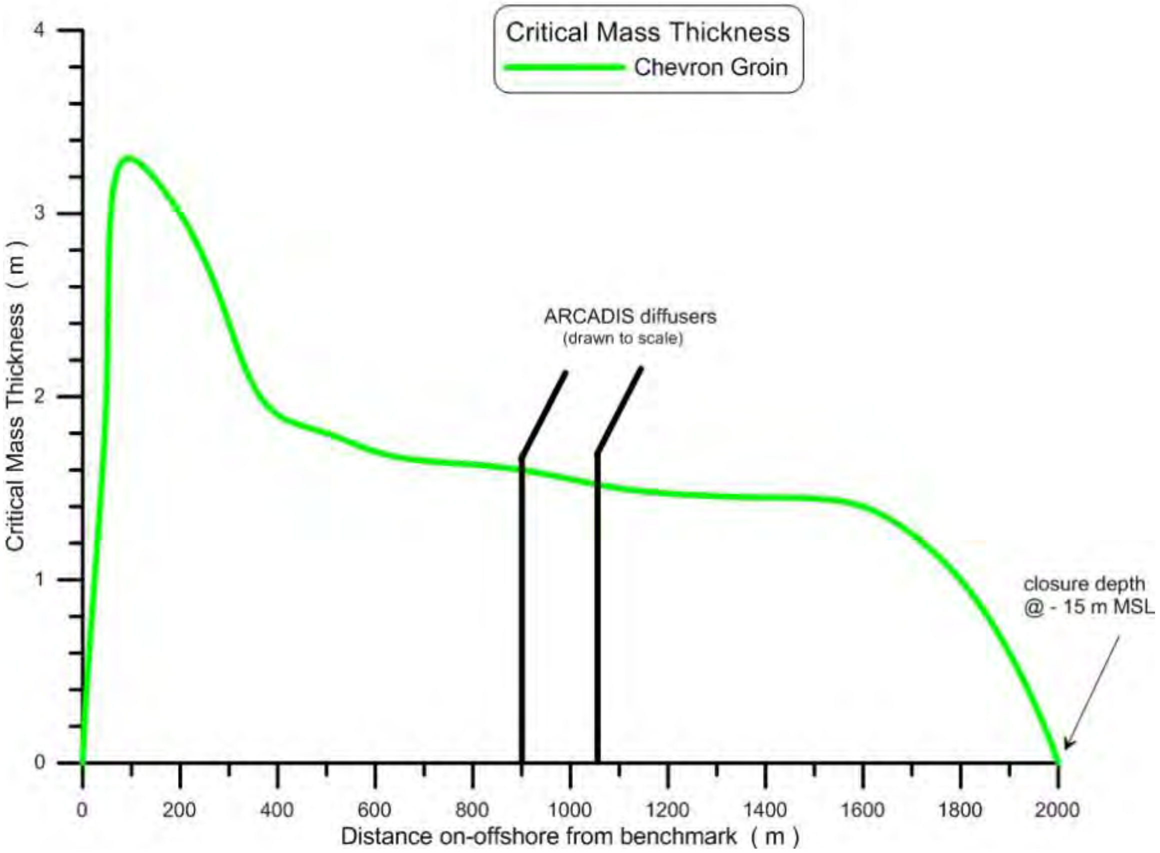


Figure 5.5: Thickness of critical mass envelope at historic Chevron Groin survey range, El Segundo, calculated by the calibrated CEM sediment budget based on the 24-year period of record CDIP monitored waves, Calleguas, Balona and Malibu Creek sediment flux APPNEDIX-A, and beach disposal of dredge material from the Marina Del Rey Dredging Project, (USACE, 1994 Measured beach profiles from Gadd et al., 2009. Closure depth = -15 m MSL calculated from equation (10). Critical mass volume = 2,941 m^3 per meter of shoreline calculated from equation (16). Note ARCADIS diffusers remain above the upper boundary of the critical mass envelope.

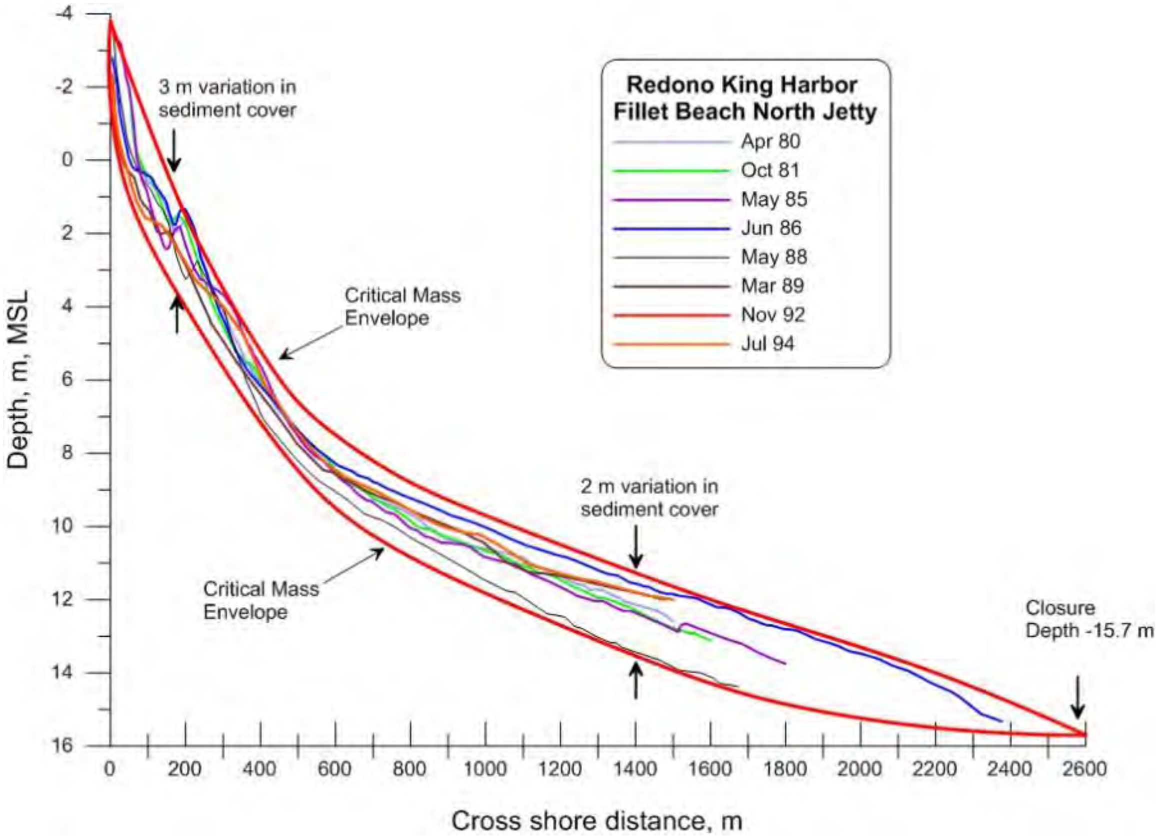


Figure 5.6: Critical mass envelope at historic north fillet beach Redondo King Harbor, Redondo Beach, CA, calculated by the calibrated CEM sediment budget for the 20.6-year period of record (1980-2000) based on CDIP monitored waves, Calleguas, Balona and Malibu Creek sediment flux APPNEDIX-A, and beach disposal of dredge material from the Marina Del Rey Dredging Project, (USACE, 1994). Measured beach profiles from Gadd et al., 2009 and USACE, 1994. Closure depth = -15.7m MSL calculated from equation (10). Critical mass volume = 3,920 m^3 per meter of shoreline calculated from equation (16).

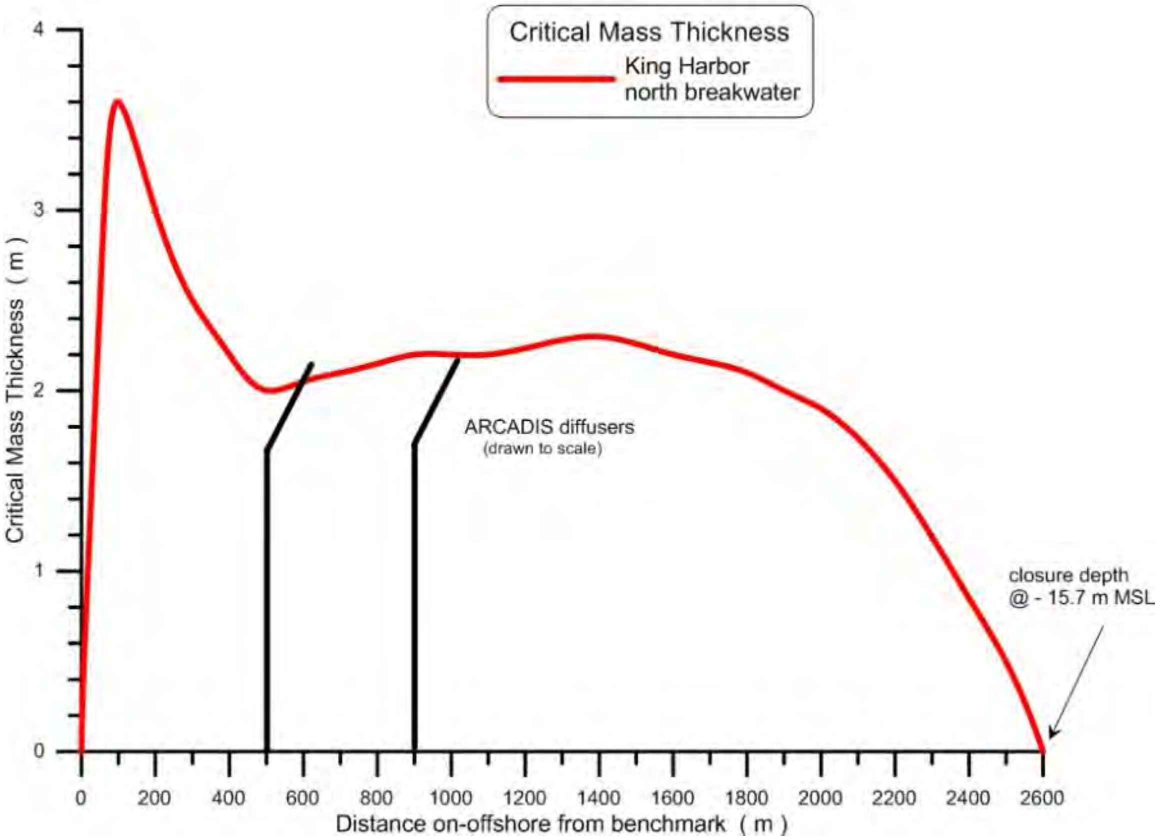


Figure 5.7: Thickness of critical mass envelope at historic north fillet beach at Redondo King Harbor survey range, Redondo Beach, CA, calculated by the calibrated CEM sediment budget based on the 24-year period of record CDIP monitored waves, Calleguas, Balona and Malibu Creek sediment flux APPNEDIX-A, and beach disposal of dredge material from the Marina Del Rey Dredging Project, (USACE, 1994 Measured beach profiles from Gadd et al., 2009. Closure depth = -15 m MSL calculated from equation (10). Critical mass volume = 2,941 m^3 per meter of shoreline calculated from equation (16). Note ARCADIS diffusers remain above the upper boundary of the critical mass envelope.

diffusers by 2 ft. should provide adequate free-board to prevent burial of the duckbill nozzles.

6.0) Conclusions:

This study provides a seafloor stability analysis for shallow sub-seabed intake systems and discharge diffusers for the proposed West Basin Municipal Water District Sea Water Desalination Project which would supplement the District's water resources.

The characteristic of an optimal sea floor for this purpose is one that is neither erosional nor depositional over the long-term, and one that is within a feasible hydraulic pathway to the launch points for the subsurface intake and concentrate discharge facilities. Two candidate sites were considered in Santa Monica Bay. One utilizes existing infrastructure on the site of the AES Redondo Beach Generating Station (*RBGS*). This site was used for the West Basin Municipal Water District's ocean water desalination demonstration facility (DDF). The second candidate site in Santa Monica Bay considered is the NRG El Segundo Generating Station (*ESGS*).

We consider only shallow subsurface intake technology because any subsurface intake system that taps into deep coastal aquifers (e.g. slant wells and vertical wells) would likely have additional environmental permitting issues due to adverse effects upon nearshore groundwater. Therefore we focus on shallow infiltration technologies that rely on minimal sediment cover (on the order of tens of feet) such as: *Sub-surface (seabed) Infiltration Galleries (SIG), Beach Infiltration galleries (BIG),* and advanced horizontal well technology like *the Neodren™ Seawater Intake.*

We review the findings of the *Independent Science and Technology Advisory Panel* (ISTAP) appointed by the California Coastal Commission who considered several coastal processes and construction aspects for implementing SIG and BIG intake technology at the Huntington Beach Desalination Facility (HBDF). The constructability of SIG's and BIG's at the RBGS and ESGS sites is questionable because it requires excavation of a dredged pit to elevations of 10 ft. below ambient seabed in which the infiltration branch pipe segments and engineered fill are subsequently placed, which is problematic and time consuming in high-energy sea states, as are common off the RBGS and ESGS sites. For this reason, the ISTAP concluded that the only sensible construction option for either a SIG or a BIG on an exposed open-ocean coastline is to first build a temporary pier from which the SIG and BIG holes can be dredged and the piping and engineered fill subsequently placed. This was found to be a very expensive construction option at Huntington Beach (these findings are addressed in detail within the ISTAP Phase I and Phase II reports).

On the other hand, the Neodren™ Seawater Intake is insulated from these construction problems due to its directional drilling techniques. Based on these considerations we proceeded with a sediment budget and seafloor stability analysis tailored to the Neodren™ system, as the SIG and BIG alternatives appear more costly and difficult to construct at either the ESGS or RBGS sites.

To make this assessment, we utilized the Coastal Evolution Model (CEM) to solve the sediment budget of the Santa Monica Littoral Cell, and to solve for the properties of the equilibrium beach and shore rise profiles over long historic periods. The Coastal Evolution Model was developed under a $1 million grant by the Kavli Foundation to make forecast predictions of the effects of sea level rise on the coastline of

California, and was validated in the Oceanside Littoral Cell for the same period of record used in the present study.

The CEM determined that the shore-rise and bar-berm seafloor profiles in the neighborhood of Chevron Groin at the ESGS site are neither depositional nor erosional, a steady-state equilibrium condition that is optimal for an intake and discharge site. Based on 8,290 solutions over the 1980-2004 simulation period, the CEM calculates in Figure 5.4 that bottom profile perturbations caused by shoaling waves at the ESGS site near the Chevron Groin were found to cease seaward of the -15 m MSL depth contour, referred to as *closure depth*. In addition, the critical mass envelope is relatively thin at the Chevron Groin (cf: red envelope boundary in Figure 5.4) due to the stabilization action of the groin.

The critical mass determines the volume of sediment cover above the Neodren™ intakes that can be potentially eroded by the action of seasonal and episodic profile change or shoreline recession. The critical mass of sand on a beach is that required to maintain equilibrium beach shapes over a specified time, usually ranging from seasons to decades. The critical mass envelope in Figure 5.5 indicates that sand level variations due to beach profile changes are no more than 3.3 m across the bar-berm beach profile a the ESGS site, and no more than 1.5 m across the shore rise profile off shore. This fortuitous sediment transport behavior was linked to an offshore feature in the continental shelf bathymetry that created a *shadow zone* (area of diminished wave height) in the refraction pattern of the large waves from distant storms (Figure 4.12). Based on the critical mass and closure depth calculations over a 20 year period, we conclude that the HDD pipeline routes posed for Neodren™ intakes provide at least a four-fold margin of safety against exposure by extreme event waves. The ESGS diffuser site as specified in the Master Plan is inside closure depth, but the 7 ft. tall riser pipe/nozzle assemblies on the ARCADIS designed diffusers should provide adequate free-board to prevent burial of the duckbill nozzles at the proposed depths of -10 to -11 m MSL at the proposed ESGS discharge site.

Sand level variations over a Neodren™ system placed off the RBGS site were found to be greater owing to positive divergence of littoral drift and episodic turbidity current activity in the *Redondo Submarine Canyon*. Figure 5.6 shows that historic beach and shorerise profile variations at a survey range on the north side of Redondo King Harbor show significantly greater vertical excursions in sand elevations, and those vertical elevation changes occur further offshore than at the Chevron Groin in Figure 5.4.

Comensurate with these empirical data, Figure 5.6 shows a greatly expanded critical mass envelope and deeper closure depths than found at the ESGS site, both based on long term CEM sediment budget calculations. The critical mass envelope in Figure 5.7 indicates that sand level variations due to beach profile changes are 3.6 m across the bar-berm beach profile at the RBGS site, but are also 2 m to 2.4 m across the shore rise profile off shore, while closure depth increases to -15.7 m.

Based on the critical mass and closure depth calculations in Figure 5.6, we conclude that the HDD pipeline routes posed for Neodren™ intakes at the RBGS provide a three-fold margin of safety against exposure by extreme event waves, slightly less than found for the ESGS site but still adequate. The RBGS diffuser site as specified in the Master Plan is inside closure depth, (at a depth of between -6 m and -9 m MSL), but extending the riser pipes on the ARCADIS design diffusers by 2 ft. should provide adequate free-board to prevent burial of the duckbill nozzles.

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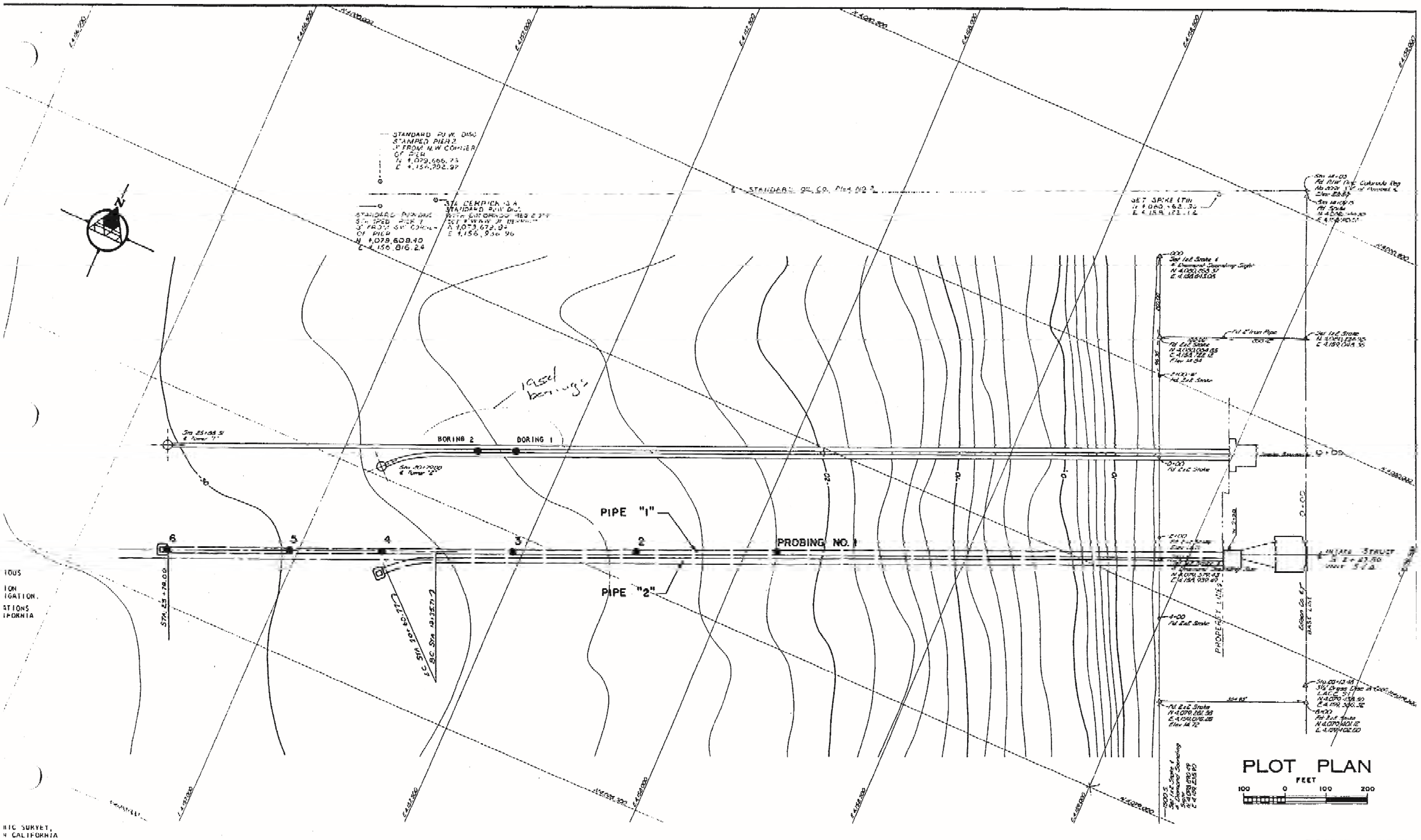
APPENDIX A: Sediment Characterization from Borings at the ESGS and RBGS Sites:



PLOT PLAN

DAMES & MOORE
SOIL MECHANICS ENGINEERS

PLATE 1

BY J.A.M. DATE 1-17-62
CHECKED BY

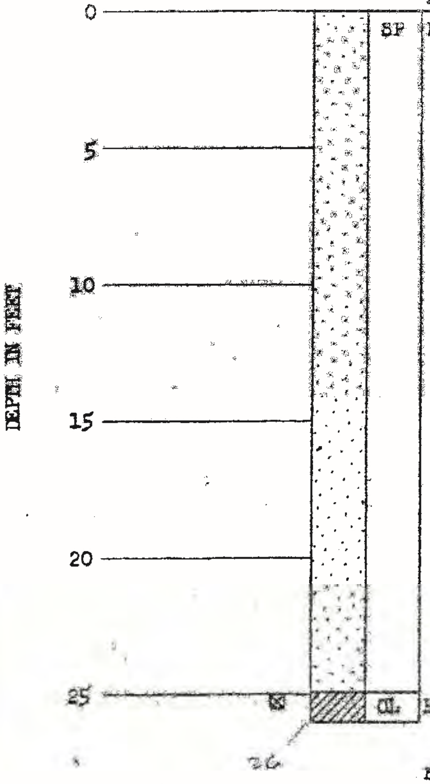
FILE 377-027

CALIF. EDISON CO.

REVISIONS
BY DATE

PROBING NO. 1

ELEVATION: -22.2 FEET



SP BROWN FINE TO MEDIUM SAND WITH SOME GRAVEL

-47.2

JET PIPE COULD NOT PENETRATE BELOW 26'

CL BROWN SILTY CLAY (FIRM)
COULD NOT PROBE BELOW 26'

BORING COMPLETED - 7/10/62

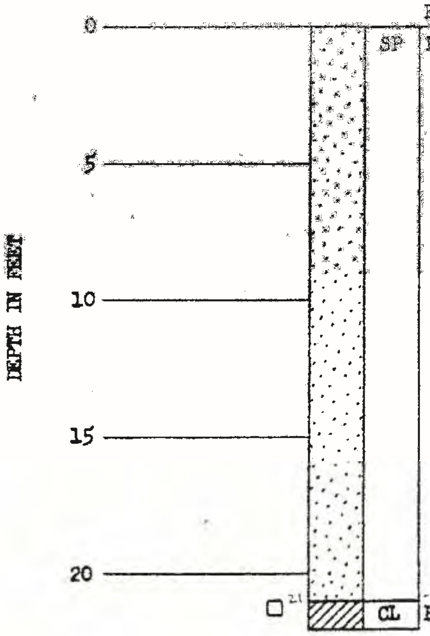
LOG OF PROBING

KEY:
☒ INDICATES DEPTH OF DISTURBED SAMPLE
☐ INDICATES DEPTH OF SAMPLING ATTEMPT
WITH NO RECOVERY
ELEVATIONS REFER TO M.L.L.W. DATUM

DAMES & MOORE
APPLIED EARTH SCIENCES

BY D.A.M. DATE 7-17-62
CHECKED BY
FILE 577-027 Calif. Edison Co.
REVISIONS
BY DATE

PROBING NO. 2



ELEVATION: -25.7 FEET

BROWN FINE TO MEDIUM SAND WITH SOME GRAVEL

MORE GRAVEL WITH INCREASING DEPTH

LARGE GRAVEL DROPPING TO BOTTOM OF
PROBING AS SAND IS WASHED OUT BY JET

BROWN SILTY CLAY (FIRM)
COULD NOT PROBE BELOW 22'

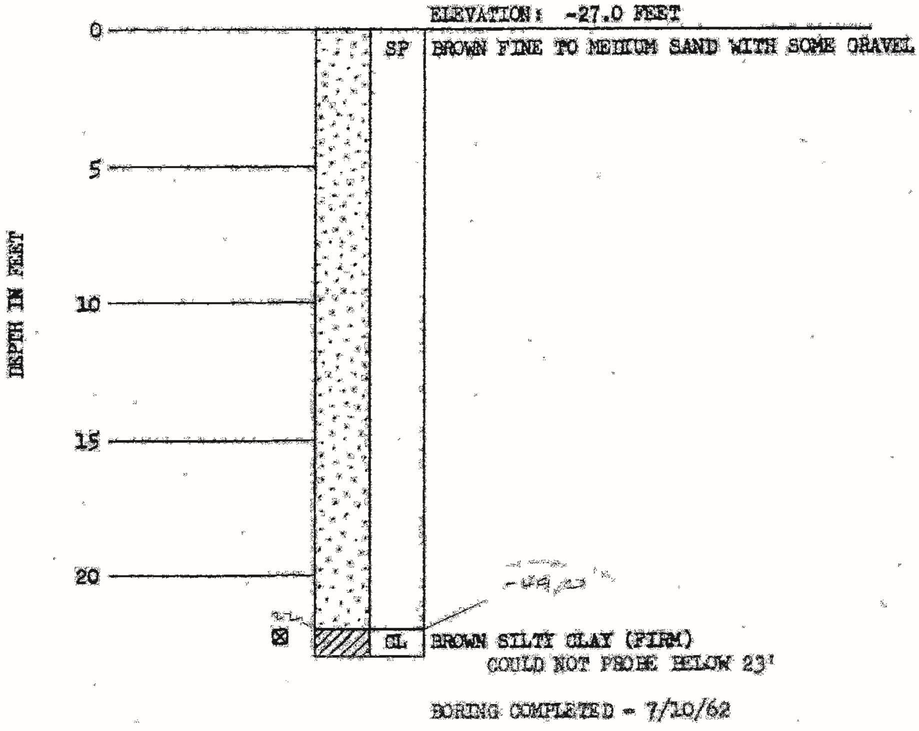
BORING COMPLETED - 7/10/62

LOG OF PROBING

DAMES & MOORE
APPLIED EARTH SCIENCES

BY D.A.M. DATE 7-17-62
CHECKED BY
FILE 327-027 Calif Edison Co.
REVISIONS
BY DATE

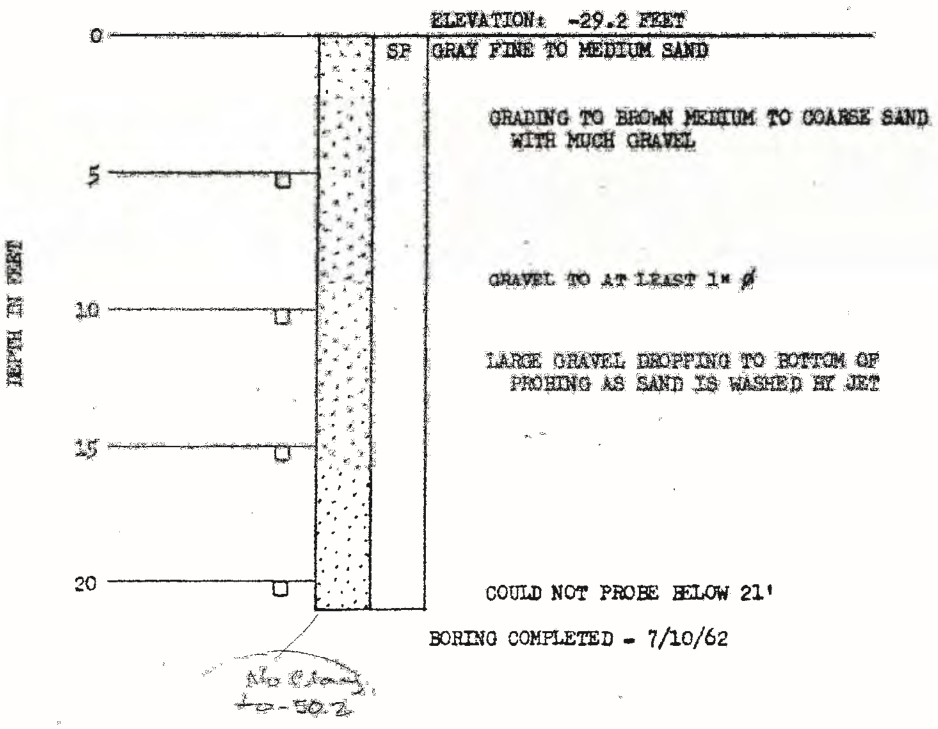
PROBING NO. 3



LOG OF PROBING

DAMES & MOORE
APPLIED EARTH SCIENCES

PROBING NO. 4



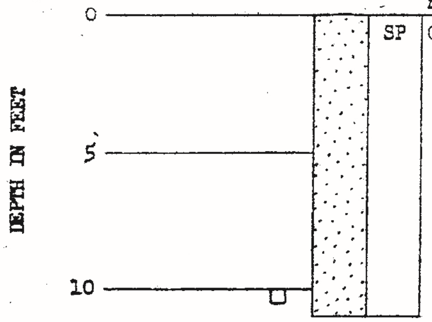
L O G O F P R O B I N G

BY R.A.M. DATE 7-17-62
CHECKED BY
FILE 377-027 Calif Edison Co.
REVISIONS
BY DATE

DAMES & MOORE
APPLIED EARTH SCIENCES

PROBING NO. 5

ELEVATION: -29.7 FEET



GRAY FINE TO MEDIUM SAND WITH SOME SMALL SHELLS & GRAVEL

GRADING TO BROWNISH GRAY MEDIUM TO COARSE SAND WITH GRAVEL

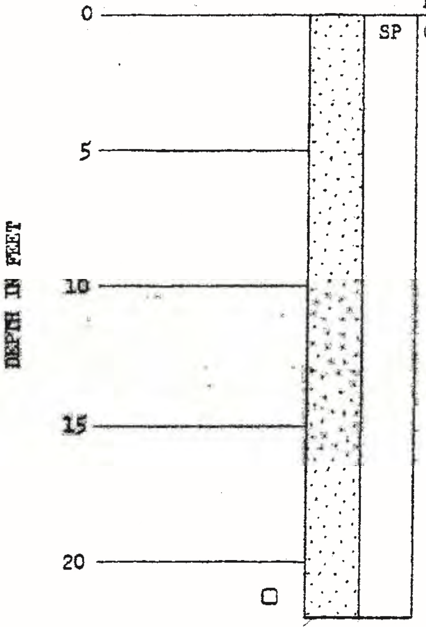
LARGE GRAVEL DROPPING TO BOTTOM OF PROBING AS SAND IS WASHED OUT BY JET

COULD NOT PROBE BELOW 11'

BORING COMPLETED - 7/10/62

PROBING NO. 6

ELEVATION: -32.1 FEET



GRAY FINE TO MEDIUM SAND WITH FEW BROKEN SHELLS

GRADING TO GRAYISH BROWN MEDIUM TO COARSE SAND WITH GRAVEL

LARGE GRAVEL DROPPING TO BOTTOM OF PROBING AS SAND IS WASHED OUT BY JET

GRAVEL CONTENT PROBABLY INCREASING WITH DEPTH

COULD NOT PROBE BELOW 22'

No Clay to
-54.1

BORING COMPLETED -7/10/62

LOG OF PROBINGS

DAMES & MOORE
APPLIED EARTH SCIENCES

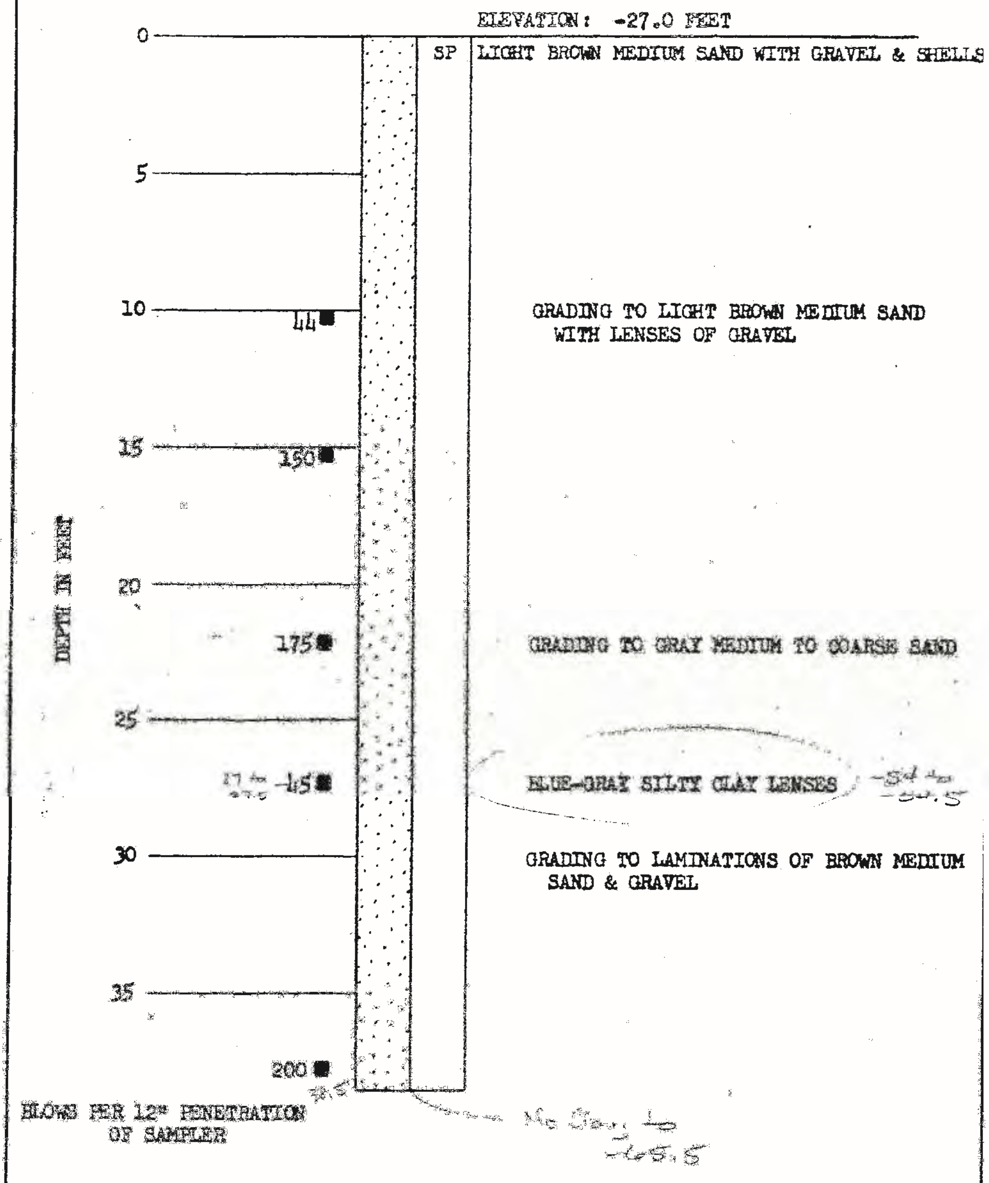
BY D.A.M. DATE 7-17-62
CHECKED BY
FILE 377-027 CALIF. EDSON CO.
REVISIONS
BY DATE

REVISIONS
BY ______ DATE ______

FILE 2327-027 Cal Edison Co.

BY J.A.M. DATE 1-24-62
CHECKED BY ______

1954 BORING NO. 1

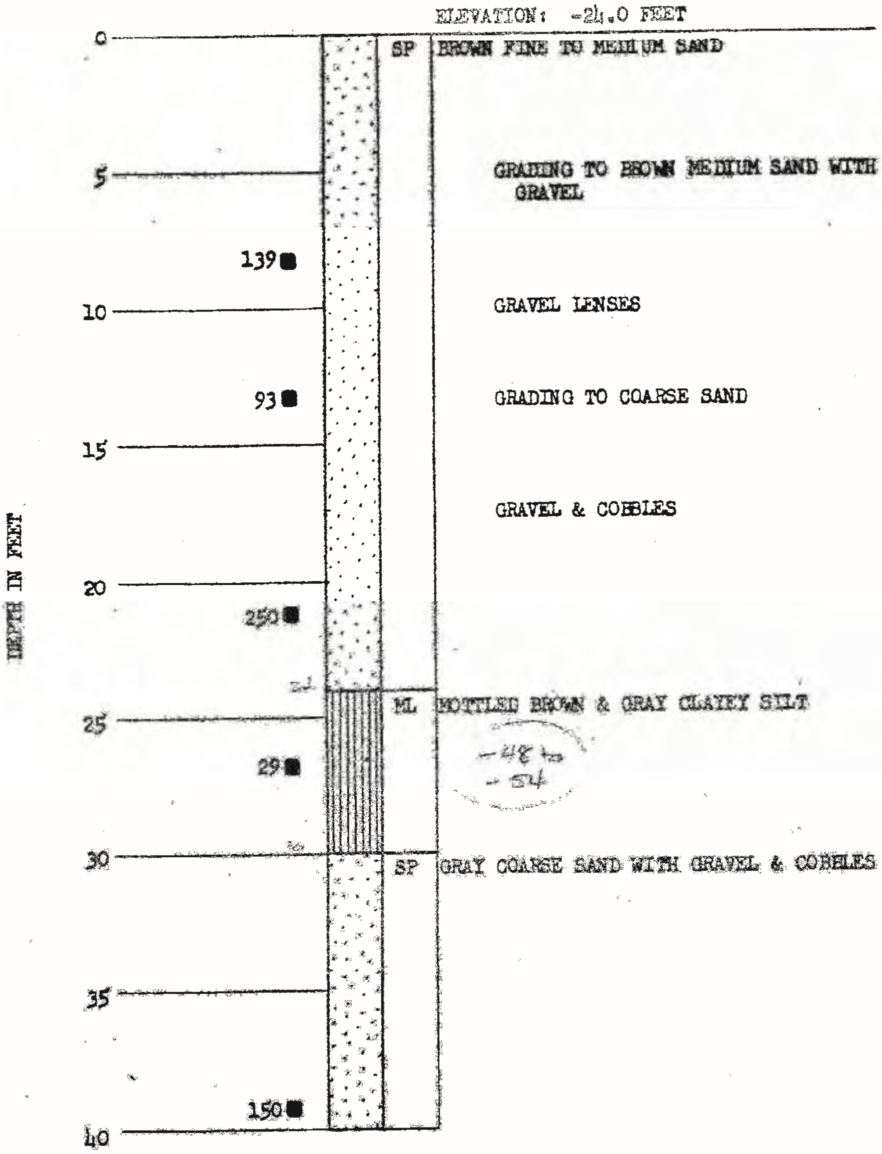


LOG OF BORING

DAMES & MOORE
APPLIED EARTH SCIENCES

PLATE 3A

1954 BORING NO. 2



LOG OF BORING

DAMES & MOORE
APPLIED EARTH SCIENCES

REVISIONS
BY ____ DATE ____

Calif. Edison Co.

FILE 02377-027

BY D.A.M. DATE 7-24-62
CHECKED BY ____