Appendix 13A

Supplemental Subsurface Intake Studies

ESA

Prepared for

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SUPPLEMENTAL FEASIBILITY ASSESSMENT OF SUBSURFACE SEAWATER INTAKES ALONG THE SANTA MONICA BAY COAST

PROPOSED DESALINATION FACILITY EL SEGUNDO, CALIFORNIA

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EXECUTIVE SUMMARY

In 2015, West Basin Municipal Water District (West Basin) initiated a study of subsurface seawater intakes (SSIs) that included a literature study and overview of SSIs; development of a general guidance tool for evaluating technical feasibility of SSIs (SSI Guidance Tool); application of the SSI Guidance Tool for initial screening of technical feasibility of SSIs for West Basin's proposed desalination facility (deal facility) at the El Segundo Generating Station (ESGS) site; and field investigations and additional analyses for a detailed site-specific SSI feasibility evaluation of SSIs at the proposed El Segundo location (Geosyntec, 2016b). This report provides information and discussion of conditions for the proposed El Segundo Site as well as alternative sites along the entire coast of Santa Monica Bay. This information is needed for the Water Board to evaluate feasibility of alternative sites along the Santa Monica Bay coast and determine the feasibility of SSI technologies for the proposed desal facility in accordance with the Ocean Plan Amendment (California State Water Board, 2015).

The coast of Santa Monica Bay was divided into four segments for the purpose of describing the setting and evaluating the feasibility of SSI technologies to provide 40 MGD of feedwater needed for the proposed desal facility to produce 20 MGD of freshwater. Figure ES-1 shows the four segments and the proposed project location, which is in Segment 3. Screening evaluation of feasibility of seven SSI technologies[1] with the SSI Guidance Tool (Geosyntec, 2016a) eliminated Segment 1 (Malibu Coast) and Segment 4 (Palos Verde Peninsula Coast) from further consideration because of cliffs and inadequate depth to bedrock (insufficient transmissivity of sediment along the coast).

With no constraints on the siting and extent of SSI infrastructure along the coast (i.e., not considering protected areas, recreational beaches, proximity to residential properties, and other regulatory or zoning constraints), the SSI Guidance Tool indicated that all SSI technologies are technically feasible in Segments 2 and 3, the middle portion of Santa Monica Bay. The feasibility scores provided by the SSI Guidance Tool indicates that SSIs are less feasible in Segment 2 than Segment 3 due to lower hydraulic conductivity of coast margin aquifers and sediments in Segment 2.

[1] 1. Vertical wells 2. Slant wells 3. Radial collector wells 4. Horizontal wells 5. Seabed infiltration galleries 6 Beach infiltration galleries 7. Deep infiltration galleries

A more detailed evaluation of feasibility of SSI technologies was conducted for Segments 2 and 3 based on further considerations including site-specific hydrogeology, groundwater modeling, SSI production potential, geochemical constraints, potential for impacts to inland aquifers, beach and seafloor stability, vulnerability to sea level rise, sensitive ecological habitats, proximity to residential properties, precedence of the SSI technology, cost, reliability and risk (probability of successful construction and sustainable performance).

Based on the more detailed evaluation of SSI feasibility in Segments 2 and 3, including model simulations of SSI pumping in Segment 3 (Appendix J of Geosyntec, 2016b), vertical wells and slant wells would draw more than half of the intake water from inland aquifers. At the El Segundo coast this would impact performance of the West Coast Basin Injection Barrier and could interfere with ongoing remediation at the Chevron Refinery (i.e., influence groundwater flow and hydraulic containment achieved with onsite extraction wells) and potentially draw impacted groundwater within the Dune Sand Aquifer down into the underlying less impacted Gage and Silverado Aquifers; the Silverado Aquifer being the main drinking water aquifer in the West Coast Basin. Moreover, in the central portion of Segment 3, the SSI pumping would withdraw groundwater in an area that is de-designated for municipal use, which would be in violation of the amended Basin Plan (Water Board, 1998).

Horizontal directionally drilled (HDD) wells, which require a minimum depth of 20 to 30 feet in unconsolidated sandy sediment, would need to be installed beneath a clay layer, which is present approximately 20 feet below the seafloor near the El Segundo coast. Model simulations indicate that while such HDD wells would draw a greater portion of water from the ocean than vertical or slant wells along the coast, the estimated maximum sustainable yield of an HDD SSI system with well heads within or adjacent to the ESGS site is less than 20 MGD (less than half the design intake rate of 40 MGD). So numerous HDD wells would be required that would span more than a mile of the coast in Segment 2 or 3.

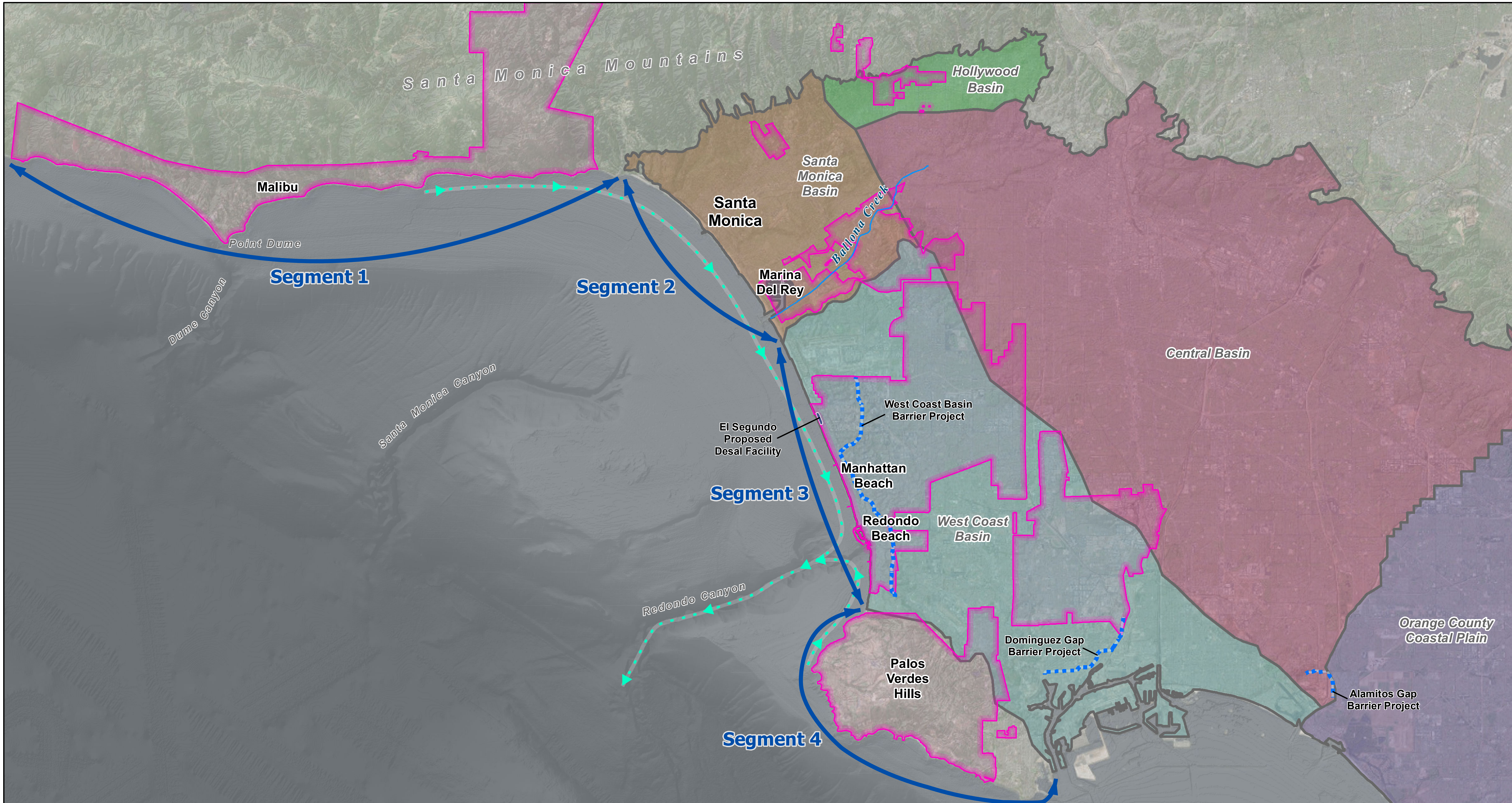
The estimated production rate of an SSI system consisting of vertical wells, slant wells, or radial collector wells with well head infrastructure completed in or adjacent to the footprint of the ESGS site is even less: 15, 16, and 10 MGD, respectively (Appendix J of Geosyntec, 2016b). Thus, to achieve the design intake rate of 40 MGD, these technologies would require many SSIs spanning 1.5 to 5 miles of the Segment 3 coast and an even greater distance in Segment 2 where the hydraulic conductivity of the aquifers along the coast is lower. Such an extensive system of SSIs would impinge on sensitive and protected ecological habitats, popular recreational beaches, residential beach front properties onshore, and offshore buried infrastructures such as pipelines and fiber optic cables.

Beach Infiltration Galleries (BIGs) would draw less water from inland aquifers, but BIGs of similar capacity to the 40 MGD needed for the proposed desal facility are without precedence in a high energy setting with unstable beaches like Santa Monica Bay. Due to the persistent southward long-shore transport in the Santa Monica littoral cell, sustainability of BIGs would be dependent on continued beach nourishment. Performance of BIGs would also be vulnerable to sea level rise, which will influence the position of the surf zone.

Offshore shallow SSI technologies such as Seabed Infiltration Galleries (SIGs), Deep Infiltration Galleries (DIGs, also called water tunnels), and shallow horizontal wells installed in offshore trenches, would draw a small portion of water from inland aquifers, but are without precedence in the high energy setting of the Santa Monica Bay. In addition to being very expensive to construct, their construction in the high-energy, unprotected conditions like the Santa Monica Bay is unprecedented. Moreover, potential deposition of silts and clays on the seafloor can occur with El Nino storms and decrease the performance yield requiring difficult, expensive, and potentially environmentally damaging maintenance. And, sea level rise may change the erosion/deposition equilibrium, which can negatively impact long-term performance. Sustainability of their production capacity would be uncertain.

In conclusion, evaluation with the SSI Guidance Tool of feasibility of SSIs along the coast of Santa Monica Bay for the proposed desal facility eliminates further consideration of SSIs along the coast of the Malibu area and the Palos Verdes Peninsula (Segments 1 and 4) because shallow bedrock and cliffs or steep slopes with narrow beaches, which are fatal flaws for technical feasibility. Although the SSI Guidance Tool indicates that SSI wells are technically feasible in central portions of the Santa Monica Bay coast (Segments 2 and 3), and most feasible in Segment 3, miles of SSI wells along the coast would be needed to achieve the design intake rate of 40 MGD. And, a significant portion of the water pumped by SSI wells would come from inland aquifers. Infiltration galleries on the beach are not sustainable due to instability of the beaches, and offshore shallow horizontal wells or infiltration galleries would be very expensive to construct, are without precedence at the design intake capacity in a high energy setting like Santa Monica Bay, would be susceptible to clogging requiring potentially environmentally damaging maintenance, and the sustainability of their production capacity would be uncertain.

Based on the limitations, challenges and constraints summarized above, none of the seven SSI technologies are recommended for the proposed desal facility on the coast of Santa Monica Bay.



Legend

- West Basin Service Area
- Groundwater Basin
- Sea Water Barrier
- Littoral Drift Pathway along Coastal Margin *(longshore transport of sediment)*

Groundwater Basin

- Central Basin
- Hollywood Basin
- Orange County Coastal Plain
- Santa Monica Basin
- West Coast Basin

Notes:
Littoral drift pathway adapted from Jenkins, 2015-- Appendix K of Geosyntec, 2016.
Bathymetry and DEM source: NOAA - https://maps.ngdc.noaa.gov

Santa Monica Bay Coastal Margin Map

Alternative Site Evaluation
Proposed Desalination Facility
West Basin Municipal Water District

Geosyntec consultants

WR2596	May 2019	Figure ES-1

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LIST OF ACRONYMS AND ABBREVIATIONS

AFY	Acre feet per year
BIG	Beach infiltration gallery
CEQA	California Environmental Quality Act
CPT	Cone Penetration Test
DDW	California Water Resource Control Board Division of Drinking Water
DIG	Deep infiltration gallery
DPW	California Department of Public Works
DWR	California Department of Water Resources
ESGS	El Segundo Generating Station
EIR	Environmental Impact Report
HDD	Horizontal Directionally Drilled or Horizontal Directional Drilling
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
LAX	Los Angeles International Airport
MGD	million gallons per day
MF	micro-filtration
NA	Not Applicable
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelometric Turbidity Unit
NWRI	National Water Research Institute
RO	Reverse Osmosis
SDI	Silt Density Index
SIG	Seabed Infiltration Gallery
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
WRD	Water Replenishment District of Southern California

CERTIFICATION

Hydrogeologic, geologic, and engineering information and findings presented in this document have been prepared under the supervision of and reviewed by a California registered Professional Geologist and Engineer.

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1. BACKGROUND AND INTRODUCTION

In 2015, West Basin Municipal Water District (West Basin) initiated a study of subsurface seawater intakes (SSIs) that included

- A literature study and overview of SSIs;
- Development of a general guidance tool for evaluating technical feasibility of SSIs (SSI Guidance Tool);
- Application of the SSI Guidance Tool for initial screening of technical feasibility of SSIs for West Basin's proposed desalination facility (desal facility) at the El Segundo Generating Station (ESGS) site; and
- Field investigations and additional analyses for a detailed site-specific SSI feasibility evaluation of SSIs at the proposed El Segundo location (El Segundo SSI Feasibility Assessment).

Development of the SSI Guidance Tool (Geosyntec, 2016a)[2] and the El Segundo SSI Feasibility Assessment (Geosyntec, 2016b) were federally funded through a grant by the United States Bureau of Reclamation and subjected to a transparent, public, and independent peer-review by a technical advisory panel facilitated by the National Water Research Institute (NWRI).[3] The site-specific assessment of SSIs at El Segundo, *Feasibility Assessment of Subsurface Seawater Intakes* (Geosyntec, 2016b) (El Segundo SSI Feasibility Assessment), was conducted in compliance with the updated *2015 California Ocean Plan*.[4,5] and is included as Appendix 2A with this EIR.

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[2] The Subsurface Seawater Intake Feasibility Screening Tool Guidance Manual is available from the USBR website (Desalination and Water Purification Research and Development Program Report No. 188): https://www.usbr.gov/research/dwpr/DWPR_Reports.html

[3] National Water Research Institute Website, *West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Feasibility Study*, http://www.nwri-usa.org/subsurface-intake-panel.htm, accessed February 17, 2016.

[4] The 2015 California Ocean Plan chapter III.M defines feasible as "capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors." The Feasibility Assessment was conducted in accordance with the May 2015 Ocean Plan Amendment Section 13142.5(b) requirements.

[5] The 2015 Ocean Plan is included as Appendix A of the, *Feasibility Assessment of Subsurface Seawater Intakes Proposed Desalination Facility El Segundo, California* (Geosyntec, 2016b);

1.1 SSI Technologies

Seven SSI technologies were considered in the 2016 Feasibility Assessment. They are illustrated by Figure 1-1 and listed below:

1. Vertical wells, which are onshore as close to beach as feasible;
2. Slant wells, which have well heads onshore as close to the beach as feasible, with wells extending towards the ocean;
3. Radial collector wells, which have caissons onshore as close to beach as feasible with collectors extending toward the ocean;
4. Horizontal directionally-drilled (HDD) wells (sometimes called drains)[6], which have well heads onshore with wells extending offshore
5. Seabed infiltration galleries (SIGs), which are offshore;
6. Beach infiltration galleries (BIGs), which are in the surf zone; and
7. Deep infiltration galleries, which are water tunnels extending offshore, and potentially with collectors extending from the tunnels.

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 a Technical Memorandum “Subsurface Seawater Intake Technology Overview”, which is provided as Appendix B to the El Segundo SSI Feasibility Assessment (Geosyntec, 2016b).

1.2 Feasibility of SSIs

The feasibility of SSI technologies depends on a variety of site-specific criteria including hydrogeologic, oceanographic, geochemical and water quality constraints, land use and sensitive habitat, maintenance requirements, and other technical and economic risk factors and uncertainties such as complexity of construction, performance risk, and economic viability.

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[6] Shallow horizontal offshore wells can be installed with HDD or installed in excavated offshore trenches and backfilled with engineered fill. The excavated alternative has also been called Seabed Wells and was previously evaluated for the vicinity of El Segundo (Geosyntec, 2017). In this document, the category of SSI technologies previously called HDD wells (Geosyntec, 2016a,b, 2019) is called horizontal wells, which can be installed by HDD or offshore trenching.

Feasibility of the SSI intake technologies were evaluated using the SSI Guidance Tool based on five general categories including:

1. SSI construction;
2. SSI operation;
3. treatment system operation;
4. potential inland interference; and
5. risk and uncertainty for project implementation.

These five general categories are further broken down into "challenge" criteria that are used in the SSI Guidance Tool to evaluate the overall feasibility of SSIs (Geosyntec, 2016a).

The initial screening with the SSI Guidance Tool presented in the El Segundo SSI Feasibility Assessment (Geosyntec, 2016b) was conducted for 8.2 miles of beach front, from Redondo (South) to Marina Del Rey (North). With no regulatory or zoning constraints on the siting and extent of SSI infrastructure, the SSI Guidance Tool indicated that all the SSI technologies are theoretically technically feasible to provide the design intake rate of 40 MGD required for production of 20 MGD of potable water. The SSI Guidance Tool and its application to the entire Santa Monica Bay coast is presented in Appendix A and summarized in Section 3 below.

Follow-up site-specific evaluation of the SSI technologies in the vicinity of the proposed El Segundo location was conducted that included consideration of constraints on the siting and extent of SSI infrastructure and utilized available local hydrogeologic information supplemented with additional field investigations including cone penetrometer testing borings to characterize the subsurface stratigraphy and permeability, and offshore sub-bottom profiling and multi-channel seismic reflection geophysical surveys to characterize the shallow offshore stratigraphy, and groundwater flow model simulations of SSIs (Geosyntec, 2016b).

1.3 Report Organization

The Ocean Plan directs the Water Board to 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.

This report provides information and discussion of conditions for the proposed El Segundo Site as well as alternative sites along the entire coast of Santa Monica Bay. This information is needed for the Water Board to review the Site-Specific Feasibility Study (Geosyntec, 2016b) and the evaluate feasibility of alternative sites along the Santa Monica Bay coast, and make a determination of the feasibility of SSIs for the proposed desal facility in accordance with the Ocean Plan Amendment (California State Water Board, 2015) and applicable portions of Water Code Section 13142.5(b).

The remainder of this report includes the following sections:

- Section 2, *Santa Monica Bay Coastal Margin Setting*, presents information and discussion of the topography and bathymetry, geology, hydrogeology, beach characteristics and stability, and ecological conditions.
- Section 3, *Screening Evaluation with the SSI Guidance Tool*, presents a summary description of the application of the SSI Guidance Tool to the entire coast of Santa Monica Bay. Model inputs and assumptions used to evaluate Santa Monica Bay as well as the outputs of the SSI Guidance Tool are detailed in Appendix A.
- Section 4, *Site-Specific Considerations for Segments 2 and 3*, presents more detailed information for further assessment of SSI feasibility at Segments 2 and 3 of the Santa Monica Bay coast, which the SSI Guidance Tool indicates are potentially suitable for SSIs.
- Section 5, *Summary of Suitability of the Santa Monica Bay Coast for SSIs,* presents a summary of suitability of SSI technologies for the four segments along the Santa Monica Bay coast.
- Section 6, *Conclusions*.

2. SANTA MONICA BAY COASTAL MARGIN SETTING

2.1 Physical Geography

Santa Monica Bay is a major coastal embayment offshore of Los Angeles that extends from Point Dume at the north to the Palos Verdes Peninsula on the south. The inland margin of the Santa Monica Bay coast from north to south consists of generally steep slopes of Santa Monica Mountains, relatively low-lying areas including the Santa Monica and West Coast Basins, and steep slopes of the Palos Verdes Peninsula (Figure 2-1).

The Santa Monica Bay coast is divided into four segments that have generally similar physiographic setting, geologic, and hydrogeologic conditions and are used for the purpose of describing the setting and evaluating feasibility of SSIs (Figure 2-1).

2.1.1 Coastal Segment 1

Segment 1 is located along Malibu Coast, south of the Santa Monica Mountains and extends several miles west of Pt. Dume. It includes the West Basin Municipal Water District service area, which extends to the border between Los Angeles and Ventura Counties. The beach widths are generally less than 100 ft and often less than 50 feet. Only a few beach areas of limited extent are up to approximately 200 ft wide. Much of Segment 1 has steep slopes close to the beach and the slope of the sea floor is also steep. Bedrock with low permeability is generally close (within a few feet) of the surface of the beaches.

2.1.2 Coastal Segment 2

Segment 2 is located along the cost of the Santa Monica Basin and includes Will Rogers, Santa Monica and Venice Beaches. The width of these beaches is generally 300 to 500 feet, but ranges from approximately 200 to 1000 feet. Topography and bathymetry of Segment 2 are generally gentle with no cliffs or steep slopes.

2.1.3 Coastal Segment 3

Segment 3 is located along the coast of the West Coast Basin and includes Playa Del Rey, Dockweiler, El Segundo, Manhattan, Hermosa, Redondo, Torrance and Rat Beaches. The width of these beaches is generally 200 to 400 feet, but ranges from less than 100 to approximately 600 feet. Topography and bathymetry of Segment 3 are generally gentle with no cliffs or steep slopes. Exceptions are some areas of Segment 3 with sand dunes areas that include local steep slopes.

2.1.4 Coastal Segment 4

Segment 4 is located along the Palos Verdes Peninsula where cliffs or steep slopes of the Palos Verdes Hills extend down to narrow rocky beaches. The widths of the beaches are mostly less than 50 feet, and only exceed 100 feet in a few local coves. Access to the Segment 4 coast is much more limited than the other three segments due to cliffs and very narrow beaches. Bedrock with low permeability is generally close (within a few feet) of the surface of the beaches.

2.1.5 Santa Monica Bay Sea Floor

The seafloor in most of Santa Monica Bay is a gently sloping continental shelf that extends to the break in the shelf at a depth of approximately 330 feet below sea level (bsl). The shelf generally extends several miles offshore of Segments 2 and 3. However, as is illustrated by Figure 2-1, the shelf is narrower in northwestern portion of Segment 1 and southern portion of Segment 4. And, the gently sloping shelf offshore of Segments 1, 2 and 3 is cut by Dume, Santa Monica and Redondo submarine canyons, which are also apparent on Figure 2-1.

2.2 Geology

Geologic conditions influence the feasibility of construction of SSIs and associated infrastructure, and can limit the intake rate of the SSIs, and require construction and operation of a larger number of SSIs. The central portion of Santa Monica Bay borders the coast of the Los Angeles Structural Basin (LA Basin). The LA Basin occupies the northern end of the Peninsular Ranges physiographic province, which comprises northwest trending mountains and valleys formed by active right-lateral strike-slip faults. The LA Basin is bounded on the north by the Transverse Ranges Physiographic Province, which comprises east-west trending valleys and mountains, including the Santa Monica and San Gabriel Mountains. Structural sub-basins along the coastal margin of the LA Basin include the Santa Monica Basin and the West Coast Basin (also called West Basin) (e.g. Reichard et al., 2003).

The Santa Monica Subbasin occupies the northwestern portion of the LA Basin (Figure 2-1). It is bordered on the north by the Santa Monica Mountains, on the east by the Newport-Inglewood Fault system, on the south by the Ballona escarpment, and on the west by the Pacific Ocean. The Santa Monica basin fill includes unconsolidated alluvial deposits ranging in age from Pliocene to Holocene (~3 million to 10,000 years ago) with a total thickness of up to a few hundred feet (DWR, 2003).

The West Coast Basin occupies the central coastal margin portion of the LA Basin (Figure 2-1). It is bordered on the north by the Ballona escarpment, on the east by the Newport-Inglewood Fault system, on the south and west by the Pacific Ocean and the Palos Verdes Hills. The West Coast Basin contains a thick (>1000 ft) sequence of marine and non-marine, unconsolidated to semi-consolidated sediments that were deposited between Pliocene and Holocene. The Pilo-Pleistocene sediments are underlain by Tertiary sedimentary and volcanic rocks (DWR, 2003).

Mesozoic metamorphic basement rocks underlie the LA Basin and Santa Monica Shelf at depths estimated between 1,000 and 8,000 feet. The Santa Monica Mountains and Palos Verdes Hills consist of uplifted Mesozoic bedrock, Tertiary sedimentary rocks, and some Tertiary volcanic rocks (Reichard, et al., 2003).

Based on seafloor photography and multibeam sonar imagery, most of the seafloor in Santa Monica Bay is reported to consist of unconsolidated sediment with silt and clay as the predominant size fraction. Maps of the seafloor of the central Santa Monica Bay identify most of the sediment as “muddy sand” and “mud” (Dartnell and Gardner, 2004). Sandy substrates are restricted to the innermost portion of the mainland shelf and a narrow outer shelf band north of Santa Monica Canyon. Cobble and gravel substrates are restricted to the innermost shelf south of El Segundo and limited parts of the shelf edge. Rocky substrates with interspersed patches of sand and gravel are reported on the high-relief marginal plateau and along parts of the shelf break offshore of Malibu (e.g. Gardner et al., 2003; Edwards et al., 2003).

2.3 Hydrogeology

Hydrogeologic conditions affect the ability of SSIs to draw water from the ocean vs. inland groundwater, constrain the intake rate of the SSIs, which influences the required number of SSIs to achieve the design flow rate. The hydrogeologic conditions are discussed below for the four segments of the coast identified in this report (Figure 2-1) with the main focus being their relevance to the installation and operation of SSIs.

2.3.1 Segments 1 and 4

The land adjacent to the Segments 1 and 4 coasts, the Santa Monica Mountains and Palos Verdes Hills, is mostly uplifted consolidated sedimentary rock with low permeability and very limited groundwater production potential. DWR Bulletin 118 refers to the rocks of the Santa Monica Mountains as “impermeable”. Also, as discussed above, sandy beaches are narrow with of limited thickness, or in places non-existent in Segments 1 and 4. And there is limited sediment thickness on the seafloor near the coast in Segments 1 and 4. (DWR, 2003; Reichard et al., 2003)

Local shallow alluvial deposits are present near the coast along drainages but have limited groundwater production due to their limited extent. An example in Segment 1 is the alluvial deposits associated with the modern and ancestral Malibu Creek. An evaluation of the hydrogeologic properties of these local alluvial deposits was conducted as part of a feasibility study of treated wastewater injection for the City of Malibu. The evaluation indicated that the local permeable alluvial deposits are up to approximately 100 feet thick beneath the inland portion near the coast and continue beneath the seafloor. The hydraulic conductivity of the targeted interval for injection is approximately 10 ft/d. The geometric mean of the hydraulic conductivities assigned to the calibrated Malibu groundwater injection model for the more typical less permeable alluvium that overlies, underlies and extends along the coast away from the ancestral Malibu Creek channel deposits, is approximately 0.3 ft/d. Groundwater modeling indicates that the channel deposits could accommodate injection of approximately 350,000 gpd (0.35 mgd) of water, which would flow to the ocean, although the capacity could be less following periods of high rainfall (RMC, 2013; Dumas, 2015)

2.3.2 Segment 2

Segment 2 is the coast of the Santa Monica Basin. The main hydrogeologic units in the Santa Monic Basin include the Bellflower aquiclude, the Ballona aquifer, and the Silverado Aquifer. Holocene age alluvium forms much of the surficial deposits for the central part of the Santa Monica Basin and fills the Ballona gap, which is an erosional channel. These unconsolidated alluvial deposits include the clay-rich Bellflower aquiclude and underlying gravels of the Ballona Aquifer, which is part of the Lakewood Formation. Yields of wells in the Ballona aquifer are variable and it is not a major water supply source. The Silverado Aquifer within the San Pedro Formation is the most productive aquifer in the Santa Monica Basin, and some wells are also completed within the underlying Pico Formation.

The distribution of hydraulic conductivity for the shallow coastal margin aquifer in the Los Angeles Basin Groundwater Model used by the Water Replenishment District (Reichard, 2003) is shown for Segments 2 and 3 by Figure 2-2. In Segment 2, the hydraulic conductivity assigned in the model to the coastal margin, which includes the Ballona Aquifer, ranges from 1 to 10 ft/d.

Recharge to groundwater in the Santa Monica Basin is primarily from percolation of precipitation and surface runoff from the Santa Monica Mountains. The Newport-Inglewood Fault appears to inhibit westward inflow of groundwater from the Central Basin, but some groundwater inflow may occur along the northern portion of the inland boundary.

Groundwater in the Santa Monica Basin generally flows southward toward the Ballona gap and then westward toward to the ocean. Because of a discontinuity of groundwater levels across the Overland Avenue Fault in the Ballona Gap (higher water levels on the east side of the fault), the fault appears to be a partial hydraulic barrier along Ballona Creek, which drains to the ocean, is the main surface water course in the Santa Monica Basins (DWR, 2003; Reichard et al., 2003).

2.3.3 Segment 3

The Santa Monica Bay coast of the West Coast Basin, which is identified as Segment 3 in this report (Figure 2-1), is underlain by a thick (>1,000 ft), interbedded sequence of Quaternary (Holocene and Pleistocene) sediments including clays, silts, sands, and gravels (Reichard, 2003; California State Lands Commission, 2010; Appendix G of El Segundo Power, 2000). The majority (80 to 90%) of groundwater production is from the Silverado aquifer, which underlies most of the West Coast Basin (DWR, 2003).

As shown on Figure 2-2, the distribution of hydraulic conductivity for the shallow coastal margin aquifer in the Los Angeles Basin Groundwater Model used by the Water Replenishment District (Reichard, 2003) for Segment 3 which includes the Gage Aquifer, ranges from 11 to 50 ft/d.

West Coast Basin is a major Los Angeles coastal groundwater basin. Both the West Coast and Central Basins were adjudicated in the early 1960s to protect and manage groundwater in these basins, which for many decades had been subjected to pumping rates that were not sustainable and caused seawater intrusion of the aquifers near the coast and impacted wetland ecosystems. The Water Replenishment District of Southern

California (WRD) was formed in 1959 to manage these groundwater basins (Reichard, 2003).

In the 1950s, the injection of imported water began at what is now known as the West Coast Basin Barrier Project (WCBBP) to create a hydraulic barrier to seawater intrusion (e.g. Reichard, 2003). Injection barriers were also constructed in Alamitos and Dominguez Gaps in 1965 and 1971, respectively (Figure 2-1). The WCBBP includes more than 150 injection wells near the coast of the West Coast Basin (Segment 3).

Injection wells in the WCBBP 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). In recent years, the majority of the water injected is recycled water that is treated at West Bain’s Edward C. Little Water Recycling Facility.

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). The total volume of water injected in the WCBBP in recent years is approximately 19,000 acre-feet (AF) of which approximately 17,000 AF is treated recycled water from West Basin’s Edward C. Little Recycling Facility (Intera, 2015; WRD, 2016).

The WCBBP injection creates a north-south trending mound of fresh groundwater from LAX to the Palos Verdes Hills. Natural recharge to the West Coast Basin groundwater consists mainly of subsurface inflow across and over the Newport-Inglewood Fault Zone from the Central Basin. The general regional groundwater flow direction in the West Coast Basin is south and westward toward the ocean.

Due to contamination of groundwater associated with the Chevron El Segundo Refinery and the terminal and other industrial facilities, and 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 (Figure 2-1) 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).

Shallow groundwater has been extracted since the mid-1980s at the Chevron Refinery for remedial measures including recovery of hydrocarbons and hydraulic containment of impacted groundwater. In recent years the total groundwater extraction rate has been approximately 400 gpm, which equates to approximately 645 acre feet per year (AFY), and includes 11 hydraulic containment wells and 37 hydrocarbon skimmer or withdrawal wells within a square mile area (Trihydro, 2019). The majority of hydrocarbon impacts and remedial pumping is from the Old Dune Sand Aquifer, but hydrocarbons have also been detected in the underlying Gage and Silverado Aquifers (Trihydro, 2019).

Pumping from SSIs such as vertical wells, slant wells or radial collectors that withdraw groundwater from inland aquifer sources could interfere with the ongoing remediation at the Chevron Refinery (i.e., influence groundwater flow and hydraulic containment) and potentially draw impacted groundwater within the Dune Sand Aquifer down into the underlying less impacted Gage and Silverado Aquifers; the Silverado Aquifer being the main drinking water aquifer in the West Coast Basin. Moreover, withdrawal of groundwater in this de-designated area would be in violation of the amended Basin Plan.

2.4 Erosion and Deposition Regime

Erosion and deposition regime (onshore and offshore) can influence the performance and sustainability of some SSI technologies and their associated infrastructure (Sections 4.2.2 and 4.2.3). The coast of Santa Monica Bay is exposed to long period swells from the Gulf of Alaska winter storms. The Redondo Submarine Canyon, which is one of the largest most active submarine canyons on the Pacific coast, is a major sink for the Santa Monica Littoral Cell[7]. The Calleguas, Malibu and Ballona Creeks supply sediment to this littoral cell. Historically the Los Angeles river did as well. And artificial contribution of sand by dredging and major construction projects has provided a major portion of the sand in the Santa Monica Littoral Cell since 1938 (e.g. Reppucci, 2012).

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[7] A littoral cell is a coastal compartment that contains a complete cycle of sedimentation including sources, transport paths, and sinks.

2.4.1 Littoral Drift

Littoral drift, which is the transport of sediments along a coast parallel to the shoreline, can cause instability in the width and thickness of beaches and thickness of seafloor sediment. The longshore currents consistently flow along the Santa Monica Bay coast toward Redondo Canyon where the currents flow down the canyon and out to sea. Marked discontinuity of the beach width is apparent on opposite sides of jetties, or groins in Segments 2 and 3 including several groins at Will Rogers State Beach, a groin at Dockweiler Beach opposite the Los Angeles International Airport, at El Segundo Beach, and at South Redondo Beach The discontinuity in beach width at the groins is due to persistent longshore transport (littoral drift) of beach and offshore sediment that accumulates on the upstream side and is eroded on the downstream side of the groin. **Figure 2-3** illustrates the discontinuity of the beach width at the groin at El Segundo. All the groins show evidence of southward longshore transport except south of Redondo Beach and Redondo Canyon, where the longshore transport is northward.

The beaches at Santa Monica Bay were much narrower in the early 1900s. Artificial addition of sand to the beaches (nourishment) and construction of jetties and groins resulted in significant widening of the beaches beginning in 1940, but the widths have been relatively stable over the last 50 years as illustrated by Figure 2-4 for Manhattan Beach. Stability of the beach width and sand thickness at Segments 2 and 3 is dependent on beach nourishment programs and ongoing reduction of littoral transport by numerous breakwaters, groins, and jetties. Some 30 million cubic yards of sand was added to the beaches of Santa Monica Bay between 1938 and 1989 by major construction along the coast including dredging of the Marina Del Rey Harbor and scavenging of the sand dunes during work on the Hyperion Waste Water Facility. Without continued beach nourishment major erosion of the Santa Monica Bay beaches will occur as a consequence of the persistent southward littoral transport (Reppucci, 2012; Jenkins 2015-- Appendix K of Geosyntec, 2016b).

2.4.2 Closure Depth

The closure depth is the closest point to the shoreline where a stable seabed occurs, and is therefore an important parameter in construction feasibility and sustainability of SSIs. Shallow offshore SSIs inside the closure depth are vulnerable to seafloor instability due to shoaling waves. Closure depth is typically at 40 to 50 ft below mean sea level (MSL) in the Santa Monica Bay (Jenkins, 2015).

Analysis of coastal processes and seafloor stability in the vicinity of the groin at El Segundo Beach and at the Fillet Beach north jetty at Redondo indicates closure depths of approximately 50 feet, which occurs approximately 6,500 and 8,500 feet offshore at El Segundo and Redondo, respectively (Jenkins, 2015, Appendix K of Geosyntec 2016b).[8]

Erosion of the seafloor, which is exacerbated during extreme winters by large waves associated with El Nino, can exhume and damage shallow SSI infrastructure beneath the seafloor (California State Lands Commission, 2010; Water Research Foundation, 2011; Geosyntec, 2016b).

2.4.3 Critical Mass Envelope

The critical mass of sand on a beach is that required to maintain equilibrium beach profiles over a specified time, usually ranging from seasons to decades (e.g. Jenkins, 2015—Appendix K of Geosyntec, 2016b). The critical mass envelope, which is the range of historical profiles of the beach topography and sea floor bathymetry, provides an indication of the volume of sediment that can be potentially eroded, and the depth below existing grade that erosion might extend, due to extreme storms, seasonal change or shoreline recession. To be safe from damage and exposure by erosion, pipelines or SSI intakes beneath the beach or seafloor should be deeper than the thickness of the critical mass envelope.

Analysis at El Segundo and Redondo indicates a depth of up to approximately 10 feet of sand erosion and deposition cycles to approximately 800 ft offshore, and a depth of approximately 6 feet to a distance of 1,200 feet and 6,500 feet offshore of El Segundo and Redondo, respectively (Figures 5.4 – 5.7 in Jenkins 2015, Appendix K of Geosyntec, 2016b). However, the Jenkins 2015 analysis was based upon bathymetric profiles for several years from the 1980s and 1990s, which did not include large El Nino storm years (e.g., 1983 or 1998). Accordingly, 10 feet may not encompass the full range of seafloor elevation and deeper installation may be necessary to ensure sustainability of subsurface pipelines or intakes.

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[8] Profiles of seafloor bathymetry for different times typically would converge at the depth of closure. However, some of the bathymetric profiles offshore of El Segundo shown on Figures 4.7 and 4.8 of Jenkins, 2015 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.

2.5 Overview of Ecological Conditions

Regulatory limitations on development and activity in ecologically sensitive and protected areas need to be considered in evaluating feasibility of SSIs for the proposed desal facility. Figure 2-5 shows the location of sensitive ecological habitat along the coast of Santa Monica Bay including

- California Marine Protected Areas (MPAs);
- Areas of Special Biological Significance (ASBS);
- Kelp beds, surfgrass, and eelgrass;
- Critical habitat of the Snowy Plover and Black Abalone; and
- Estuaries and wetlands.

Figures 3-1 through 3-4 show locations of sensitive ecological habitat for each of the four Segments.

Segments 1 and 4, which are the coasts of the Malibu area and the Palos Verdes Peninsula, include extensive portions of rocky coastlines in contrast to Segments 2 and 3, which consist dominantly of unconsolidated sandy coastlines. The rocky coastline settings are ecologically more diverse than the sandy coastlines. Within the Segment 2, the coastline near Ballona Creek is expected to have relatively higher ecological diversity. And within Segment 3, the coast in central portion of Santa Monica Bay is less diverse ecologically than the Redondo Beach area (Applied Marine Science, 2018).

3. SCREENING LEVEL EVALUATION WITH THE SSI GUIDANCE TOOL

3.1 Overview of SSI Guidance Tool

An SSI Feasibility Screening Tool (SSI Guidance Tool) was developed to evaluate the technical feasibility of SSIs (Geosyntec, 2016a). The SSI Guidance Tool is a screening level methodology to assess the potential technical feasibility of the seven SSI technologies to provide the necessary amount of feed water to meet the design desalination production capacity at a particular site along the California coast. ***The SSI Guidance Tool intentionally addresses just the technical feasibility of SSI***

technologies, defined as "*able to be built and operated using currently available methods*" (ISTAP, 2014)[9]. Additional analyses are required to determine feasibility with consideration of specific environmental, economic, and social factors. The SSI Guidance Tool provides an initial screening of theoretical technical feasibility ***with no constraints on the siting of the SSI infrastructure***: e.g., the entire coast within each of the four designated segments of the Santa Monica Bay is assumed to be available for the development of a SSI system and the associated infrastructure. The SSI Guidance Tool is designed for screening purposes and as such the input values provide optimistic screening level results. Additional analyses are required to determine feasibility with consideration of specific environmental, economic, and social factors.

The intended users of the SSI Guidance 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 SSI Guidance Tool for assessing the technical feasibility of SSIs. The SSI Guidance Tool was peer-reviewed by the ISTAP, which was coordinated and facilitated by NWRI.

The SSI Guidance Tool is an Excel-based platform that consists of two steps: (1) evaluation of potential fatal flaws and (2) evaluation of potential challenges. A fatal flaw is defined as a factor that cannot be reasonably mitigated and therefore the SSI technology is determined infeasible and eliminated from further consideration.

3.1.1 Fatal Flaws for SSI Feasibility

The SSI Guidance Tool includes three general criteria that constitute fatal flaws:

1. Land type makes construction of the SSI infeasible:
    a. Shallow bedrock:

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[9] 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 for 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.

i. Depth to bedrock less than 100 feet is a fatal flaw for slant wells, which are assumed to be drilled at an angle of approximately 20˚ (ISTAP, 2014);

ii. Depth to bedrock less than 25 feet is a fatal flaw for radial collectors, as the caisson depth of the radial collector ranges typically from 30 to over 150 feet (Water Research Foundation, 2011);

iii. Depth to bedrock less than 10 feet is assumed to be a fatal flaw for HDD wells, as 10 feet is considered the minimum thickness to be able to drill and install a HDD well[10];

iv. Depth to bedrock less than 5 feet for beach and seabed infiltration galleries, as engineered fill is used for these galleries and 5 feet is considered the minimum thickness for installation and operation of the filter media (NWRI, 2015); and

v. Depth to bedrock less than 15 feet for DIG.

b. Presence of a cliff and narrow beach:

i. For all SSIs, except SIGs, the presence of a cliff with a beach narrower than 50 feet constitutes a fatal flaw in the Screening Tool because it is assumed there would not be enough space available for construction of the SSIs (NWRI, 2015).

c. Presence of an inlet:

i. In the SSI Guidance Tool an inlet, which is a river, a channel, or waterway opening that connects the ocean to a bay or lagoon, constitutes a fatal flaw for all SSIs for that portion of the coast, except SIGs and DIGs, because it is assumed to be unstable due to tides, currents and sediment deposition (NWRI, 2015).

2. Available coast length is insufficient to construct the SSIs to achieve the design intake rate:

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[10] Although 10 ft is used as a minimum depth in the SSI Guidance Tool for horizontal wells installed by HDD. They typically would need to deeper than 20 or 30 feet to accommodate necessary pressure of drilling fluid. Shallower attempts at HDD beneath the sea floor would likely fail and result in leakage of drilling fluid from the sea floor (Geosyntec, 2019).

d. Length of the coast less than 80% of the required length need for an SSI system to achieve the design intake rate is a fatal flaw in the Screening Tool for the feasibility of an SSI technology. A value of 80% of the required length is used to account for redundancy and safety factor (ISTAP, 2014).

3. The area of available land (offshore and/or onshore) is insufficient to construct the SSI system to achieve design intake rate:

   e. Area of land (offshore and/or onshore) less than 80% of the required area for an SSI system to achieve the design intake rate is a fatal flaw in the Screening Tool for the feasibility of an SSI technology. A value of 80% of the required area is used to account for redundancy and safety factor (ISTAP, 2014).

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

3.1.2 Summary of Application of the SSI Guidance Tool to the Santa Monica Bay Coast

The SSI Guidance Tool was used to provide a screening level evaluation of feasibility of SSI technologies for each of the four segments along Santa Monica Bay coast. Figures 3-1 through 3-4 are maps of each of the four segments of the Santa Monica Bay coast that delineate conditions that are potential constraints on feasibility of SSIs. Appendix A includes additional details on the SSI Guidance Tool, the inputs for the four segments along the Santa Monica Bay coast, the detailed screening results, and the input and output tables from the SSI Guidance Tool.

Based on the presence of low permeability bedrock close to the surface, and the presence of cliffs accompanied by limited width of the beaches along the majority of the coast of Segments 1 and 4, the SSI Guidance Tool indicates that none of the SSI technologies are technically feasible in Segments 1 and 4 due to fatal flaws[11] for all SSIs in these two segments of the Santa Monica Bay coast.

In contrast, based on the SSI Guidance Tool, all SSI technologies are technically feasible in Segments 2 and 3 with the assumption that there are no constraints (e.g., protected areas, recreational beaches, proximity to residential properties) on the siting and extent of the SSIs and associated infrastructure. These initial screening results are optimistic for Segments 2 and 3, because favorable conditions are assumed in using the SSI Guidance Tool. The screening level of feasibility of SSI technologies based on the average scores from the SSI Guidance Tool for Segments 2 and 3 is as follows (from most to least feasible): vertical wells > BIGs > radial collectors > SIGs > slant wells > DIGs (Table A-1, Appendix A). SSIs are less feasible at Segment 2 than at Segment 3 due to less favorable hydrogeological properties (lower sediments transmissivity and leakance) at Segment 2.

The SSI Guidance Tool used for the initial screening also provides estimates of length of the coast, onshore areas, and offshore areas required for SSI systems to achieve the design intake rate as summarized in Table A-2 of Appendix A for Segments 2 and 3.

Numerous criteria need to be considered when assessing the overall feasibility of different SSI technologies. Many are unique to specific sites and are not adequately assessed by the SSI Guidance Tool, which was developed for general screening purposes. More detailed assessments of the specific intake technologies for Segments 2 and 3, which included further review of available data on hydrogeology, coastal processes, and sensitive ecological habitats are provided in Section 4 below.

[11] The presence of cliffs and a beach width less than 50 feet is fatal flaw for vertical wells, slant wells, radial collector wells, horizontal wells installed by HDD, and beach infiltration galleries. And a depth to bedrock less than 5 ft is a fatal flaw for all SSI technologies

4. SITE-SPECIFIC CONSIDERATIONS FOR SEGMENTS 2 AND 3

The feasibility of the SSI technologies depends on a variety of site-specific criteria, and in accordance with the factors listed in the Ocean Plan (2015), the following criteria were used in Section 4 below:

- Hydrogeologic constraints, including impacts on water supply aquifers and injection barriers;
- Oceanographic constraints, including vulnerability to sea level rise and sensitivity to beach/seafloor instability;
- Geochemical and water quality constraints; including risk of clogging and impact of contaminated groundwater;
- Land use and sensitive habitat, including ecologically sensitive and protected areas, recreational and residential areas;
- Maintenance, including potentially environmentally damaging maintenance; and
- Other technical and economic risk factors and uncertainties; including construction complexity, and intake reliability.

This section describes criteria for evaluation of the feasibility of SSI technologies beyond the results of SSI Guidance Tool. Site-specific discussion is focused on Segments 2 and 3 because screening with the SSI Guidance Tool (Section 3 above) indicates that SSIs are not feasible for the proposed desalination facility in Segments 1 and 4.

4.1 Hydrogeologic Constraints

4.1.1 Hydraulic Connection to Ocean

The objective of a system of SSIs is to produce large volumes of filtered seawater for treatment at the desal facility. The ability of an SSI system to extract seawater is dependent on the hydraulic connection of the intake works to the ocean (e.g. 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 from the sea. Hydraulic connection to the ocean can be limited by the presence of low permeability layers between the seafloor and the SSI. Such lower permeability layers would impact the vertical infiltration rate of seawater to the intake works and can limit the SSI capacity and result in higher horizontal flow from inland groundwater sources. The feasibility of horizontal wells, slant wells, vertical wells, and radial collectors may be influenced by low permeability layers, depending on the depth of the SSIs and the locations and depths of these layers. Note that horizontal wells installed by offshore trenching with high permeability engineered backfill, would have enhanced hydraulic connection to the ocean, at least in the short-term. Long-term hydraulic connection to the ocean would be dependent on seafloor stability and lack of deposition of fine-grained, low-permeability sediment on the seafloor (Section 4.2.3).

A low permeability layer occurs at depth of approximately 20 feet below the seafloor along the El Segundo coast in Segment 3 (Geosyntec, 2016b). Muddy sediment on the sea floor, which is common in Santa Monica Bay (e.g. Dartnell and Gardner, 2004), also is a limitation of the hydraulic connection between SSIs and the ocean.

4.1.2 Impact on Water Supply Aquifers Along the Coast

Aquifers along the coast are present in the Santa Monica and West Coast Basins (Segments 2 and 3) as discussed in Sections 2.3.2 and 2.3.3 above.

Large-scale subsurface pumping from SSIs completed in coastal aquifers in the vicinity of the shoreline of Segments 2 and 3 would result in withdrawal of inland groundwater from the Santa Monica and West Coast Basins, respectively, which would impact the water budget of the basins and cause drawdown of groundwater levels (e.g. ISTAP, 2014). This could affect groundwater supplies for the City of Santa Monica, which operates production wells within the Santa Monica Basin (Segment 2) for drinking water supply. In addition, the West Coast Basin is adjudicated, so withdrawal of inland groundwater by pumping from SSIs along the Segment 3 coast would require authorization by the Watermaster since West Basin is not a groundwater rights holder.

4.1.3 Potential Impact to Injection Barriers

As discussed in Section 2.3.3 above, a mix of treated recycled water and imported potable water is injected into a series of approximately 150 wells in the West Coast Basin near the Santa Monica Bay coast (Figures 2-1 and 3-3). 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. For SSIs that would draw a portion of the intake water from inland aquifers, some of the water could come from the injection wells, which would impact the performance of the injection barriers both for protection of seawater intrusion and replenishment of aquifers.

4.1.4 Groundwater Modeling to Evaluate Hydrogeologic Constraints

Based on offshore and onshore hydrogeologic data including additional field investigations conducted in 2015[12], Geosyntec developed numerical groundwater flow models as tools to further evaluate the feasibility of four SSI technologies (vertical wells, radial collector wells, horizontal wells, and slant wells) because these technologies have the highest potential to draw groundwater from inland aquifers. The groundwater flow models were used to specifically assess

- The ability of the different SSIs to provide the design intake rate of 40 MGD,
- The maximum yield of the different SSIs, and
- The amount of water withdrawn from inland sources including the injection barrier of West Coast Basin Barrier Project.

The models were designed to provide optimistic estimates of product capability of SSIs. Appendix J of Geosyntec 2016b provides detailed documentation of the model designs and results including figures. A brief overview follows below.

The model layering was based on the hydrostratigraphy inferred from the following sources with refinements to facilitate representation of the geometry of specific SSIs:

- Logs of onshore and offshore borings and onshore CPT data (see Section 3.1 of Geosyntec 2016b);
- Profiles developed based on the seismic reflection survey conducted by Fugro in September 2015 (see Section 3.2.3 and Appendix E);
- Numerical model of the West Coast Basin Barrier (e.g. Intera, 2015);

Assigned hydraulic properties were based on the West Coast Basin Barrier Model (Intera, 2015) with refinements consistent with site-specific data including representation of a shallow clay that occurs near the coast margin approximately 20 feet

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[12] Additional field-investigations included on-shore cone penetration testing (CPT), and an off-shore seismic reflection survey that were conducted to further characterize the geology and hydrostratigraphy of the coastal margin in the vicinity of the proposed desal facility at El Segundo. The data and results are reported in the Geosyntec 2016 SSI Feasibility Study,

below the seafloor. Hydraulic head was specified in groundwater models at the inland and offshore boundaries based on observed groundwater elevations for current conditions.

The groundwater flow models only include pumping from the hypothetical SSIs (Appendix J of Geosyntec 2016b). The influence of the simulated SSI pumping on boundary condition fluxes and initial groundwater levels indicates the portions of flow to the SSIs from inland and from the ocean, as well as change in groundwater levels in coastal margin aquifers.

The groundwater modeling shows that 40 MGD is not a sustainable flow rate from any of the modeled SSI technologies if the well heads are limited to the width of the ESGS site. Results for SSIs located to the north or south of the proposed location at El Segundo would be similar due to the generally consistent hydrogeologic characteristics of the Segment 3 coast.

Based on the model calculations, the maximum sustainable yields and portion of flow from inland aquifers for SSIs with well head infrastructure completed in or adjacent to the ESGS footprint (approximately 2,500 feet of linear beach front) are summarized below:

- Vertical Wells (10 wells with approximately 200 feet spacing): about 15 MGD maximum sustainable yield. 56% of the water pumped by the wells originates from inland sources, including the West Coast Basin Injection Barrier.
- Slant Wells (10 wells with approximately 200 feet spacing): about 16 MGD maximum sustainable yield. 55% of the water pumped originates from inland sources, including the West Coast Basin Injection Barrier.
- Horizontal Wells (13 wells with approximately 200 feet spacing): about 18 MGD maximum sustainable yield. 8% of the water pumped originates from inland sources, including the West Coast Basin Injection Barrier. The model horizontal wells are completed in the Gage Aquifer beneath the shallow clay layer, which is approximately 20 feet below the seafloor at El Segundo.
- Radial Collector Wells (six clusters [three collector wells each] with approximately 250 feet spacing): less than 10 MGD maximum sustainable yield. Because the sustainable flow rate is well below the design intake rate, the proportion of water from inland sources was not assessed.

The groundwater flow model calculations indicate that pumping from SSIs beneath the coast of El Segundo, even at rates far less than the design intake rate of 40 MGD (as listed above), would cause several feet of drawdown of groundwater levels to distances of thousands of feet from the SSIs. The drawdown of groundwater levels could mobilize contaminated groundwater and interfere with remedial measures. Moreover, pumping from four SSI well technologies (discussed above) could be detrimental to the performance of the West Coast Basin Injection Barrier and would withdraw groundwater from areas that are de-designated for municipal water supply (California Water Board, 1998, 1999). The drawdown of groundwater levels (e.g. Figures J.8 and J.10 of Appendix J, Geosyntec, 2016a) could also result in subsidence of the ground surface,[13] which could impact the structural integrity of the ESGS site, the Chevron Refinery, the proposed desal facility, roads, and other structures in the vicinity.

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 performance and sustainability of infrastructure located beneath it.

4.2.1 Sea level rise

Sea level rise can pose a threat to the onshore SSI infrastructure (mainly the well heads and pumps) if it is constructed at an elevation lower than the elevation to which sea level is projected to rise during the expected life of the infrastructure. The expected life of the infrastructure is assumed to be 40 years from project initiation, which includes 8 years for planning and permitting, 2 years for construction, and 30 years for operation as suggested by the Independent Advisory Panel[14]. Estimates of sea level rise at the

[13] 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).

[14] The SSI Guidance Tool and the El Segundo SSI Feasibility Study (Geosyntec, 2016a,b) were reviewed by an Independent Advisory Panel (IAP) that consisted of Thomas M. Missimer (Florida Gulf Coast University), Claudio Fassardi (CH2M Hill), Heidi R. Luckenbach (City of Santa Cruz Water Department) and Robert G. Maliva, (Schlumberger Water Services). The IAP was coordinated and moderated by Jeff Mosher and his team at the National Water Research Institute (NWRI). The NRWI IAP reports are included in Appendix C to Geosyntec, 2016b.

Santa Monica coastline are 2.6 feet by Mid-Century (2050 to 2060) and 6.8 feet by Late Century (2082 to 2100) and represent the high-risk, and extreme risk aversion scenarios (CA Ocean Protection Council Science Advisory Team, 2018). These values are based on the Ocean Protection Council's April 2017 *Rising Seas in California: An Update of Sea-Level Rise Science and the Coastal Commission's 2018 State Sea Level Rise Guidance*.

Although the predicted increases in sea level would not lead to inundation for normal conditions of the onshore SSI infrastructure, such as well heads, pumps, pipes, valves and other controls, sea level rise would increase the risk of inundation and damage 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.

SIGs, BIGs and horizontal wells (especially if installed in shallow offshore trenches), though designed to be inundated, can also be negatively affected by sea level rise because of changes to the erosion/deposition equilibrium that may occur with changes in sea level. Maintaining this equilibrium is a critical element of the design of SIGs, BIGs, and shallow horizontal wells and disturbances of equilibrium conditions would likely have negative long-term impacts to their performance and reliability (e.g. Jenkins, 2015 in Appendix K of Geosyntec, 2016b).

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, horizontal wells, or radial collectors) or at the shoreline (e.g., BIGs). Either erosion or deposition of sediment could 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 are located further away from the shoreline, however this can reduce the hydraulic connection with the ocean and therefore increase the portion of freshwater from inland aquifers extracted by the intake. As a result, SSI systems with well heads that can be further inland (e.g., slant wells, horizontal wells installed by HDD) provide potential to mitigate this technical risk (e.g. Missimer et al., 2013). Beach instability and migration of the shoreline could be a factor in the sustainability of a BIG. Beach erosion could result in the location of a BIG becoming too far offshore from the surf zone, which would impact the self-cleaning function, and may even erode away the engineered sand and destroy the galleries. And beach deposition could result in dewatering of a BIG if the beach becomes wider and leaves the BIG "high and dry" (Missimer et al., 2013; ISTAP, 2015).

As indicated in Section 2.4.1, major erosion occurs on Santa Monica Bay beaches as a consequence of the persistent southward littoral transport, and the beaches are only stable because of continued beach nourishment.

4.2.3 Seafloor stability (erosion/deposition)

Seafloor instability poses a threat to shallow SSI infrastructure beneath the seafloor (e.g., horizontal wells, SIG). High sedimentation rate would result in deposition of fine-grained material (silt and clay) on the seabed and decrease hydraulic connection between horizontal wells and the ocean. It could also decrease the infiltration rate of a SIG and require frequent rehabilitation (e.g., scraping of the seabed surface) (Missimer et al., 2013). Generally, high sedimentation rates are associated with discharge into the sea from rivers, streams or sewer outfalls (Missimer et al., 2013). Elevated sedimentation rates have been documented 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 and impact the performance of SSI infrastructure that is located too shallow beneath the seafloor (Water Research Foundation, 2011). Scouring of the seafloor generally occurs in high-energy environments, such as at the Santa Monica Bay coast, and is exacerbated during extreme winters by large waves such as associated with El Nino storms (California State Lands Commission, 2010). Analysis of coastal processes and seafloor stability in the vicinity of the El Segundo indicates a closure depth of 50 feet, which occurs approximately 6,500 feet offshore (Jenkins, 2015 included as Appendix K of Geosyntec 2016b)[15]. 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.

[15] 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 (Appendix K of Geosyntec, 2016b) 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.

4.3 Geochemical and Water Quality Constraints

Geochemical conditions (redox conditions, concentrations of iron or manganese, alkalinity) and the quality of the source water are important criteria in the evaluation of reliability and long-term performance of SSIs. Challenging water quality conditions can result in loss of performance and decreased capacity of the system (Missimer et al., 2013; ISTAP, 2014). In addition, desal facilities use reverse osmosis (RO) technology, which requires feed water with low concentrations of suspended solids and organic compounds, and stable water chemistry (ISTAP, 2014). The lifespan and performance of RO membranes are strongly dependent on the feed water quality (Bartak et al., 2012).

4.3.1 Adverse fluid mixing

The quality of the feed water can be impacted by mixing of different water sources. 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 can 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 SSIs that extract water from different sources, i.e., vertical wells, radial collectors and slant wells, which typically extract a mix of seawater and freshwater, and SSIs drilled through zones of varying oxidation conditions, i.e., horizontal wells with screens between 1,000 and 2,000 feet offshore (Missimer et al., 2013). SSIs with the lowest risks of water quality problems are infiltration galleries, which produce water mainly by vertical infiltration of sea water (ISTAP, 2014). At the El Segundo site, elevated concentrations of both iron and manganese exist in the groundwater in the vicinity of the ESGS site (MWH, 2007). Similar groundwater chemistry is likely at other locations along Segment 3 and Segment 2 that could impact the performance of the intake works for SSIs and require additional pretreatment at a desal facility (MWH, 2007).

4.3.2 Clogging

Clogging (also referred to as plugging) of an SSI system will result in decreased intake capacity, loss of performance, and would require rehabilitation of the intake. Consequently, clogging is of greatest concern for SSIs with complex and expensive rehabilitation requirements, e.g., slant wells, horizontal wells and SIGs (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 can occur due to deposition of fine-grained material (silt and clay) in a low-energy environment where re-working of the seafloor by 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 and horizontal wells installed in trenches with engineered fill, 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 and intake rates of horizontal wells and other SSIs. 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) and sporadic discharge of mud from Ballona Creek following periods of heavy rain as discussed above.

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 can improve feed water quality and 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 of water within the sediment 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 SDI values in the range of 0.3 to 1 (Bartak et al., 2012), and have been shown to provide feed water of better quality than other SSIs (Rachman et al., 2014). Horizontal wells installed by HDD have been shown to be less efficient and have been documented to provide feed water with higher SDI (Rachman et al., 2014). SDI values for SIGs 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). The SDI is site-specific and neither predictable nor consistent for specific SSI technologies. With the potential variability of incoming water quality, pretreatment may still be required to protect the RO membranes and achieve acceptable operational reliability.

4.3.4 Contaminated Groundwater

The presence of contaminated groundwater in the vicinity of SSIs is of concern if a portion of the intake water would be derived from inland sources. This is most likely to be important for relatively deep intakes such as vertical wells, slant wells, radial collectors, or horizontal wells with poor hydraulic connection to the ocean. Pumping from these SSIs can cause seaward movement of contaminants in groundwater and potentially require additional treatment of the source water. In some locations, the potential exists for the source water to be considered an extremely impaired source by the California Water Resource Control Board Division of Drinking Water (DDW), which would require additional permitting (California Department of Health Services, 1997).

Presence of contaminated soil and groundwater is documented at many locations near the coast of Segments 2 and 3. Known groundwater contamination near the coast was identified based on records from the Water Board's GeoTracker and the Department of Toxic Substances Control EnviroStor websites[16] are shown on Figures 3-2 and 3-3 for Segments 2 and 3, including a large area impacted by the Chevron Refinery in El Segundo. The majority of the chemicals of concern at documented contaminated sites are likely volatile organic compounds (VOCs) and hydrocarbon-related constituents. Further evaluation is recommended for specific sites if SSIs are considered further for locations near documented contamination.

4.3.5 De-designated Area in Segment 3

Due to contamination of groundwater associated with the Chevron El Segundo Refinery 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

[16] https://geotracker.waterboards.ca.gov/
https://www.envirostor.dtsc.ca.gov/public/

coast of Segment 3 (Figure 3-3) 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, or horizontal wells with poor hydraulic connection to the ocean that would withdraw groundwater from inland aquifer sources in this de-designated area would be in violation of the amended Basin Plan.

4.4 Land Use and Sensitive Habitat

4.4.1 Residential Properties and Recreational Use

Locating permanent infrastructure or temporary construction staging on the beach in front of residential properties for SSIs could escalate public safety issues and increases the risk for active public opposition to the project. Moreover, Segments 2 and 3 include some of the most famous beaches in the world, such as Will Rogers, Santa Monica, and Dockweiler State Beaches. The beaches of Segment 2 and 3 of Santa Monica Bay are world class beaches that are popular recreational destinations for thousands of visitors every day[17].

Nearly all the Segment 2 coast has residential properties bordering the beach (Figure 3-2). And in Segment 3, Manhattan, Hermosa, and Redondo Beach all have residential properties bordering the beach, as does the northern most 4,450 ft of coast just south of Marina Del Rey.

Based on the feasibility definition that takes into account economic and social factors, public opposition is likely to be a significant challenge for locating SSI infrastructure, staging construction, or conducting operation and maintenance activity on these beaches due to the heavy recreational use and adjacent residential areas. This could restrict the potential locations where SSIs could be constructed thereby limiting the available footprint for onshore SSIs and potentially presenting an impediment for offshore SSIs that require access to shoreline areas for construction staging. Public opposition could potentially be partially mitigated by constructing subsurface well heads, but this would increase the risk of damage caused by sea level rise and may still result in opposition due to the need for access for construction and maintenance.

[17] https://www.californiabeaches.com/best-beaches-in-los-angeles/

4.4.2 Snowy plover habitat

Segments 2 and 3 include four areas that are designated as critical habitat for the western snowy plover. Segment 2 has one area in the northern portion that is approximately 4,800 feet long. And, the three areas in Segment 3 are a total of 12,300 ft long and occupy approximately 44 acres (Figure 3-3). 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. The snowy plover 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).

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 prohibit siting permanent SSI infrastructure in the snowy plover habitat, or at a minimum cause delays in construction since access would not be allowed during the nesting season from March through August. In addition, maintenance operations likely could not take place during the nesting season. Even for SSIs that could be located outside of snowy plover habitat (e.g., BIGs and SIGs) but require construction or maintenance staging in the critical habitat area, scheduling would be similarly restricted. Moreover, locating SSI infrastructure within the designated critical habitat may not be allowed.

4.4.3 Existing buried infrastructure

A variety of buried offshore infrastructure is present in portions of Segment 2 and 3, including sewer lines, oil pipelines, and fiber optic cables (Figure 3-3). Although sufficient area is present between the offshore infrastructure to construct SSIs (i.e., SIG, DIG, and horizontal wells) on or under the seafloor, additional undocumented buried infrastructure may exist. Subsurface infrastructure could pose significant technical risks during construction, including delays and cost overruns.

Furthermore, oil pipelines beneath portions of the Segment 2 and 3 coasts, present a risk of leaking pipes introducing oil to the SSIs and the desal facility via seepage through sand.

In addition to offshore infrastructure, buried infrastructure onshore needs to be considered that could complicate construction for onshore SSIs.

4.5 Maintenance

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

4.5.1 Frequency of Maintenance

The frequency of required maintenance activities depends on both the SSI technology and site-specific conditions. For example, the presence of fine-grained material in the source water can increase the potential for screen clogging of vertical wells, slant wells, radial collectors or horizontal wells. Similarly, precipitation of iron or manganese oxides due to mixing of different sources of water can result in screen clogging. For infiltration galleries, the frequency of maintenance would be influenced by the sedimentation rates on the seabed or scouring of the seabed that might disturb the engineered fill and intakes (also called drains) (Missimer et al., 2013). As discussed in Section 4.3.2 above sedimentation rates in Segments 2 and 3 of Santa Monica Bay are sometimes high because of the accumulation of fine sediment in the vicinity of the wastewater outfalls (Farnsworth and Warrick, 2007), and sporadic discharge of mud from Ballona Creek and other drainages from the Santa Monica Mountains following periods of heavy rain.

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 horizontal wells is much more complex than for vertical wells for several reasons including need for specialized equipment, location of the well screens a long distance from the shoreline, and risk of damaging the screens or porous pipe. (Water Research Foundation, 2011; Missimer et al., 2013). Although potential maintenance of seafloor infiltration galleries is conceptually simple (e.g., scraping or dredging of the seabed surface), it would be challenging in the high energy offshore environment of the Santa Monica coast (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. Existing systems at similar capacity (40 MGD) include vertical well systems in Oman and Spain and HDD wells in Spain (Missimer et al. 2013). However, the facility in Oman is in a karst aquifer, a very productive aquifer containing cavities and fractures (Missimer et al., 2015). The facility in Spain is also in a limestone aquifer with overlying unlithified calcareous sediments (Missimer et al., 2015). In addition, both have experienced lower capacity than expected and have reported water quality issues (Rachman et al., 2014). Even for these existing systems, limited data are available to assess actual performance and long-term operating efficiency.

4.6.2 Complexity of construction

Construction complexity refers to issues that can increase cost, extend the construction schedule, or increase the technical risk of successful project completion, which influences the feasibility of a specific SSI option. These issues are generally inherent to the type of SSI, e.g., 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;
- Constrained construction schedules due to seasonal restrictions on beach access from public use;
- Constraints on offshore construction schedules due to seasonal conditions;
- Difficulties in offshore construction because of:
    - Water depth (complexity and cost of construction increase with water depth);

  - Wave and wind energy (complexity and cost of construction increase geometrically with increased levels of wave energy);
  - Weather predictability (construction risk and cost increase with decrease in predictability); and
  - Instability of seabed.
- Potential environmental impacts resulting from construction (ISTAP, 2014).

Specific complexities involved with each SSI technology are discussed for Segments 2 and 3 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 an SSI system 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 and the expected water quality

Performance risk is higher for intakes or site conditions for which it is difficult to implement a pilot test to assess intake 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 settings contributes to the uncertainty 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. 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 can impact the reliability of the intake system, including vertical wells, and could increase the required frequency of rehabilitation.

Evaluation of the reliability of some SSIs is challenging because of the absence of operational history for comparable systems constructed in similar settings. For example, some long-term performance data are available for a SIG located in Japan, which is in a protected calm sea (Missimer et al., 2013; Pankratz, 2014). However, the high-energy ocean setting of Santa Monica Bay makes comparison to the SIG performance in the protected location in Japan irrelevant. Similarly, due to the relatively recent development of the technology for SSIs, data are not available for the long-term performance of horizontal wells and slant wells.

5. SUMMARY OF SUITABILITY OF THE SANTA MONICA BAY COAST FOR SSI TECHNOLOGIES

The evaluation criteria discussed above in Section 4 were applied to each specific SSI technology for Segments 2 and 3 coasts. As discussed in Section 3, initial screening with the SSI Guidance Tool determined that no SSI technologies are feasible due to fatal flaw conditions in Segments 1 and 4.

For this assessment the design production capacity of the proposed desal facility is 20 MGD, corresponding to an intake rate of 40 MGD. A production capacity of 20 MGD for the proposed desal facility is at the low end of the range of production capacity (20 and 60 MGD) outlined in the West Basin Desal Master Plan (Arcadis, 2013), and is considered the minimum production capacity for the proposed desal facility.

As discussed in Sections 3 and 4, the additional assessment for each of the specific SSI technologies is based on results of initial screening using the SSI Guidance Tool, review of the site-specific data, groundwater modeling results, 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 judgment provided by expert advisors and reviewers[18] for the previous evaluation for El Segundo (Geosyntec, 2016b). Emphasis is on criteria that represent potential fatal flaws for the SSI technologies, although other challenging criteria are also discussed.

Table 5-1 below summarizes the SSI feasibility evaluation for Segments 2 and 3 of the Santa Monica Bay coast. The table is followed by discussion of each SSI technology for Segments 2 and 3.

[18] 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: Summary of Supplemental SSI Feasibility Evaluation for Segments 2 and 3 of Santa Monica Bay

	Vertical Wells	Slant Wells	Radial Collector Wells	Horizontal Wells		Beach Infiltration Gallery	Seabed Infiltration Gallery	Deep Infiltration Gallery
				Below 20 feet	Above 20 feet			
Hydrogeologic Constraints								
Hydraulic connection to ocean	Moderate	Moderate	Moderate	Moderate	High	High	High	High
Impact on inland aquifers	Yes	Yes	Yes	Yes	Unlikely	No	No	Unlikely
Impact on Injection Barrier	Seg 2: NA Seg 3: Yes	Seg 2: NA Seg 3: Yes	Seg 2: NA Seg 3: Yes	Seg 2: NA Seg 3: Possibly	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 silt content of intake water	Low	Low	Low	Low	Low	High	Low	Low
Draws contaminated water	Possibly	Possibly	Possibly	Possibly	No	No	No	Unlikely
Draws from aquifer area *de-designated* for municipal use	Seg 2: NA Seg 3: Possibly	Seg 2: NA Seg 3: Possibly	Seg 2: NA Seg 3: Possibly	Seg 2: NA Seg 3: Possibly	Unlikely	No	No	Seg 2: NA Seg 3: Possibly
Land Use and Sensitive Habitat								
Need to construct in snowy-plover habitat and/or in front of residential properties	Seg 2: Yes Seg 3: Likely	Seg 2: Yes Seg 3: Likely	Seg 2: Yes Seg 3: Likely	Possibly	Possibly	No	No	No
Need to perform O&M in snowy-plover habitat and/or in front of residential properties	Seg 2: Yes Seg 3: Likely	Seg 2: Yes Seg 3: Likely	Seg 2: Yes Seg 3: Likely	Seg 2: Yes Seg 3: Likely	Possibly	No	No	No
Risk of encountering undocumented buried infrastructure	Low	Low	Low	Possibly	Possibly	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 similar scale and hydrogeologic / oceanographic conditions	No	No	Yes	No	No	No	No	No
Complexity of construction	Low*	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

Vertical wells along the coast of Segments 2 or 3 for intake water for the proposed desal facility would withdraw a substantial amount of water from inland sources. Groundwater modeling[19] for the central portion of Segment 3, which is summarized in Section 4.1.4 above and detailed in Appendix J of Geosyntec, 2016b, indicates that more than 50% of the feed water would originate from inland sources, including the injection barrier, areas of contaminated groundwater and groundwater de-designated for municipal use (Water Board, 1999).

An optimistic transmissivity was used in the screening analysis with the Guidance Tool for Segments 2 and 3, assuming wells would extend into the Silverado Aquifer to a depth of 200 feet. However, wells deeper than 100 feet, although more productive, would draw a larger portion of water from inland aquifers. Consequently, for this additional evaluation we have assumed the wells would be limited to the upper aquifer: Layer 2 in the WRD groundwater model of the Los Angeles Basin (Reichard et al., 2003), for which the hydraulic conductivity is illustrated by Figure 2-2. Based on the LA Basin model, the production capability from the shallow coastal margin aquifers in Segment 2 is approximately seven times lower than in Segment 3. Consequently, vertical wells along the Segment 2 coast would need to span in the range of 6 to 12 miles to provide the design intake rate of 40 MGD to the proposed desal facility. However, the entire length of the Segment 2 coast is less than 9 miles. Thus, production capability of shallow coastal margin aquifers in Segment 2 is likely insufficient for SSI wells such as vertical wells, slant wells, and radial collector wells along the coast to achieve the design feedwater intake capacity for the proposed desal facility. Moreover, nearly the entire length of the Segment 2 coast includes beaches that are popular for recreational use and are bordered by residential properties.

Groundwater modeling (Section 4.1.4 above and Appendix J of Geosyntec, 2016b) indicates that vertical wells would need to span in the range of 4500 to 9000 feet of the coast of Segment 3 to provide the design intake rate of 40 MGD to the proposed desal facility. This would likely require a sequence of wells to extend along heavily used recreational beaches, in front of residential properties and into critical habitat of the

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

Snowy Plover. Moreover, for the majority of Segment 3, coast pumping would interfere with the performance of the West Coast Basin Injection Barrier. And, vertical wells would potentially draw water from contaminated sites near the coast of Segments 2 and 3.

In the central portion of Segment 3, vertical wells would withdraw groundwater from inland aquifer sources in an area de-designated for municipal beneficial use (Figure 3-3), which would be in violation of Resolution No. 98-18 that amended the Basin Plan (CA RWQCB LA Region, 1998).

These factors present major problems for the use of vertical wells as SSIs along the coast of Segment 2 and 3 for the proposed desal facility. And screening with the SSI Guidance Tool indicates that no SSI technologies are feasible due to fatal flaw conditions in Segments 1 and 4. Accordingly, vertical wells are not recommended for the proposed desal facility on the coast of Santa Monica Bay.

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 requirements and angle drilling limitations, angle of 20˚ being considered the practical minimum. Groundwater modeling (Appendix J of Geosyntec, 2016b) represents slant wells drilled at an angle of 20˚ from the ESGS site, with the well screen intervals located between 35 and 170 feet below sea level, for a length of 600 feet. 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, slant wells in Segments 2 and 3 would be subject to the same problems as vertical wells discussed in Section 5.1 above. Their production capacity would be similar to vertical wells and they would draw a substantial amount of water from inland sources. Also, 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 associated with inland contaminated groundwater, slant wells could 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 as discussed in Section 4.3 above. Oxidation of the iron and manganese would result in precipitation of minerals that would require filtration prior to RO. At Segment 3 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 ESGS site (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, respectively) (MWDOC, 2014), and resulted in concerns regarding mixing with oxic seawater.

Several factors present major problems for the use of slant wells along the coast of Segment 2 and 3 to provide the design feedwater intake for the proposed desal facility. And screening with the SSI Guidance Tool indicates that no SSI technologies are feasible due to fatal flaw conditions in Segments 1 and 4. Accordingly, slant wells are not recommended for the proposed desal facility on the coast of Santa Monica Bay.

5.3 Radial Collectors Wells

Radial collector wells suffer from the same fatal flaws as vertical and slant wells in both Segments 2 and 3 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. And in Segment 3 they would likely compromise the performance of West Coast Basin Injection Barrier and draw water from the area that was de-designated for municipal beneficial use.

Groundwater modeling indicates that the maximum production capacity for radial collector wells with well head caissons located inside the ESGS footprint would be less than 10 MGD (Section 4.1.4 above and Appendix J of Geosyntec, 2016b), significantly less than the design intake rate of 40 MGD. Accordingly, well head caissons would need to span an estimated distance of 8,000 feet of the coast in Segment 3 to achieve the design intake rate, and thus would likely encroach on areas in front of residential properties and/or snow-plover habitat (Section 4.4), as well as requiring additional mitigation to provide protection from sea level rise and beach erosion (Section 4.2).

And like vertical wells and slant wells, radial collector wells would likely need to span essentially the entire coast of Segment 2 to achieve the design intake rate, nearly all of which is heavily used recreational beaches, and much of which is residential beachfront.

In addition to the water quality concerns indicated above, the redox state of the pumped water could be critical for radial collector wells because the caissons 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 mg/L and 10 mg/L respectively) exist in shallow groundwater in the vicinity of the ESGS site (MWH, 2007) as discussed in Section 4.3 above. Oxidation of the iron and manganese would change it to a form which has minimal solubility, resulting in a precipitant that could impact the performance of the intake and would require filtration prior to RO. In addition, the presence of hydrogen sulfide in the pumped water, which can occur in the shallow subsurface beneath the sea floor, could result in the precipitation of elemental sulfur, which could also foul the filters and membranes (Missimer et al., 2013).

Radial collector wells along the entire length of the Segment 2 coast likely could not achieve the design intake rate, and in Segment 3 they would be subject to several problems. And screening with the SSI Guidance Tool indicates that no SSI technologies are feasible due to fatal flaw conditions in Segments 1 and 4. Accordingly, radial collector wells are not recommended for the proposed desal facility on the coast of Santa Monica Bay.

5.4 Shallow Subsurface Intakes on the Beach or Offshore

Seabed Infiltration Galleries (SIGs), the Beach Infiltration Galleries (BIGs), and horizontal wells beneath the seafloor installed either by horizontal directional drilling (HDD) or offshore trenching all require the following specific conditions for successful operation:

1. Adequate sediment cover,
4. Sufficient permeability and appropriate thickness of the sediment cover (no lenses of silts and clays), and
5. A stable beach and/or seabed.

All are vulnerable to exposure by erosion, and all are vulnerable to impaired infiltration rates due to deposition of silts and clays on the seabed following installation. Generally, these subsurface intake technologies should have at least 10 ft of sediment cover that is predominantly sands and/or gravels to provide adequate permeability to facilitate high infiltration rates of seawater and protect the intakes (e.g. Jenkins, 2015). If fine-grained silts or clays are deposited on the seafloor over the intakes, the hydraulic connection between the intakes and the ocean will decrease so the feed water intake capacity will decrease.

A summary discussion of each shallow SSI technology follows:

5.4.1 Horizontal Wells

Shallow horizontal wells beneath the seafloor can provide a better hydraulic connection to the ocean than deeper SSIs. But, compared to other SSI technologies, discussed above, shallow horizontal wells have a greater degree of construction complexity, more performance risk, less known reliability, and higher frequency and complexity of maintenance. Horizontal wells can be installed by horizontal directional drilling (HDD) or installed in trenches excavated offshore which typically would be backfilled with engineered permeable fill.

5.4.1.1 HDD Installation of Horizontal Wells

Successful installation of shallow horizontal offshore wells by HDD can be complicated or prevented by presence of gravel and cobbles, which have been documented offshore of El Segundo in Segment 3. And the depth of an HDD boring must be sufficient for the overburden pressure to prevent pressurized drilling fluid from escaping, so cuttings are returned and the boring stays open. Typically, the minimum depth for HDD in unconsolidated sandy sediment is 20 to 30 feet (Geosyntec, 2016b; Geosyntec, 2019). 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 in the shallow sediments beneath the seafloor of Segment 3. However, based on available information from borings and the geophysical survey offshore of El Segundo (Geosyntec, 2016b), the presence of cobbles and gravel is localized and variable so a single pilot HDD well would not be representative of conditions and feasibility at other locations in the vicinity.

At El Segundo, and likely for other portions of Segment 3, a low-permeability layer approximately 20 feet below the seabed poses significant challenges for HDD technology. HDD at depths shallower than 20 feet below the sea floor, is likely not possible because drilling fluid likely would not be contained in the boring and would leak out on the seafloor (Geosyntec, 2019). And horizontal wells installed below the clay layer would have limited hydraulic connection with the ocean, so like deeper well technologies, they would draw a portion of the water from inland sources, thereby impacting water supply aquifers and the injection barrier. Groundwater modeling[20] for Segment 3 indicates that approximately 8% of the feed water would originate from inland sources, including the injection barrier (Section 4.1.4 above and Appendix J of Geosyntec, 2016b).

Additionally, groundwater modeling indicates that the maximum production capacity for HDD wells, approximately 2000 feet long, originating inside or adjacent to the ESGS footprint and completed beneath the shallow clay layer, would be approximately 18 MGD, significantly less than the design intake rate of 40 MGD. Accordingly, to achieve the design intake rate, numerous HDD wells would be required spanning more than a mile of the coast for Segment 2 or 3, so the well heads and infrastructure would extend along heavily used recreational beaches, much of which is bordered by residential properties.

Horizontal Wells have a high degree of construction and maintenance challenges and technical risks during construction and operation. Moreover, they have no precedence in similar settings to the coast of Segments 2 and 3. The uncertainty of the construction, maintenance and long-term performance coupled with the estimated cost of $80M to $120M[21] to drill and install the wells would present major economic risk for West Basin to assume as a public agency.

5.4.1.2 Installation of Horizontal Wells by Offshore Trenching

An alternative approach is to install the horizontal wells by offshore trenching, likely from trestles (Geosyntec, 2017a). This would facilitate installation above the shallow clay layer, which is about the 20-feet beneath the seafloor off El Segundo in Segment 3.

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

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

However, installation of horizontal wells with offshore excavation from trestles would be very expensive and challenging in the high energy coastal margin setting of Segments 2 and 3 of the Santa Monica Bay coast, and there is no precedence. (Geosyntec, 2017a). The estimated construction cost for horizontal well intake system designed for an intake rate of 40 MGD is $372M (Geosyntec, 2017a). The intake system would consist of fourteen 20-inch-diameter, micro-porous horizontal wells in 15-foot-deep trenches that would be excavated and backfilled with the excavated material in pairs from trestles extending 1,850 feet offshore. Installation of horizontal wells by offshore trenching would present major economic risk for West Basin to assume as a public agency.

5.4.2 Additional Challenges for Horizontal Wells

Challenges and potential problems for shallow horizontal offshore wells regardless of the installation method are discussed below.

For both installation methods, there is a risk of encountering undocumented buried infrastructure (e.g., abandoned pipes) within the upper portion of the seabed for Segments 2 and 3.

Shallow horizontal wells inside the reported closure depth[22] of 50 feet, which occurs approximately 6,500 feet offshore (Section 2.4.2 above and Jenkins, 2015—Appendix K to Geosyntec, 2016b) 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 (Missimer et al., 2013).

In addition, the shallow wells would draw water from zones of sediments potentially containing varying oxidation conditions along the length 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 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 RO. At El Segundo, elevated

[22] The closure depth represents the closest point to the shoreline where a stable seabed occurs. Closer to shore than the closure depth, the seabed is vulnerable to erosion by waves and currents.

concentrations of both iron and manganese exist in the groundwater in the vicinity of the ESGS at up to 49 mg/L and 10 mg/L, respectively (MWH, 2007). And hydrogen sulfide is common in the shallow subsurface beneath the sea floor (Missimer et al., 2013).

Installation of horizontal wells by HDD or offshore trenching presents major economic risk for West Basin to assume as a public agency and is not recommended for the proposed desal facility on the coast of Santa Monica Bay.

5.5 Beach Infiltration Galleries

BIGs should be in the surf zone, so that the permeability of the overlying sand is maintained by the turbulence caused by breaking waves. Therefore, a successful BIG should be located on beaches that are stable, with minimal erosion and deposition cycles. This is not the case on the beaches of Santa Monica Bay, which have a 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 (Jenkins, 2015), that can lead to long-term patterns of coastal erosion. The erosion can be exacerbated by extreme winter storms (such as those caused by El Nino events). As an example, up to 400 cubic yards/yard of erosion has been observed in a winter season along the beach in front of the ESGS in Segment 3 (California State Lands Commission, 2010).

Maintaining stable beach width in Segment 3 requires continued beach nourishment to replace sand lost due to erosion. In the vicinity of the Marina Del Rey harbor the US Army Corps of Engineers perform dredging every 3 to 5 years, which is a source of sand for beach nourishment (Jenkins, 2015). 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 coastline north and south of the jetty or rock groin adjacent to the ESGS (much wider beach north of the jetty, Figure 2-3) is evidence of substantial southward long-shore transport of sand and beach instability (Google Earth, 2015; California State Lands Commission, 2010). There is no precedence for BIGs in high-energy unstable beach settings like Santa Monica Bay. A BIG is not recommended for the proposed desal facility on the coast of Santa Monica Bay.

5.6 Seabed Infiltration Galleries

The optimal location for a SIG is at or beyond the "closure depth" where the change in sedimentation due to coastal processes is essentially zero and the risk of deposition or erosion is minimal. The closure depth offshore of Segments 2 and 3 is approximately 50 feet, which is located approximately 6,500 feet offshore from the shoreline.

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 in Santa Monica Bay. SIGs at Huntington Beach that were found to be not economically viable for the 50 MGD production capacity (ISTAP, 2015). Segments 2 and 3 of Santa Monica Bay are generally similar to Huntington Beach in terms of wave exposure, bathymetry and a high energy ocean environment. Therefore, the same constraints and challenges at Huntington Beach apply for construction of a SIG in Santa Monica Bay. Based on comparison of some key parameters (Table 5-2, below), total capital costs for a desal facility utilizing a SIG in Santa Monica Bay are likely to exceed $774M[23]. Moreover, the unit costs (i.e., cost per acre-foot) are likely to be greater due to reduced economies of scale.

Based on further evaluation of site-specific conditions, the estimated capital cost just for the construction of a 40 MGD SIG in Santa Monica Bay is $278M, or $334M including professional services, but not including construction of the desal facility (Geosyntec, 2017b, which is included as Appendix 2b of the Environmental Impact Report). The current Class V estimates for constructing a 20 MGD desal facility, intake, discharge, and product distribution pipeline as described in the Environmental Impact Report Section 3 is approximately $485M including contingency and professional services (CH2M, 2018). The estimated cost for constructing a SIG would translate to a 70% increase in the overall capital costs.

[23] This cost estimate includes construction of a SIG using a float in method, the desal facility, intake pump station, financing, decommissioning, etc. (ISTAP, 2015).

Table 5-2: Comparison of El Segundo and Huntington Beach

	Huntington Beach (ISTAP, 2015)	**Santa Monica Bay**
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 desal facility with a SIG Intake System ($M)	1,936 – 2,347	> 774*
Estimated capital cost per MGD ($M/MGD)	18 - 22	>$19

* 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 (Jenkins, 2015)

In addition to economic arguments, the construction of a SIG in the high-energy and relatively unprotected conditions is without precedence. 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. And, a small-scale test SIG at Long Beach is located inside a breakwater system where it is completely sheltered from wave exposure. The high energy deep offshore setting at Santa Monica Bay would substantially increase the complexity of construction and the performance risk for a SIG due to the lack of precedence.

Moreover, erosion of massive amounts of sediments from the watershed, which can occur with El Nino winter storms, can deposit silts and clays on the Santa Monica Bay seafloor that would reduce the permeability of the engineered fill at a SIG (Jenkins, 2015), and require difficult, expensive, and potentially environmentally damaging maintenance.

The uncertainty of performance coupled with the estimated cost in excess of $300M to build a SIG presents major technical and economic risk for West Basin that is not appropriate for a public agency. A SIG is not recommended for the proposed desal facility on the coast of Santa Monica Bay.

5.7 Deep Infiltration Gallery

DIGs or water tunnels are a range of conceptual offshore subsurface seawater collector systems without precedence for conditions similar to the Santa Monica Bay coast. Accordingly, no direct information is 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 parallel to the coast (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 in unconsolidated sediment offshore (e.g., may require ground freezing to allow tunneling [ISTAP, 2014]), coupled with potentially high technical risks and lack of precedence for similar conditions, result in DIGs being an unrealistic SSI option that is not recommended for implementation in Santa Monica Bay for the proposed desal facility.

6. CONCLUSIONS

The coast of Santa Monica Bay was divided into four segments (Figure 2-1) for the purpose of describing the setting and evaluating the feasibility of SSI technologies to provide 40 MGD of feedwater for West Basin’s proposed desal facility.

Screening evaluation of feasibility of seven SSI technologies using the Guidance Tool (Geosyntec, 2016a) eliminated Segment 1 (Malibu Coast) and Segment 4 (Palos Verde Peninsula Coast) from further consideration because of the presence of cliffs accompanied by narrow beaches as well as shallow impermeable bedrock (insufficient transmissivity of coastal margin sediment). With no constraints on the siting and extent of infrastructure along the coast (i.e., no consideration of protected areas, recreational beaches, proximity to residential properties), the SSI Guidance Tool indicates that all SSI technologies are technically feasible in Segments 2 and 3 (Figure 2-1). The feasibility scores provided by the SSI Guidance Tool indicates that SSIs are less feasible in Segment 2 than Segment 3 due to lower hydraulic conductivity of coast margin aquifers and sediments in Segment 2.

Based on the findings of the SSI Guidance Tool, a more detailed evaluation of feasibility of SSI technologies was conducted for Segments 2 and 3 with further considerations including site-specific hydrogeology, groundwater modeling results, SSI production potential, geochemical constraints, potential for impacts to inland aquifers, beach and seafloor stability, vulnerability to sea level rise, sensitive ecological habitats, beaches with heavy recreational use, proximity to residential properties, precedence of the SSI technology, cost, reliability and risk (probability of successful construction and sustainable performance).

Based on the more detailed evaluation of SSI feasibility in Segments 2 and 3, including model simulations of SSI pumping in Segment 3 (Appendix J of Geosyntec, 2016b), vertical wells and slant wells would draw more than half of the intake water from inland aquifers. At the El Segundo coast this would impact performance of the West Coast Basin Injection Barrier and could interfere with remediation of contaminated groundwater at the Chevron Refinery. Moreover, in the central portion of Segment 3, the SSI pumping would withdraw groundwater in an area that is de-designated for municipal use, which would be in violation of the amended Basin Plan (Water Board, 1998).

The estimated production rate of an SSI system consisting of vertical wells, slant wells, or radial collector wells with well head infrastructure completed in or adjacent to the ESGS footprint is even less: 15, 16, and 10 MGD, respectively (Section 4.1.4 above and Appendix J of Geosyntec, 2016b). Thus, to achieve an intake rate of 40 MGD, these technologies would require many SSIs spanning 1.5 to 5 miles along the Segment 3 coast, and an even greater distance of Segment 2 where hydraulic conductivity of the coastal margin aquifers is lower. Such an extensive system of SSIs would impinge on sensitive and protected ecological habitats, beaches with heavy recreational use, and residential beach front properties. Moreover, the drawdown of groundwater levels by an extensive system of SSI wells, which would extend thousands of feet inland from the coast, could result in subsidence of the ground surface, which could impact the structural integrity roads and buildings near the coast.

The hydraulic connection between the ocean and horizontal wells would be limited for HDD wells installed beneath a low permeability clayey layer approximately 20 feet below the seafloor along the coast of El Segundo. Installation of HDD well shallower than 20 feet below the seafloor is likely not possible due to inadequate overburden pressure to contain the drilling fluid and the presence of gravel and cobbles. Installation of shallow horizontal wells in trenches excavated offshore is very expensive and without precedence in a similar high energy environment. Model simulations indicate that horizontal wells extending nearly 2000 feet offshore beneath the clay layer would draw a greater portion of water from the ocean than vertical or slant wells, but the estimated maximum sustainable yield of an HDD SSI system with well heads within or adjacent to the ESGS site is less than 20 MGD (less than half the design intake rate of 40 MGD). So numerous HDD wells would be required that would span more than a mile of the coast in Segment 2 or 3 and also would be subject to limitations associated with sensitive and protected habitats, beaches with heavy recreational use and beach front residential properties.

BIGs would draw less water from inland aquifers, but BIGs of similar capacity to the 40 MGD needed for the proposed desal facility are without precedence in a high energy setting with unstable beaches like Santa Monica Bay. Due to the persistent southward long-shore transport in the Santa Monica littoral cell, sustainability of BIGs would be dependent on continued beach nourishment. Performance of BIGs would also be vulnerable to sea level rise, which will influence the position of the surf zone.

Offshore shallow SSI technologies such as SIGs, DIGs, and horizontal wells installed in offshore trenches, also would draw less water from inland aquifers, but are without precedence in the high energy setting of the Santa Monica Bay. They would be very expensive to construct, and the sustainability of their production capacity would be uncertain.

In closing, based on the limitations, challenges and constraints discussed in this report, none of the seven SSI technologies are recommended for the proposed desal facility.

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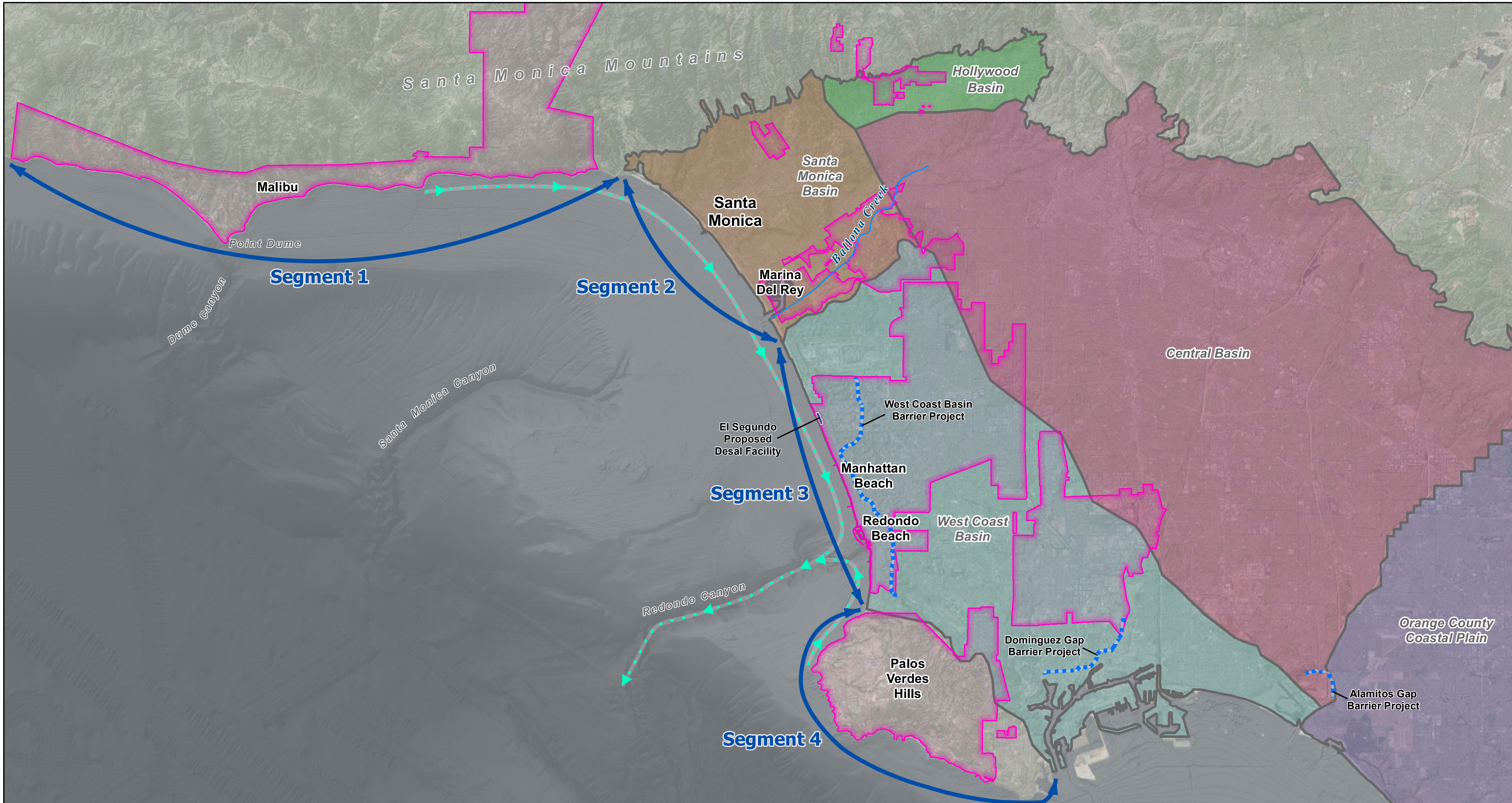
FIGURES



Legend

- West Basin Service Area
- Groundwater Basin
- Sea Water Barrier
- Littoral Drift Pathway along Coastal Margin *(longshore transport of sediment)*

Groundwater Basin

- Central Basin
- Hollywood Basin
- Orange County Coastal Plain
- Santa Monica Basin
- West Coast Basin

Notes:
Littoral drift pathway adapted from Jenkins, 2015-- Appendix K of Geosyntec, 2016.
Bathymetry and DEM source: NOAA - https://maps.ngdc.noaa.gov

Santa Monica Bay Coastal Margin Map

Alternative Site Evaluation
Proposed Desalination Facility
West Basin Municipal Water District

Geosyntec consultants

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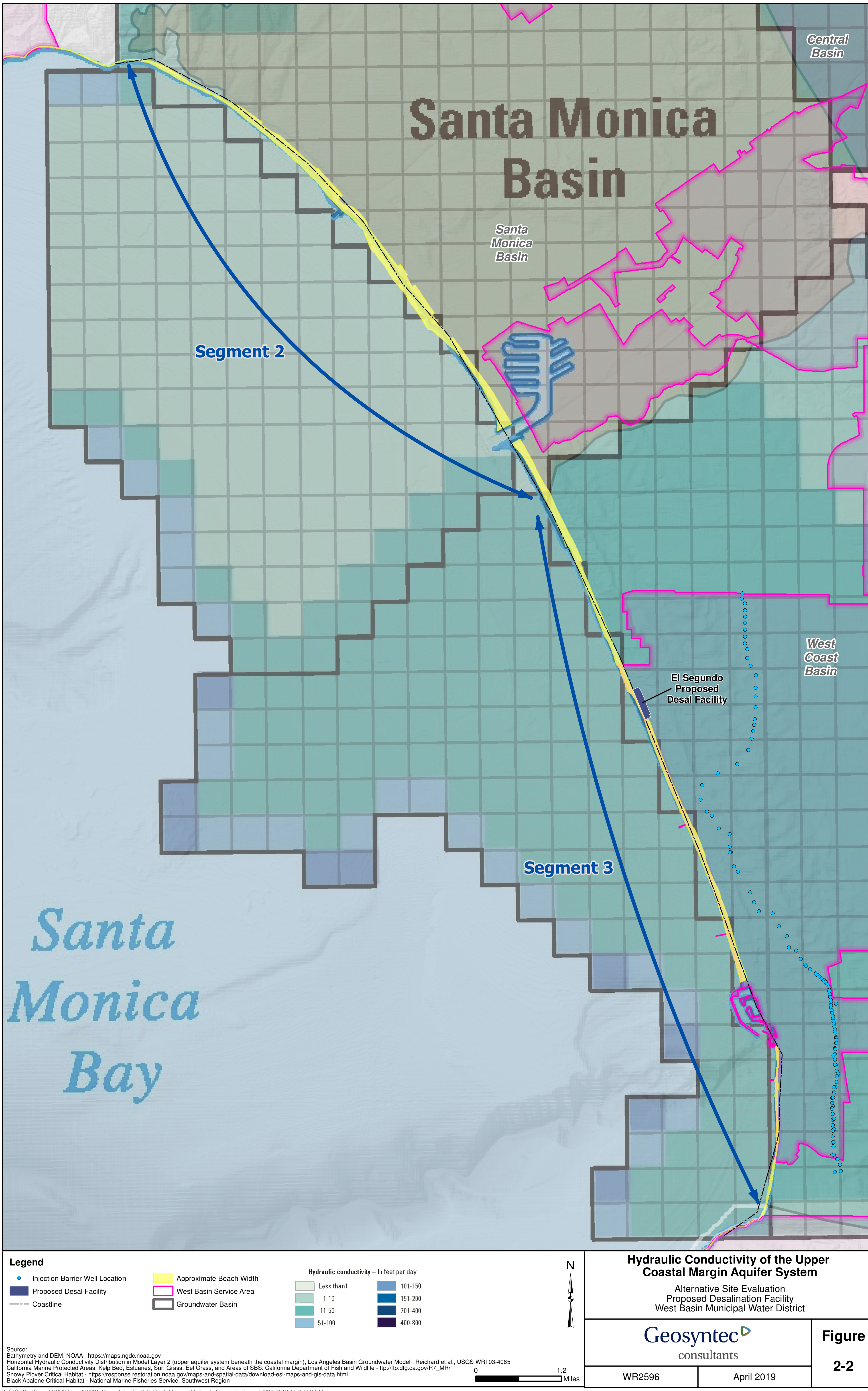
Figure 2-1

P:\GIS\WestBasinMWD\Project\2019-03_updates\Fig2-1_SantaMonica_CoastalMargin.mxd 5/14/2019 11:19:24 AM



Source:
Bathymetry and DEM: NOAA - https://maps.ngdc.noaa.gov
Horizontal Hydraulic Conductivity Distribution in Model Layer 2 (upper aquifer system beneath the coastal margin), Los Angeles Basin Groundwater Model : Reichard et al., USGS WRI 03-4065
California Marine Protected Areas, Kelp Bed, Estuaries, Surf Grass, Eel Grass, and Areas of SBS: California Department of Fish and Wildlife - ftp://ftp.dfg.ca.gov/R7_MR/
Snowy Plover Critical Habitat - https://response.restoration.noaa.gov/maps-and-spatial-data/download-esi-maps-and-gis-data.html
Black Abalone Critical Habitat - National Marine Fisheries Service, Southwest Region

Hydraulic Conductivity of the Upper Coastal Margin Aquifer System

Alternative Site Evaluation
Proposed Desalination Facility
West Basin Municipal Water District

Geosyntec consultants

Figure 2-2

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P:\GIS\WestBasinMWD\Project\2019-03_updates\Fig2-2_SantaMonica_HydraulicConductivity.mxd 4/22/2019 12:37:56 PM

N

0 400 Feet

Discontinuity of Beach Width at the Groin at El Segundo Beach

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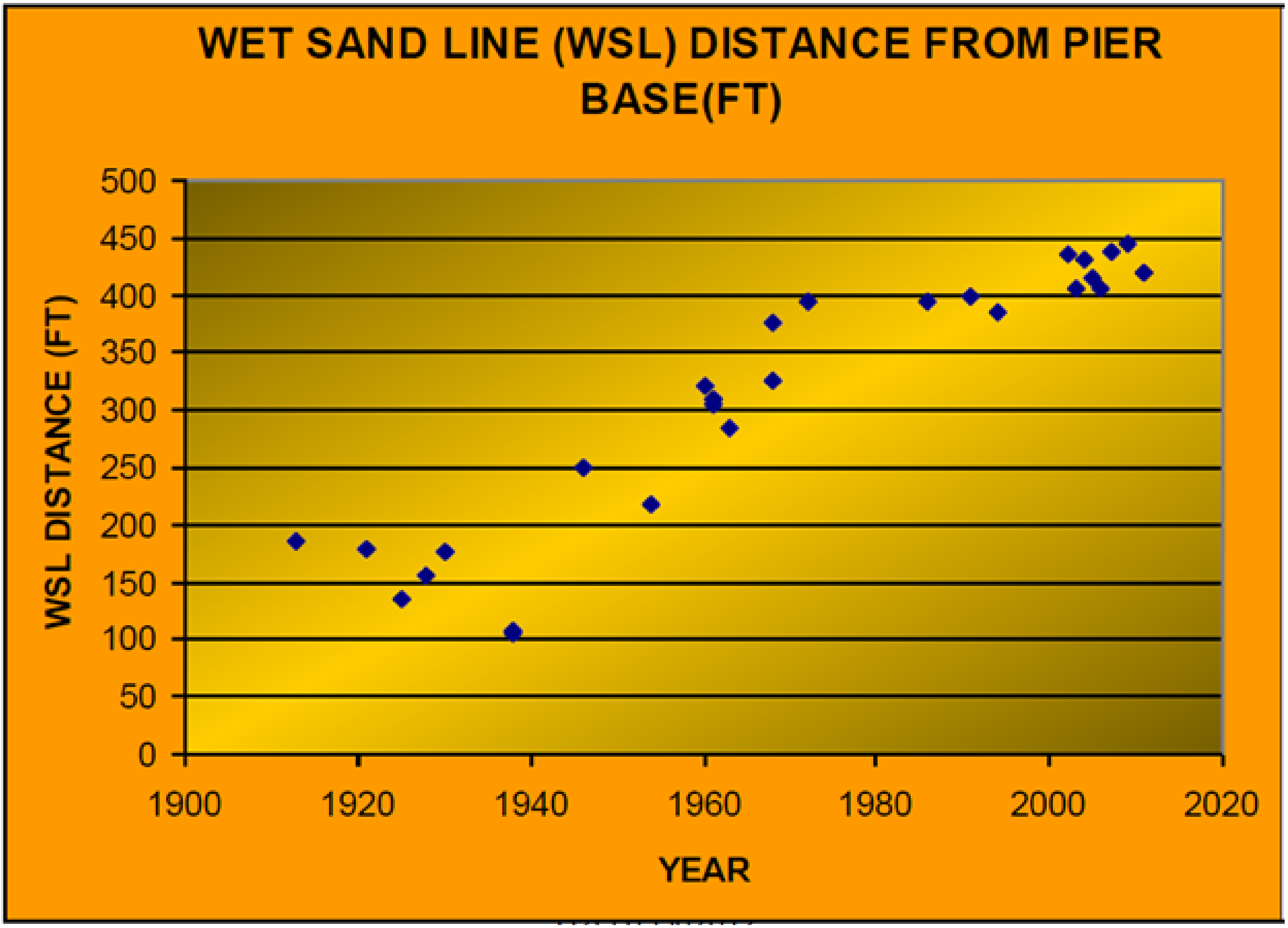
Figure 2-3

Notes:
Aerial Source: Google Earth Pro, 24 April, 2007.
The wider beach on the north side of the groin (jetty) is due to persistent southerly longshore current that transports sand along the coastal margin.
The aerial photo also shows evidence of strong currents stirring up the sea floor sediment.

P:\GIS\WestBasinMWD\Project\2019-03_updates\Fig2-3_DiscontinuityOfBeachWidth.mxd 4/19/2019 1:27:49 PM



Source: Reppucci, 2012
http://hermosabeach.granicus.com/MetaViewer.php?view_id=4&clip_id=3118&meta_id=151400

Increase in Width of Manhattan Beach with Time Due to Beach Nourishment
Alternative Site Evaluation
Proposed Desalination Facility
West Basin Municipal Water District

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Figure 2-4

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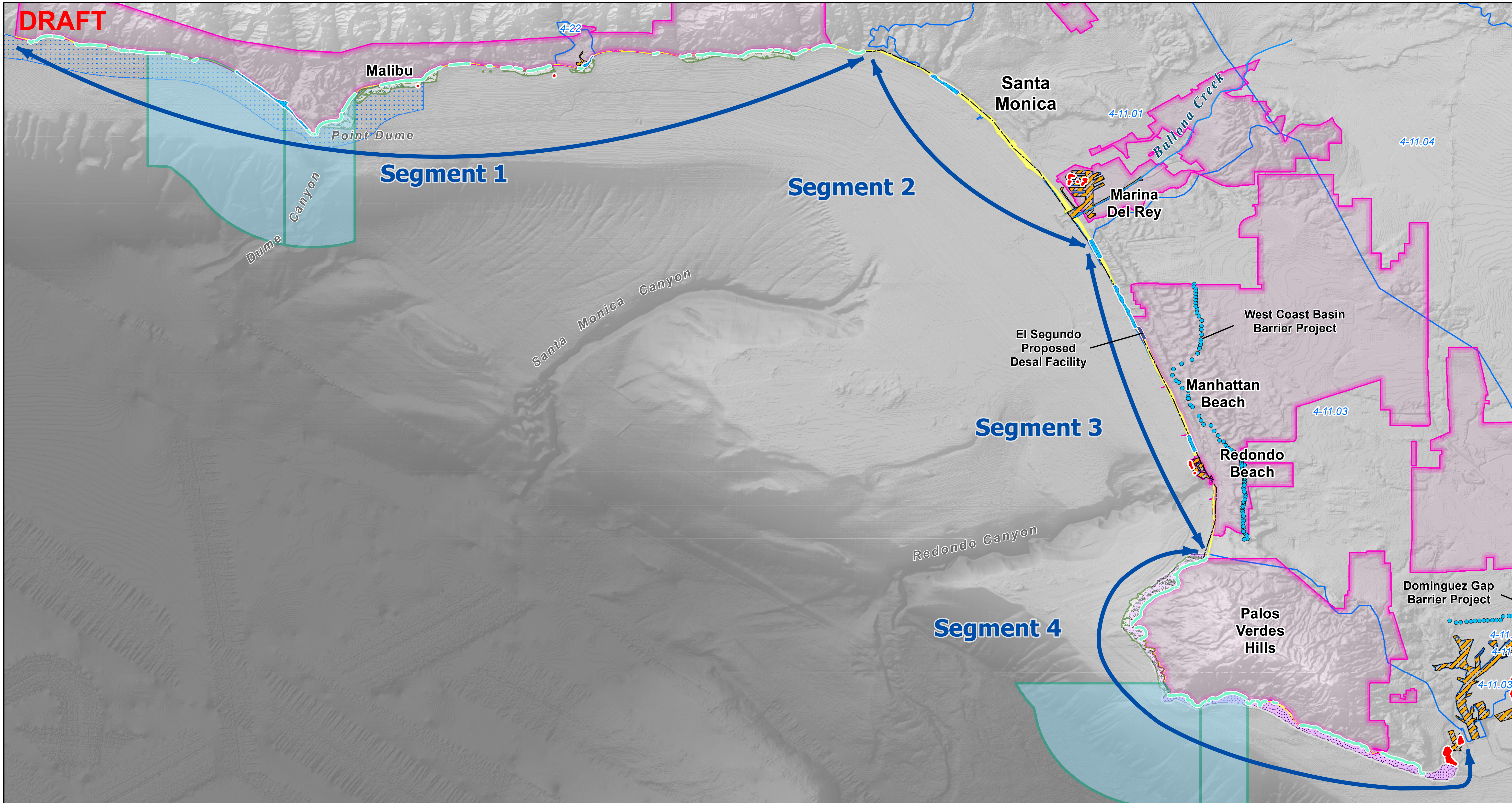
P:\GIS\WestBasinMWD\Project\2019-03_updates\Fig2-4_IncreaseInBeachWidth.ai



Legend

- Injection Barrier Well Location
- Proposed Desal Facility
- Coastline
- Approximate Beach Width
- Groundwater Basin
- Surf Grass
- Eel Grass
- Kelp Bed
- Estuaries
- California Marine Protected Areas
- Areas of Special Biological Significance
- West Basin Service Area
- Snowy Plover Critical Habitat
- Black Abalone Critical Habitat

Source:
Bathymetry and DEM: NOAA - https://maps.ngdc.noaa.gov
California Marine Protected Areas, Kelp Bed, Estuaries, Surf Grass, Eel Grass, and Areas of SBS: California Department of Fish and Wildlife - ftp://ftp.dfg.ca.gov/R7_MR/
Snowy Plover Critical Habitat - https://response.restoration.noaa.gov/maps-and-spatial-data/download-esi-maps-and-gis-data.html
Black Abalone Critical Habitat - National Marine Fisheries Service, Southwest Region

N

0 6 Miles

Sensitive Ecosystems

Alternative Site Evaluation
Proposed Desalination Facility
West Basin Municipal Water District

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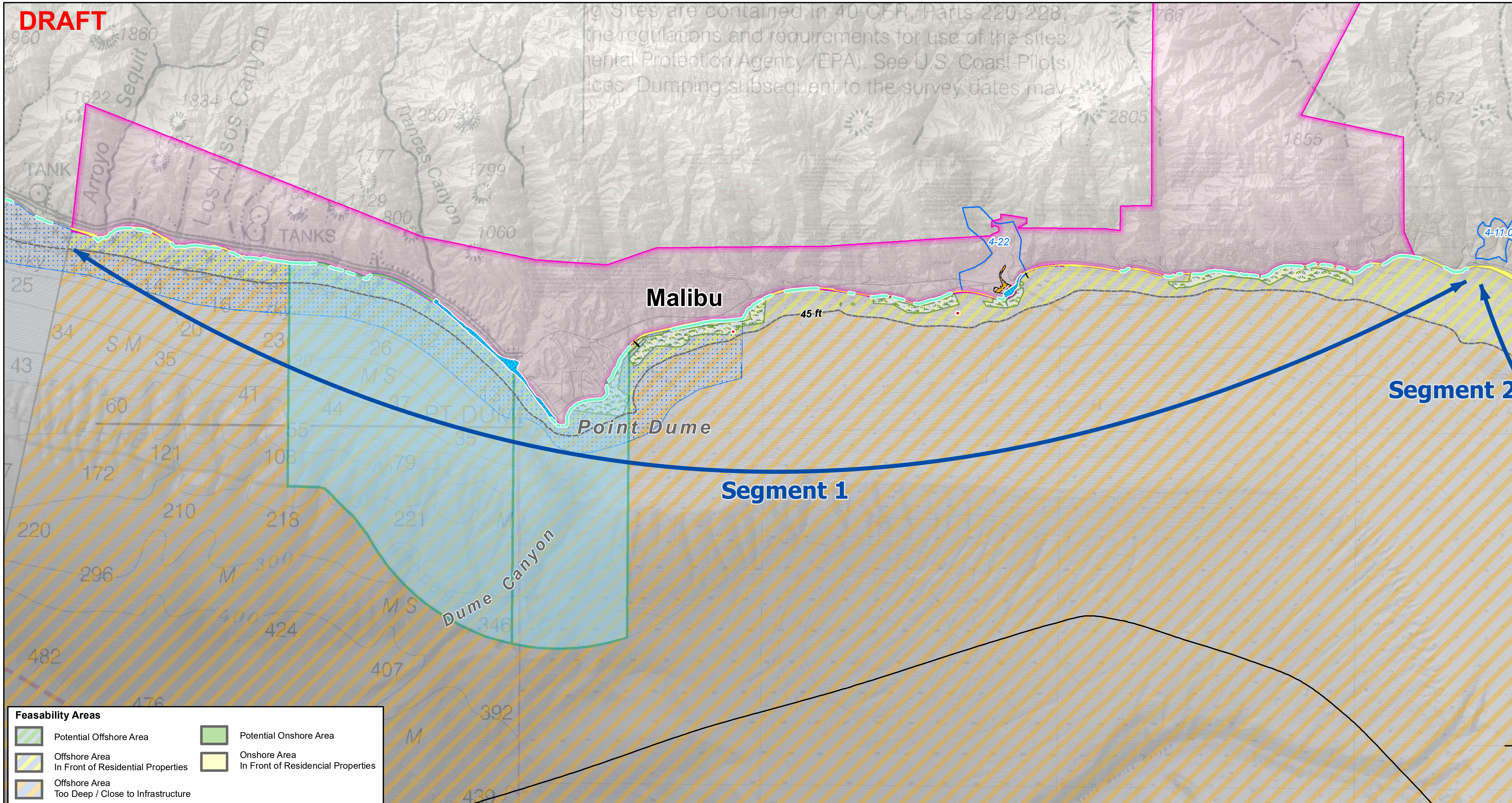
Figure 2-5

P:\GIS\WestBasinMWD\Project\2019-03_updates\Fig2-5_SantaMonica_SensitiveEcosystems.mxd 5/14/2019 11:19:17 AM



Legend

- Injection Barrier Well Location
- Pipes and Cables
- Approximate Beach Width
- Groundwater Basin
- Surf Grass
- Eel Grass
- Kelp Bed
- Estuaries
- California Marine Protected Areas
- Areas of Special Biological Significance
- West Basin Service Area
- Snowy Plover Critical Habitat
- Black Abalone Critical Habitat

Source:
Bathymetry and DEM: NOAA - https://maps.ngdc.noaa.gov
California Marine Protected Areas, Kelp Bed, Estuaries, Surf Grass, Eel Grass, and Areas of SBS: California Department of Fish and Wildlife - ftp://ftp.dfg.ca.gov/R7_MR/
Snowy Plover Critical Habitat - https://response.restoration.noaa.gov/maps-and-spatial-data/download-esi-maps-and-gis-data.html
Black Abalone Critical Habitat - National Marine Fisheries Service, Southwest Region

N

0 8,000 Feet

Constraints on SSI Feasibility, Segment 1

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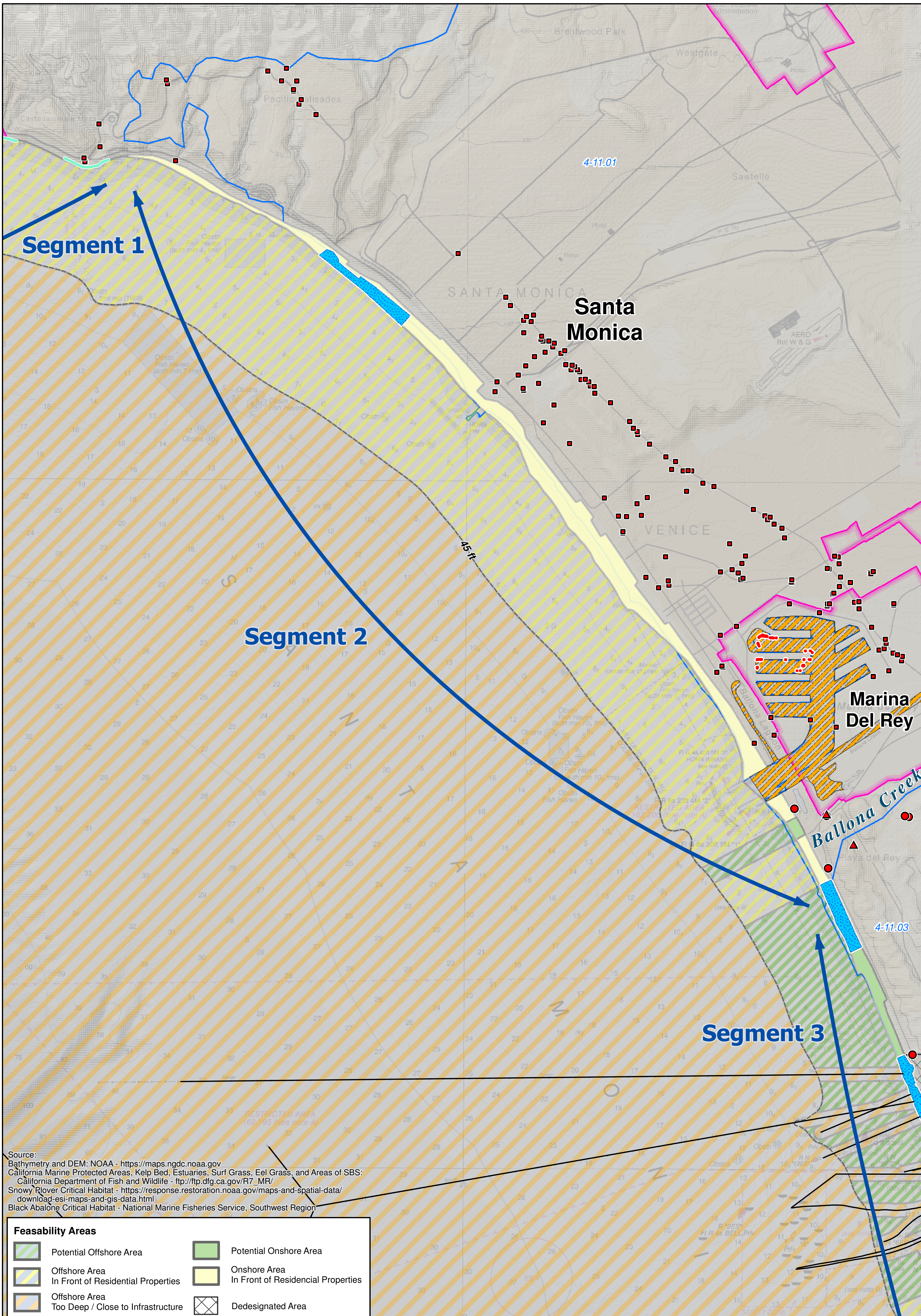
Figure 3-1

P:\GIS\WestBasinMWD\Project\2019-03_updates\Fig3-1_SSI_Constraints_Segment_1.mxd 5/14/2019 11:18:09 AM



Legend

- Injection Barrier Well Location
- Pipes and Cables
- Groundwater Basin

Sites with Contamination

- Fuel
- Solvent
- Other

- Surf Grass
- Eel Grass
- Kelp Bed
- Estuaries
- California Marine Protected Areas
- West Basin Service Area
- Snowy Plover Critical Habitat
- Black Abalone Critical Habitat

N

0 4,000 Feet

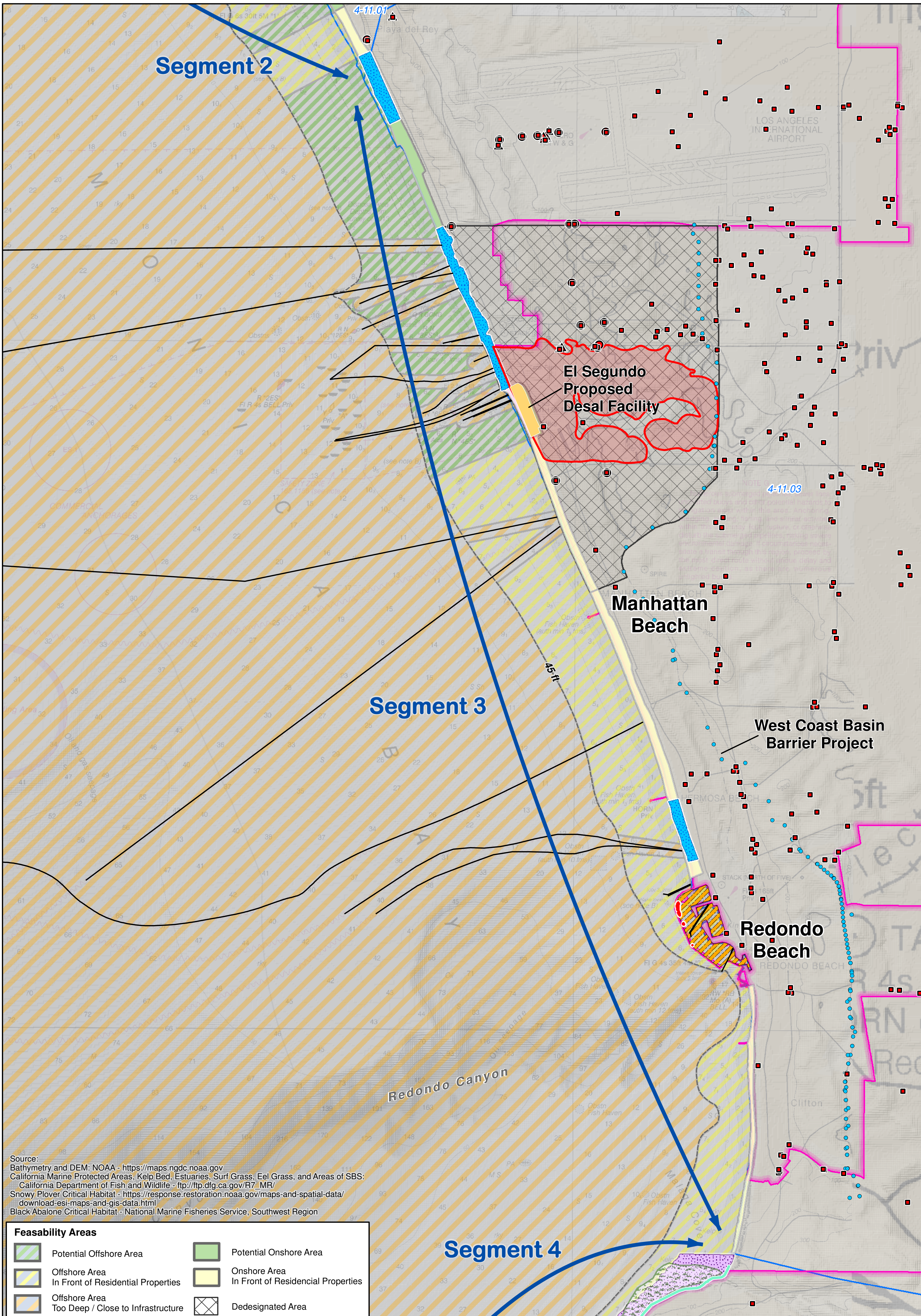
Constraints on SSI Feasibility, Segment 2

Alternative Site Evaluation
Proposed Desalination Facility
West Basin Municipal Water District

Geosyntec consultants

WR2596	April 2019	Figure 3-2

P:\GIS\WestBasinMWD\Project\2019-03_updates\Fig3-2_SSI_Constraints_Segment_2.mxd 4/22/2019 1:13:20 PM



Legend

- Injection Barrier Well Location
- Pipes and Cables
- Proposed Desal Facility
- Groundwater Basin

Sites with Contamination

- Fuel
- Solvent
- Other
- Affected Area in Vicinity of Refinery

- Surf Grass
- Eel Grass
- Kelp Bed
- Estuaries
- California Marine Protected Areas
- West Basin Service Area
- Snowy Plover Critical Habitat
- Black Abalone Critical Habitat

N

0 4,000 Feet

Constraints on SSI Feasibility, Segment 3

Alternative Site Evaluation
Proposed Desalination Facility
West Basin Municipal Water District

Geosyntec consultants

Figure 3-3

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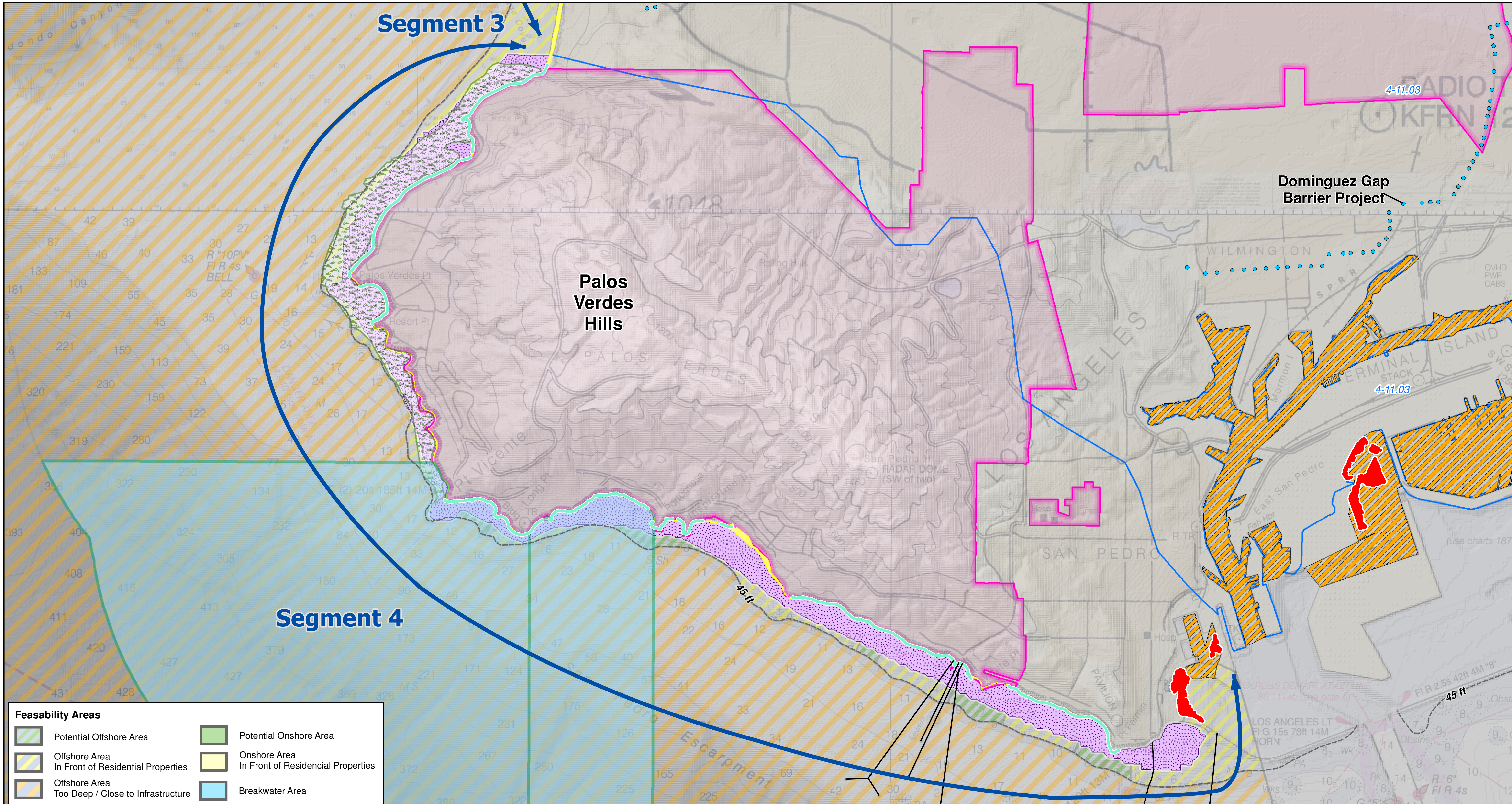
P:\GIS\WestBasinMWD\Project\2019-03_updates\Fig3-3_SSI_Constraints_Segment_3.mxd 4/23/2019 12:42:57 PM



Legend

- Injection Barrier Well Location
- Pipes and Cables
- Approximate Beach Width
- Groundwater Basin
- Surf Grass
- Eel Grass
- Kelp Bed
- Estuaries
- California Marine Protected Areas
- West Basin Service Area
- Snowy Plover Critical Habitat
- Black Abalone Critical Habitat

Source:
Bathymetry and DEM: NOAA - https://maps.ngdc.noaa.gov
California Marine Protected Areas, Kelp Bed, Estuaries, Surf Grass, Eel Grass, and Areas of SBS: California Department of Fish and Wildlife - ftp://ftp.dfg.ca.gov/R7_MR/
Snowy Plover Critical Habitat - https://response.restoration.noaa.gov/maps-and-spatial-data/download-esi-maps-and-gis-data.html
Black Abalone Critical Habitat - National Marine Fisheries Service, Southwest Region

N

0 5,000 Feet

Constraints on SSI Feasibility, Segment 4

Alternative Site Evaluation
Proposed Desalination Facility
West Basin Municipal Water District

Geosyntec consultants

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Figure 3-4

P:\GIS\WestBasinMWD\Project\2019-03_updates\Fig3-4_SSI_Constraints_Segment_4.mxd 4/23/2019 12:29:47 PM

APPENDIX A

Details of the Application of the SSI Guidance Tool to the Santa Monica Bay Coast

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ATTACHMENTS

Attachment A-1: Input and Output Tables of the SSI Guidance Tool

A-1. OVERVIEW OF SSI GUIDANCE TOOL

The SSI Feasibility Screening Tool (SSI Guidance Tool) was developed to evaluate the technical feasibility of SSIs (Geosyntec, 2016a). Development of the SSI Guidance Tool (Geosyntec, 2016a)[1] and the El Segundo SSI Feasibility Assessment (Geosyntec, 2016b) were federally funded through a grant by the United States Bureau of Reclamation and subjected to a transparent, public, and independent peer-review by a technical advisory panel facilitated by the National Water Research Institute (NWRI).[2]

The SSI Guidance Tool is a screening level methodology to assess the potential technical feasibility of the seven SSI technologies (Figure A-1) to provide the necessary amount of feed water to meet the design desalination production capacity at a particular site along the California coastline. The SSI Guidance Tool intentionally addresses just the technical feasibility of an SSI, defined as "*able to be built and operated using currently available methods*" (ISTAP, 2014)[3]. Moreover, the SSI Guidance Tool provides initial screening of theoretical technical feasibility ***with no constraints on the siting of the SSI infrastructure***: e.g., the entire coast for each of the four designated segments of the Santa Monica Bay coast is assumed to be available for a system of SSIs and the associated infrastructure. The Tool is designed for screening purposes and as such the input values provide optimistic screening level results. Additional analyses are required to determine feasibility with consideration of specific environmental, economic, and social factors.

The intended users of the SSI Guidance Tool are primarily water industry professionals and regulators who could evaluate technical feasibility of various types of SSIs based

---

[1] The Subsurface Seawater Intake Feasibility Screening Tool Guidance Manual is available from the USBR website (Desalination and Water Purification Research and Development Program Report No. 188): https://www.usbr.gov/research/dwpr/DWPR_Reports.html

[2] National Water Research Institute Website, *West Basin Municipal Water District's Ocean Water Desalination Subsurface Intake Feasibility Study*, http://www.nwri-usa.org/subsurface-intake-panel.htm, accessed February 17, 2016.

[3] 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 for 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.

on site setting, conditions and production requirements. Other stakeholders involved in the decision-making process for desal projects might also use the SSI Guidance Tool for assessing the technical feasibility of SSIs. The SSI Guidance Tool was peer-reviewed by the ISTAP, which was coordinated and facilitated by NWRI.

The SSI Guidance Tool is an Excel-based platform that consists of two steps: (1) evaluation of potential fatal flaws and (2) evaluation of potential challenges. A fatal flaw is defined as a factor that cannot be reasonably mitigated and therefore the SSI technology is determined infeasible and eliminated from further consideration.

A-1.1 Fatal Flaws

A-1.1.1 Land-Types

The following land types make construction of the SSI infeasible in the SSI Guidance Tool:

1. **Shallow bedrock:**

- Depth to bedrock less than 100 feet is a fatal flaw for slant wells, which are assumed to be drilled at an angle of approximately 20˚ (ISTAP, 2014);
- Depth to bedrock less than 25 feet is a fatal flaw for radial collectors, as the caisson depth of the radial collector ranges typically from 30 to over 150 feet (Water Research Foundation, 2011);
- Depth to bedrock less than 10 feet is assumed to be a fatal flaw for HDD wells, as 10 feet is considered the minimum thickness to be able to drill and install a HDD well[4];
- Depth to bedrock less than 5 feet for beach and seabed infiltration galleries, as engineered fill is used for these galleries and 5 feet is considered the minimum thickness for installation and operation of the filter media (NWRI, 2015b); and
- Depth to bedrock less than 15 feet for DIG.

[4] Although 10 feet is used as a minimum depth in the SSI Guidance Tool for horizontal wells installed by HDD. They typically would need to be install deeper than 20 or 30 feet to accommodate necessary pressure of drilling fluid. Shallower attempts at HDD beneath the seafloor would likely fail and result in leakage of drilling fluid from the sea floor (Geosyntec, 2019).

2. **Presence of a cliff and narrow beach:**

- For all SSIs, except SIGs, the presence of a cliff with a beach narrower than 50 feet constitutes a fatal flaw in the Screening Tool because it is assumed there would not be enough space available for construction of the SSIs (NWRI, 2015b).

3. **Presence of an inlet: an inlet:**

- In the SSI Guidance Tool an inlet, which is a river, a channel, or water-way opening that connects the ocean to a bay or lagoon, constitutes a fatal flaw for all SSIs for that portion of the coast, except SIGs and DIGs, because it is assumed to be unstable due to tides, currents and sediment deposition (NWRI, 2015b).

A-1.1.2 Insufficient Length of Coast

Length of the coast less than 80% of the required length need for an SSI system to achieve the design intake rate is a fatal flaw in the Screening Tool for the feasibility of an SSI technology. A value of 80% of the required length is used to account for redundancy and safety factor (ISTAP, 2014).

A-1.1.3 Insufficient Area of Land (Offshore and/or Onshore)

Area of land (offshore and/or onshore) less than 80% of the required area for an SSI system to achieve the design intake rate is a fatal flaw in the Screening Tool for the feasibility of an SSI technology. A value of 80% of the required area is used to account for redundancy and safety factor (ISTAP, 2014).

A-1.2 Potential Challenges for Feasibility

For SSIs not eliminated by a fatal flaw (first step), the SSI Guidance Tool utilizes a scoring system to characterize the technical features and potential challenges of the remaining SSIs (second step). For the five following general categories, a total of 18 criteria are identified as potential challenges affecting the technical feasibility of an SSI system (Geosyntec, 2016a):

1. Construction of the SSI system;
2. Operation of the SSIs;
3. Operation of the treatment system;

4. Potential inland interference; and
5. Risk/uncertainty for project implementation.

The score generated with the SSI Guidance Tool for each SSI technology can be used to assess their relative potential technical feasibility. Because the 18 criteria are not considered fatal flaws, a low feasibility score does not indicate that the SSI is technically infeasible but indicates that significant challenges and mitigation measures likely need to be addressed to construct and/or operate the SSI system. The SSI Screening Tool has 31 questions, which are used to define both the intake scenario, the project setting, and conditions. The SSI Guidance Tool uses default values if the user does not input specific information. The 31 questions and responses are listed in the input tables provided with this Appendix for both Segments 2 and 3.

The user also 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 SSI Guidance Tool development and setup is provided in the Guidance Manual for the SSI Guidance Tool (Geosyntec, 2016a).

A-2. APPLICATION OF THE SSI GUIDANCE TOOL TO THE SANTA MONICA BAY COAST

The Guidance Tool was previously applied for an initial assessment of technical feasibility of the seven SSI technologies for the proposed desal facility along the coastal margin from Marina Del Ray (North) to Redondo (South) to identify field investigations to enhance the feasibility evaluation (Geosyntec 2016b). For the supplemental evaluation of SSI feasibility required for consideration of alternative sites, the SSI Screening Tool was used for the entire coast of Santa Monica Bay.

A-2.1 Inputs for Initial Screening

The inputs and data quality qualifiers assigned to the Tool for four segments of the Santa Monica Bay coast are provided in tables that are attached. The four segments are shown on Figure A-2 and described in main text of the Supplemental SSI Feasibility Evaluation. Discussion is provided below of the data sources for inputs that are not based on default values in the SSI Guidance Tool.

As explained above, the SSI Guidance Tool provides screening results of theoretical SSI feasibility with no constraints on the extent or number of SSIs and associated infrastructure along a beach. Accordingly, the entire length of the coast is assumed to be available for an SSI system in each of the four segments when applying the SSI

Guidance Tool. Also, because the SSI Guidance Tool is for screening purposes the input values were selected to provide optimistic screening level results.

Figures A-3 through A-6 show conditions that are potential constraints on the feasibility of SSIs and a desal facility along the coastline for each of the four segments. Some are used as inputs to the SSI Guidance Tool as discussed below, and some are factors considered for further evaluation of feasibility beyond the SSI Guidance Tool screening, which is discussed in the Section 4 of the main text of this Report.

A-2.1.1 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. This is the low end of the desired production capacity of the proposed facility. A contingency factor of 20% is applied, which results in a design intake rate of 48 MGD that is assigned to Tool.

A-2.1.2 Presence of Cliff and Narrow Beach

As explained above, in the SSI Guidance Tool, the presence of cliffs with a narrow beach (< 50 ft wide) are assumed to be fatal flaws for feasibility of all SSI technologies except SIGs due to inadequate space and inaccessibility for an SSI system and its construction. Much of the Segment 1 coast and the majority of the Segment 4 coast includes cliffs or steep slopes, but none of the coastal margin of Segments 2 and 3 have cliffs or very steep slopes[5].

A-2.1.3 Presence of Inlet

As explained above, in the SSI Guidance Tool, water-way opening that connects the ocean to a bay, lagoon, or river constitutes a fatal flaw for that portion of the coast for all SSIs, except SIGs and DIGs, because the inlets are assumed to be unstable due to tides, currents and sediment deposition (NWRI, 2015b). A small lagoon at Malibu in Segment 1 occasionally has an inlet to the ocean. Segment 2 includes a major inlet from the ocean to the Marina Del Rey Harbor and Ballona Creek, which is maintained with dredging by the Army Corps of Engineers. Segment 3 includes a major inlet to the

[5] Steep sand dune slopes are present in portions of the coast in Segment 3, however for the SSI Guidance Tool, the sandy slopes are assumed not to be fatal flaw impediment to construction like rock cliffs. Moreover the beach adjacent to the steep sand dune slopes are wider than 50 ft.

harbor at Redondo Beach. Segment 4 does not include any inlets along the coastal margin to the ocean.

A-2.1.4 Depth to Bedrock

Shallow bedrock[6] limits feasibility of SSIs because when bedrock is shallow, thickness of coastal margin sediments is not sufficient to transmit enough water to SSIs.

Bedrock is within a few feet of the ground surface or the seafloor along the majority of the coastal margin of Segments 1 and 4. There are a few locations in Segment 1 where bedrock is located deeper than a few feet, including the alluvial deposits associated with the modern and ancestral Malibu Creek. However, those local alluvial deposits are limited in extent and are not sufficient to accommodate an SSI system for the proposed project. The depth to bedrock for Segments 1 and 4 is assigned as 4 ft in the SSI Guidance Tool.

The depth to basement bedrock along the coastlines of Segments 2 and 3 is generally at least 3,000 ft, and the combined thickness of the mostly unconsolidated Holocene and Pleistocene sediments that comprise the coastal margin aquifers in the Santa Monica and West Coast Basin groundwater basins is approximately 1,000 ft (Fisher et al., 2003; Reichard et al., 2003).

A-2.1.5 Width of the Beach

Narrow width of the beach limits feasibility of access for construction and maintenance of SSIs and makes infrastructure relatively vulnerable to erosion or inundation by storm waves and sea level rise. Also, narrow beaches typically are less stable and more susceptible to variation in thickness and width, which could expose buried SSI infrastructure.

The width of beaches in each Segment is summarized below:

- Segment 1: generally < 100 ft
- Segment 2: mostly 300 to 500 ft, but range from 200 to 1,000 ft
- Segment 3: mostly 200 to 400 ft, but range from <100 to 600 ft

---

[6] All bedrock along the California coast is assumed to have negligible permeability relative to unconsolidated coastal margin sediments.

- Segment 4: mostly < 50 ft, with a few in local coves >100 ft.

These widths are primarily based on aerial photos (Google Earth, 2019) without compensation for tides and whether they are formed naturally or artificially.

Based on the presences of low permeability bedrock, and the presence of cliffs and limited width of the beaches along the Segments 1 and 4 coasts, the SSI Guidance Tool indicates that none of the SSI technologies are technically feasible in Segments 1 and 4[7]. Therefore most of the inputs described in the remainder of this section pertain to Segments 2 and 3.

A-2.1.6 Length of Available Coast

For initial screening, regardless of accessibility, the length of potentially available coastline for SSIs and desal facility infrastructure is assumed to be the entire length of the coast for each segment with the exception of Marina Del Rey and Redondo Beach harbors:

- Segment 1: 133,000 ft[8]
- Segment 2: 46,500 ft
- Segment 3: 55,600 ft
- Segment 4: 88,000 ft[8]

A-2.1.7 Area of Available Land Onshore

The estimated area of potentially available onshore land is based on the length of available coast and the general width of the beach and available land on aerial photos. The potentially available onshore land is illustrated on Figures A-3 through A-6 for each of the segments, and listed below for Segments 2 and 3.

- Segment 2: 26,000,000 ft^2 (600 acres)
- Segment 3: 17,000,000 ft^2 (390 acres)

---

[7] The presence of cliffs is fatal flaw for vertical wells, slant wells, radial collector wells, horizontal wells installed by HDD, and beach infiltration gallery, and a depth to bedrock less than 5 ft is a fatal flaw for all SSI technologies

[8] Length of Segments 1 and 4 are provided but as discussed above, the SSI Guidance Tool indicated that no SSI technologies are feasible in Segments 1 and 4.

A-2.1.8 Area of Available Land Offshore

The area of available offshore land was estimated to be 208,000,000 ft^2 (4,800 acres) for Segment 2 and 167,000,000 ft^2 (3,800 acres) for Segment 3. This is based on the length of available coast and the seafloor area shallower than 45 feet below sea level, but excluding areas within a 300 feet buffer distance from existing offshore infrastructure, such as sewer discharge lines, oil pipelines, etc. The 45-foot sea floor depth is considered a practical limit for offshore construction 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 on Figures A-4 and A-5.

A-2.1.9 Area Available for Drilling and Staging Equipment

The area available for drilling and staging equipment to construct each hypothetical SSI is estimated to be 100,000 ft^2 (2.3 acres) for both Segments 2 and 3. This assumes that one or multiple properties along the coastline could be used or purchased, and no limitations associated with zoning, sensitive habitats, recreational areas, and residential properties, etc.

A-2.1.10 Topography

The topography along the coast of Segments 2 and 3 is generally flat or slightly sloping. Exceptions are some areas of Segment 3 with sand dunes areas that include local steep slopes.

A-2.1.11 Slope of the Seabed

In Segments 2 and 3, the slope of the seabed in Santa Monica Bay to distances of a few thousand feet offshore is low, approximately 0.5 degrees (California State Lands Commission, 2010).

A-2.1.12 Depth to Seabed

The depth to the seafloor at potential offshore construction sites along Segments 2 and 3 was assumed to be 20 feet, which is the midpoint between the shore and a depth of 45 feet, beyond which offshore construction is not practical.

A-2.1.13 Transmissivity of the Sediments

The transmissivity of the sediments was 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 region. Specific transmissivity values were assigned for different SSI technologies as discussed below:

- **Segment 2:**
  - Vertical wells are assumed to be screened in both the Ballona and Silverado aquifers. The hydraulic conductivity of the Ballona and Silverado aquifers in the vicinity of Segment 2 is approximately 1 – 10 and 10 – 50 feet per day (ft/day), respectively, based on the numerical model developed for the Water Replenishment District by the U.S. Geological Survey (USGS, 2003); the thickness is less than 50 feet (Ballona) and at least 100 feet (Silverado) (Kennedy/Jenks, 2011). A transmissivity value of 30,000 gallons per day per foot (gpd/ft) (4,000 ft^2/day) was used in the SSI Guidance Tool for coastal margin aquifer from which SSI wells would pump.
  - Slant wells are also assumed to be screened in both the Ballona and Silverado aquifers. As for vertical wells, a transmissivity value of 30,000 gallons gpd/ft (4,000 ft^2/day) was used in the SSI Guidance Tool.
  - Radial collectors are assumed to be screened in the Ballona aquifer only. A transmissivity value of 2,000 gpd/ft (250 ft^2/day) was used in the SSI Guidance Tool.
  - Horizontal wells are assumed to be 20 feet below the seafloor, which is considered the minimum depth technically feasible if installed by HDD. The hydraulic conductivity of the seafloor in the vicinity of Segment 2 is approximately 1 ft/day (USGS, 2003). For screening purposes, an optimistically high transmissivity value of 1,000 gpd/ft (150 ft^2/day) was used in the SSI Guidance Tool.
  - A water tunnel is assumed to be installed 50 feet under the seabed. Similarly to horizontal wells, a transmissivity value of 2,500 gpd/ft (350 ft^2/day) was used in the SSI Guidance Tool.

- **Segment 3:**
  - Vertical wells are assumed to be screened in both the Gage and Silverado aquifers. The hydraulic conductivity of the Gage and Silverado aquifers in the vicinity of Segment 3 is approximately 10 – 100 and 100 – 200 ft/day, respectively, based on the numerical model developed for the West Basin Injection Barrier (Geoscience, 2009), and the thickness is approximately 50 feet (Gage) and at least 100 feet (Silverado) (MWH, 2007). A transmissivity value of 130,000 gpd/ft (17,500 ft^2/day) was used in the SSI Guidance Tool.
  - Slant wells also are assumed to be screened in both the Gage and Silverado aquifers. Like vertical wells, a transmissivity value of 130,000 gpd/ft (17,500 ft^2/day) was used in the SSI Guidance Tool for slant wells.
  - Radial collectors are 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 SSI Guidance Tool.
  - Horizontal wells were assumed to be screened 20 feet below the seafloor, which is considered the minimum depth technically feasible if installed by HDD. 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 El Segundo indicated hydraulic conductivity between 1 and 6 ft/day (Appendix G of El Segundo Power, 2000). If horizontal offshore wells were installed by HDD the permeability of the overlying sediment would constrain the intake capacity, but if installed by offshore trenching with engineered backfill the intake capacity could be higher. For screening purposes, a transmissivity value of 5,000 gpd/ft (600 ft^2/day) is used in the SSI, which is optimistically high for horizontal wells installed by HDD, but reasonable, at least in the short term, if installed by offshore trenching.
  - A water tunnel is assumed to be installed 50 feet under the seabed and a transmissivity value of 12,000 gpd/ft (1,500 ft^2/day) was used in the SSI Guidance Tool.

A-2.1.14 Leakance Through Overlying Sediments

The leakance through the sediments overlying the depth interval in which SSI are installed is controlled by the vertical hydraulic conductivity divided by thickness. This leakance parameter has units of 1/day and is used to assess the vertical hydraulic connection between SSIs and the ocean. A good hydraulic connection between SSIs and the ocean is necessary for SSIs to efficiently draw seawater. The leakance values assigned for each specific SSI technology are discussed below:

- For vertical wells, the vertical hydraulic conductivity of the Ballona and Gage aquifers is assumed to be 1/10th of the horizontal hydraulic conductivity.[9] Leakance values of 0.005 and 0.05 1/day were used in the SSI for Segments 2 and 3, respectively.
- Similarly, for slant wells, leakance values of 0.005 and 0.05 1/day were used in the SSI for Segments 2 and 3, respectively.
- Radial collectors are screened shallower than vertical wells and slant wells, so leakance values of 0.01 and 0.1 1/day were used in the SSI for Segments 2 and 3, respectively.
- Horizontal wells are assumed to be screened 20 feet below the seabed, which is considered the minimum depth technically feasible if installed by HDD (see Section 6.5.1). Based on the estimated hydraulic conductivity of the seafloor in the vicinity of Segment 2, a leakance value of 0.03 1/d was used in the SSI. Based on data in the vicinity of El Segundo, a leakance value of 0.15 1/day was used in the SSI for Segment 3. For horizontal wells installed by offshore trenching with engineered backfill, the leakance value, at least in the short-term would likely be higher.
- A water tunnel is assumed to be installed 50 feet under the seabed. Similar to horizontal wells, leakance values of 0.012 and 0.06 1/day were used in the SSI for Segments 2 and 3, respectively.

A-2.1.15 Expected Capacity Per Unit

The expected capacities per unit for Segment 3 are based on default (high estimate) values provided in the SSI Guidance Tool. Because of lower transmissivity and leakance for Segment 2, the expected capacities per unit are decreased by a factor of 4 compared to the default values that are used for Segment 3.

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[9] 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.

A-2.1.16 Closure Depth and Distance to Closure Depth

At depths greater than the closure depth, sediments on the seafloor are not influenced by waves. Sediments inside the closure depth (shallower water conditions-closure to shore) are subject to influence by wave action. The thickness of sediment overlying shallow SSIs and buried infrastructure inside the closure depth potentially can change and impact the performance of the SSI system. Closure depth is typically at 40 to 50 ft below MSL in the Santa Monica Bay (Jenkins, 2015), which generally occurs at least 5,000 feet offshore along Segments 2 and 3 (Figures A-4 and A-5).

A-2.1.17 Typical Significant Wave Height

Average deep-water wave heights offshore of El Segundo (Segment 3) for the period 1980 to 2001 were 2.5 feet (California State Lands Commission, 2010), which was used in the SSI Guidance Tool for the typical significant wave height for both Segments 2 and 3.

A-2.1.18 Beach Nourishment and Mean Sea Level Shoreline

The Calleguas, Malibu and Ballona Creeks supply sediment to the Santa Monica Littoral Cell. Historically the Los Angeles River did as well. Artificial contribution of sand by dredging and major construction projects has provided a large component of the sand to the Santa Monica Littoral Cell since 1938. Approximately, 30 million cubic yards of sand has been added to the beaches of Santa Monica Bay between 1938 and 1989 by major construction along the coastal margin including dredging of the Marina Del Rey Harbor and scavenging of the sand dunes during work on the Hyperion Waste Water Facility (e.g. Reppucci, 2012). As a consequence of artificial beach nourishment and slowing of longshore transport of sediment by jetties and groins (Figures A-7 and A-8 and Section 2.4.1 of text of main Supplemental SSI Evaluation), the width of Manhattan Beach increased four-fold between 1940 and 1975 but has remained relatively constant the last 45 years.

However, based on the fact that the beach in front of El Segundo (Segment 3) 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 El Segundo (Figure A-7): much wider beach north of the jetty (Google Earth, 2015; California State Lands Commission, 2010), the beach for Segment 3 was defined as re-nourished in the past 10 years, and a value of 20 feet was used in the SSI Guidance Tool for the annual mean shoreline change.

A-2.1.19 Inland Groundwater Level

Groundwater levels in the Santa Monica Basin inland of Segment 2 are generally at or above MSL, although low water levels at or below MSL exist in the coastal portion of the basin (City of Santa Monica, 2016). Inland groundwater levels in the coastal aquifer along Segment 3 are generally above sea level with the influence of the WBCCB as shown on groundwater contour maps of West Coast Basin (WRD, 2016) and the vicinity of El Segundo (MWH, 2007). Inland groundwater levels are defined as above sea level in the SSI Guidance Tool for Segments 2 and 3.

A-2.1.20 Contaminated Groundwater in the Vicinity

Sites with contaminated groundwater are present in the vicinity of Segments 2 and 3 (Figures A-4 and A-5) based on information compiled from regulatory environmental files available from the GeoTracker and Envirostor websites. In the SSI Guidance Tool, a contaminant plume is specified as in the vicinity for both Segments 2 and 3. However, the potential influence of the contamination on the feasibility of SSIs is site-specific and typically would require more evaluation.

A-2.1.21 Sedimentation Rate

Sedimentation rates in Santa Monica Bay are reported to range from 1.8 and 9.7 mm/year (Farnsworth and Warrick, 2007). A value of 6 mm/year was used in the SSI for both Segments 2 and 3.

A-2.1.22 Source Water Turbidity

The water clarity within Santa Monica Bay is generally high (California State Lands Commission, 2010). Feed water turbidity below 7 Nephelometric Turbidity Units (NTUs) was measured at the El Segundo pilot plant during operation between 2004 and 2009 (SPI, 2010). A turbidity value of 5 NTUs was used in the SSI Guidance Tool for intake water pumped from below the seafloor (horizontal wells, BIG, SIG and water tunnel).

A-2.1.23 Feed Water Silt Density Index (SDI)

Most of the seafloor in 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 SSI Guidance Tool for water from SSIs below the seafloor (horizontal wells, BIGs, SIGs, and a water tunnel).

A-2.1.24 Extremely Impaired Source

Because of the presence of contaminated groundwater in many areas of the coastal margin of Santa Monica Bay, the feed water could include contribution from an extremely impaired source based on the California Water Resource Control Board Division of Drinking Water (DDW).

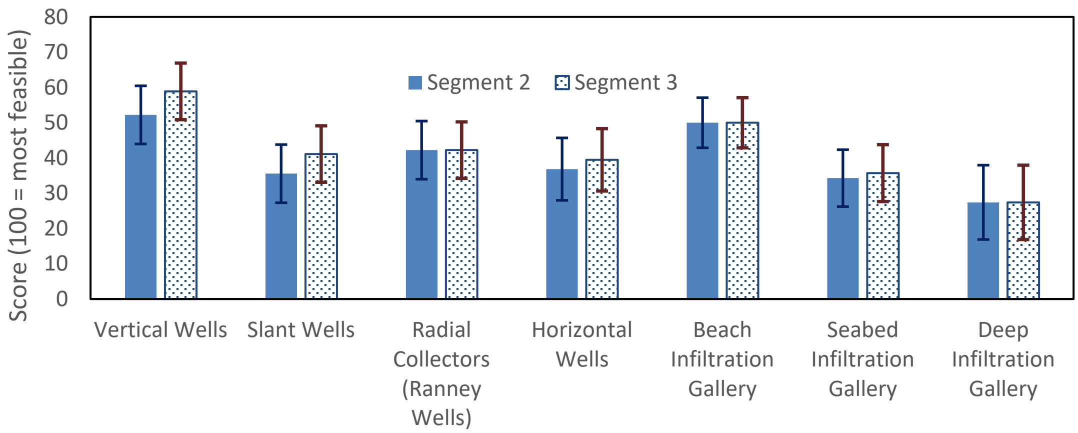
A-2.2 Results of Screening with the SSI Guidance Tool

The screening results for each of the four segments are presented in Table A-1 and Figure A-9 below. The SSI Guidance Tool indicates that no SSI technologies are feasible in Segments 1 and 4, but all are technically feasible in Segments 2 and 3 with the assumption that there are no constraints on the siting of the SSI infrastructure. The initial screening results are optimistic, because favorable conditions were assumed. The screening level scores with the error bars calculated based on the quality of the input data are illustrated by the graph below for Segments 2 and 3. In general, SSIs are less feasible at Segment 2 than at Segment 3 due to more challenging geological properties (lower sediments transmissivity and leakance) at Segment 2.

Table A-1: Scores from the SSI Guidance Tool

		Normalized Feasibility Scores 0=most challenging 100=most feasible						
		Vertical Wells	**Slant Wells**	**Radial Collectors (Ranney Wells)**	**Horizontal Wells**	**BIG**	**SIG**	**DIG**
Totals (100 = most feasible)[1]	**Segment 1**	**Fatal Flaws (Cliffs and Inadequate Depth to Bedrock)**						
	Segment 2	52	36	42	37	50	34	27
	Segment 3	59	41	42	39	50	44	27
	Segment 4	**Fatal Flaws (Cliffs and Inadequate Depth to Bedrock)**						

[1] The scores are 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.



The error bars represent the uncertainty of the results and are calculated based on the quality of the input data error bars calculated based on the quality of the input data.

Figure A-9: Scores from the SSI Guidance Tool

In addition to the compiled feasibility scores, the results of the SSI Guidance Tool can be used to identify the main challenges for each SSI, as detailed below.

Vertical wells are the most technically feasible technology for Segments 2 and 3 based on the screening tool. The main challenges for vertical wells are beach instability, clogging potential of the well screens, potential inland interference, and potential consideration of the water as an extremely impaired source.

Based on the uncertainty associated with the scores, BIGs, SIGs, horizontal wells, slant wells and radial collector wells are all approximately equally feasible based on the screening tool. The main challenges for BIGs are the beach instability, clogging potential of the gallery, and the potential consideration of the water as an extremely impaired source. In addition, we are not aware of any examples of successful BIGs in similar high energy wave environments for facilities with similar capacities. SIGs have similar challenges to BIGs, in addition to significant challenges for construction and maintenance.

Challenges for horizontal wells, radial collectors and slant wells include beach and seafloor instability, geological conditions, 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 horizontal wells are expected to be challenging to maintain, and a high clogging potential is anticipated for horizontal wells. Installation of horizontal wells is considered challenging and is without precedence by either HDD or offshore trenching in a setting similar to Segments 2 and 3 of the Santa Monica Bay.

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

Based on the initial high-level screening analysis (Level 1), since all technologies are indicated to be technically feasible, they all are carried forward for additional analysis for Segments 2 and 3 in Section 4 of text of main Supplemental SSI Evaluation. Additional analysis included further review of available data on hydrogeology, costal processes, and sensitive ecological habitats that are discussed in Section 4 of text of main Supplemental SSI Evaluation.

A-2.3 Estimates of Areas Required for SSI Systems

The SSI Guidance Tool used for the initial screening also provides estimates of length of the coast, onshore areas, and offshore areas required for SSI systems to achieve the design intake rate as summarized in Table A-2: below for Segments 2 and 3, which indicates that none of the SSI technologies which requires available beach front (vertical wells, radial collector wells, slant wells, horizontal wells, BIG) can provide 40 MGD if the well heads/beach front are limited to the width of the ESGS Site.

Table A-2: Preliminary Calculations for Feasibility of SSIs in Segments 2 and 3

	Vertical Wells	Slant Wells	Radial Collector Wells	Horizontal Wells	Beach Infiltration Gallery	Seabed Infiltration Gallery	Deep Infiltration Gallery
	Segment 2						
Yield estimate	0.2 MGD per well	1 MGD per three-well cluster	1 MGD per well	0.6 MGD per horizontal well	0.02 gpm/ft^2	0.02 gpm/ft^2	0.4 gpm/ft
Units required for 40 MGD with 20% safety factor	240 wells	48 three-well clusters	48 wells	80 horizontal wells	1,700,000 ft^2	1,700,000 ft^2	85,000 ft
Linear beachfront	25,000 ft	28,000 ft	16,000 ft	10,000 ft	5,500 ft	NA	NA
Onshore area	48,000 ft^2	190,000 ft^2	190,000 ft^2	minimal$^+$	minimal$^+$	minimal$^+$	minimal$^+$
Offshore area	NA	NA^{++}	NA^{++}	8,000,000 ft^{2*}	1,700,000 ft^2	1,700,000 ft^2	170,000 ft$^{2\wedge}$
	Segment 3						
Yield estimate	1 MGD per well	5 MGD per three-well cluster	5 MGD per well	3 MGD per horizontal 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 horizontal 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	48,000 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$^{2\wedge}$

+ The onshore area for horizontal wells, BIGs, SIGs and DIGs is minimal as only a few wellheads (horizontal wells) and one single intake pipe

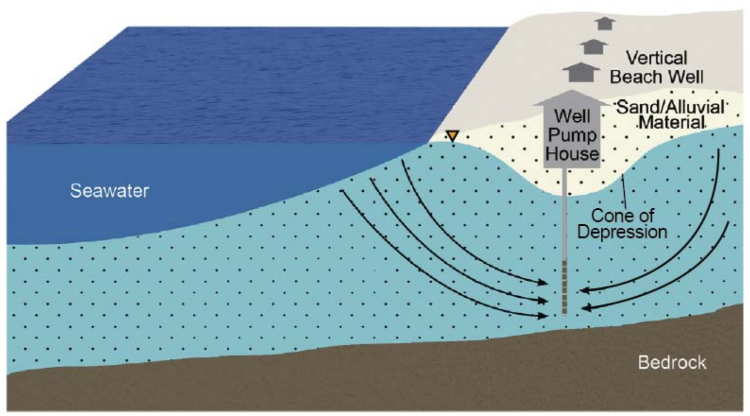
++ The offshore area for slant wells and radial collector wells is not applicable as they would be constructed onshore

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

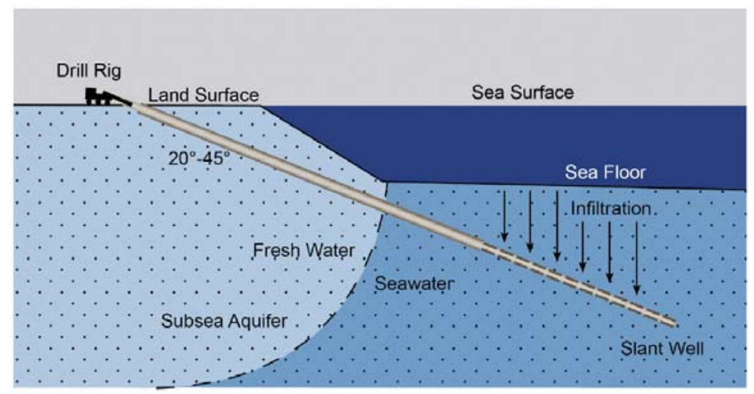
^ The offshore area of a DIG is based on a tunnel type design.

Numerous criteria need to be considered when assessing the overall feasibility of different SSI technologies. Many are unique to specific sites and are not adequately assessed by the SSI Guidance Tool, which was developed for general screening purposes. More detailed assessments of the specific intake technologies for Segments 2 and 3 are provided in Section 4 in main text of the Supplemental SSI Feasibility Evaluation.

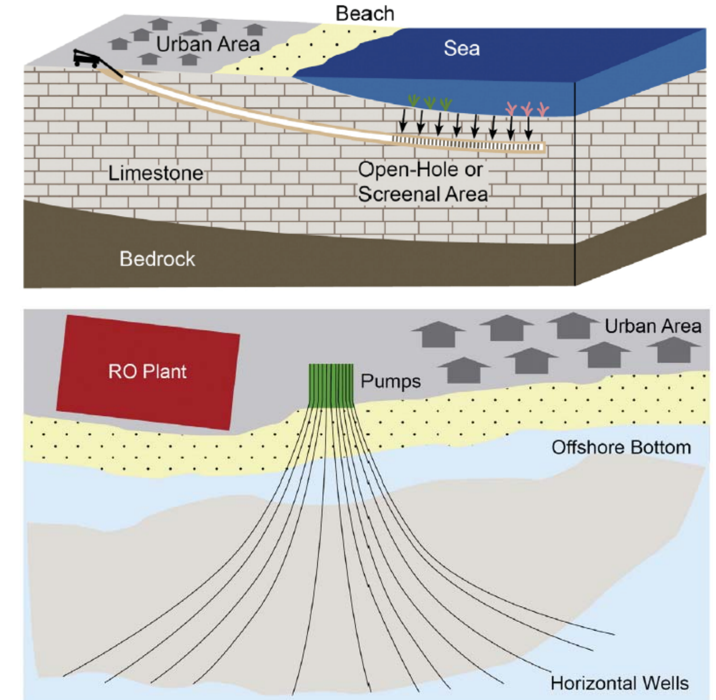
Appendix A Figures



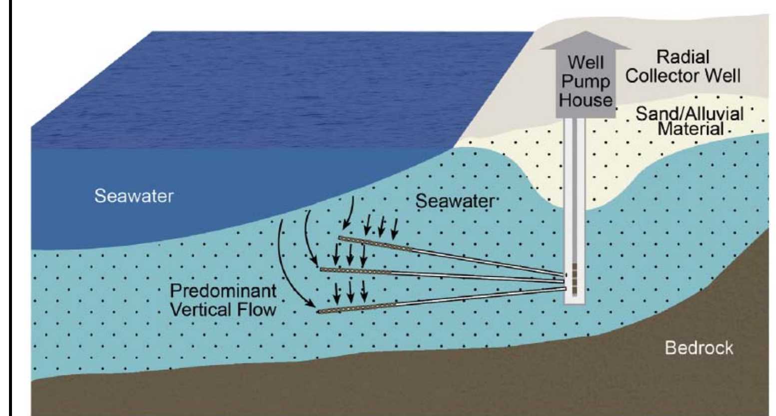
Schematic Representation of a Series of Vertical Wells Along a Beach.
(Adapted from Missimer et al., 2013)



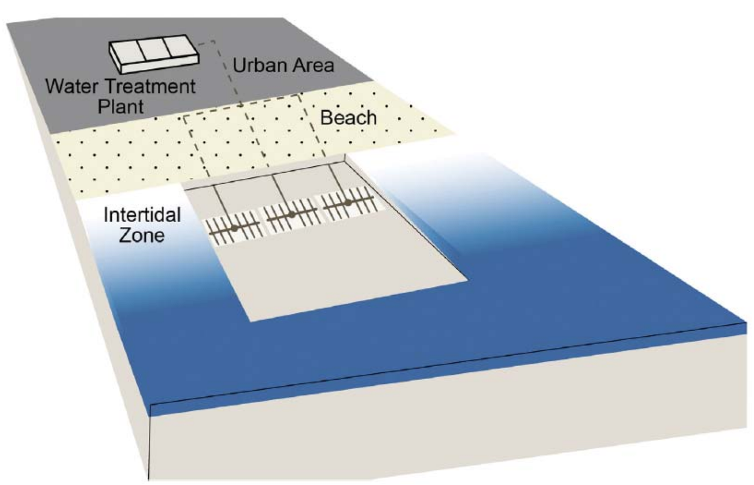
Schematic Representation of a Slant Well.
(Adapted from Missimer et al., 2013)



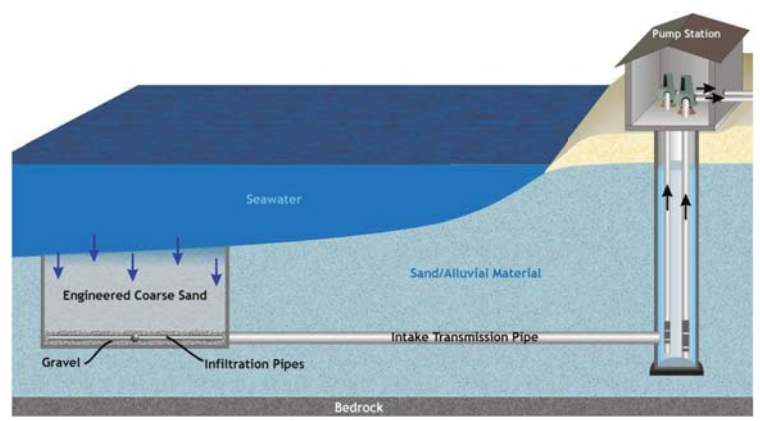
Schematic Representation of an HDD Well Installation (Cross-Section) and a Cluster of Horizontal Wells installed by HDD[1]. (Adapted from Missimer et al., 2013)



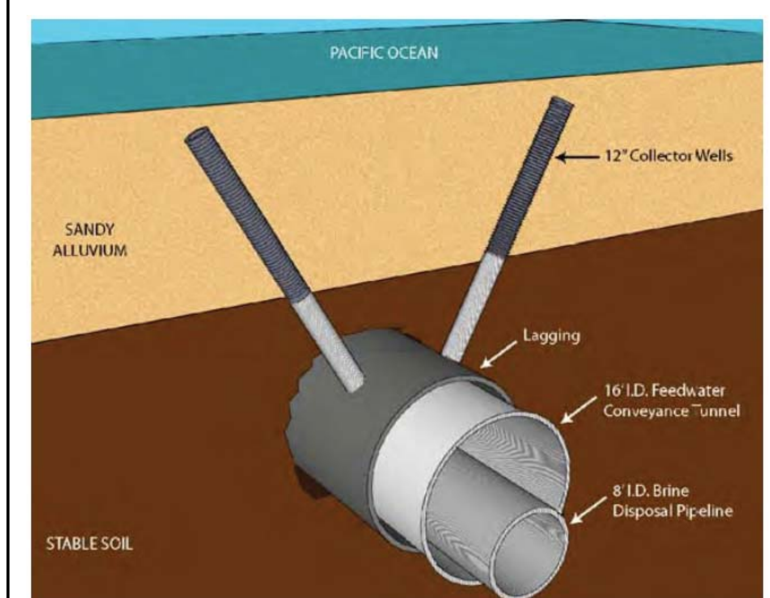
Schematic Representation of Radial Collector Wells.
(Adapted from Missimer et al., 2013)



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)

Note:
[1] Shallow horizontal wells (also called intakes or drains) can also be installed in trenches excavated offshore.

Schematic Illustrations of Subsurface Seawater Intake Technologies

Subsurface Seawater Intake Study
West Basin Municipal Water District

Geosyntec consultants

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Figure A-1

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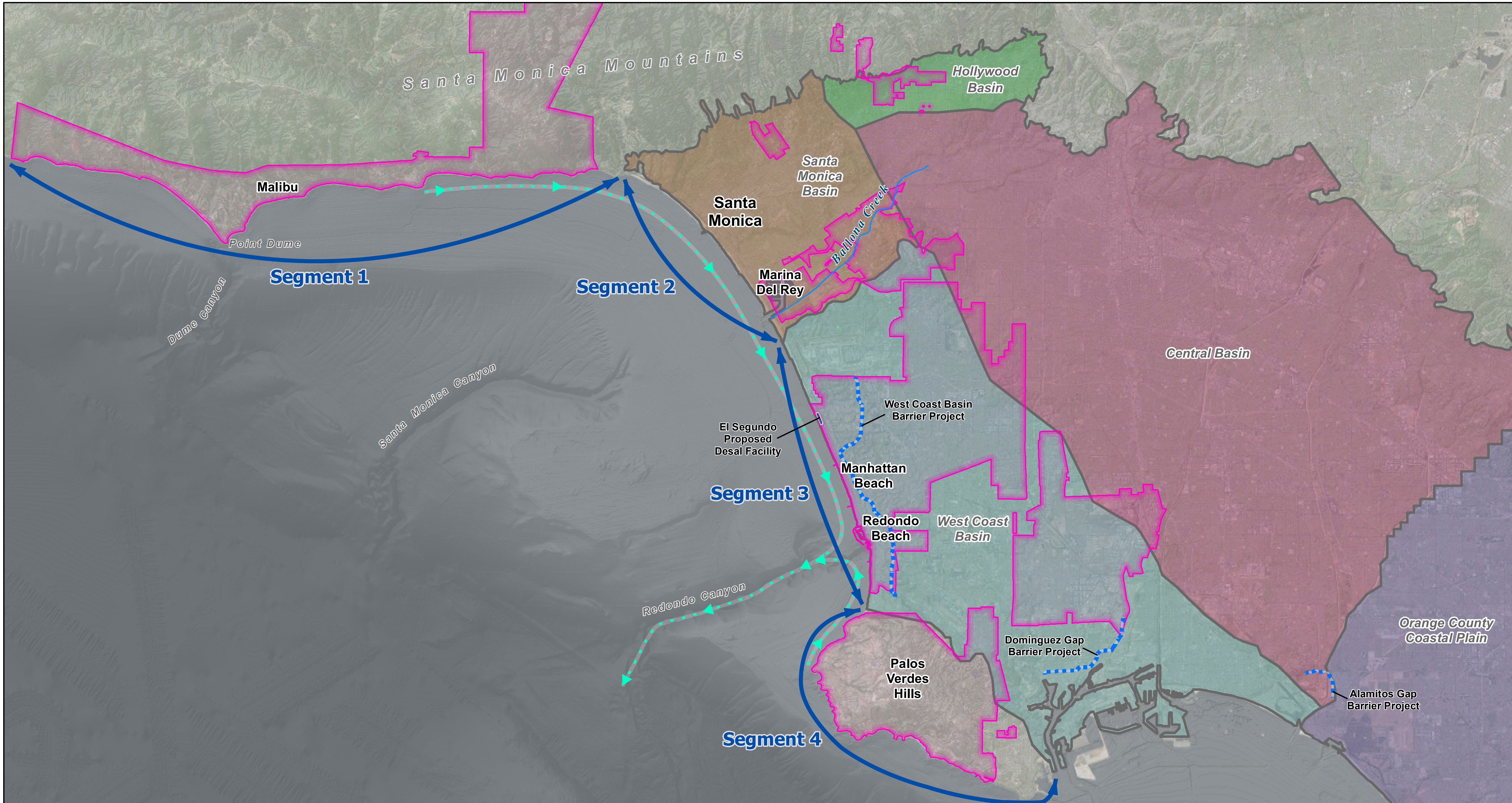

Legend

- West Basin Service Area
- Groundwater Basin
- Sea Water Barrier
- Littoral Drift Pathway along Coastal Margin *(longshore transport of sediment)*

Groundwater Basin

- Central Basin
- Hollywood Basin
- Orange County Coastal Plain
- Santa Monica Basin
- West Coast Basin

Notes:
Littoral drift pathway adapted from Jenkins, 2015-- Appendix K of Geosyntec, 2016.
Bathymetry and DEM source: NOAA - https://maps.ngdc.noaa.gov

N

0 6 Miles

Santa Monica Bay Coastal Margin Map

Alternative Site Evaluation
Proposed Desalination Facility
West Basin Municipal Water District

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Figure A-2

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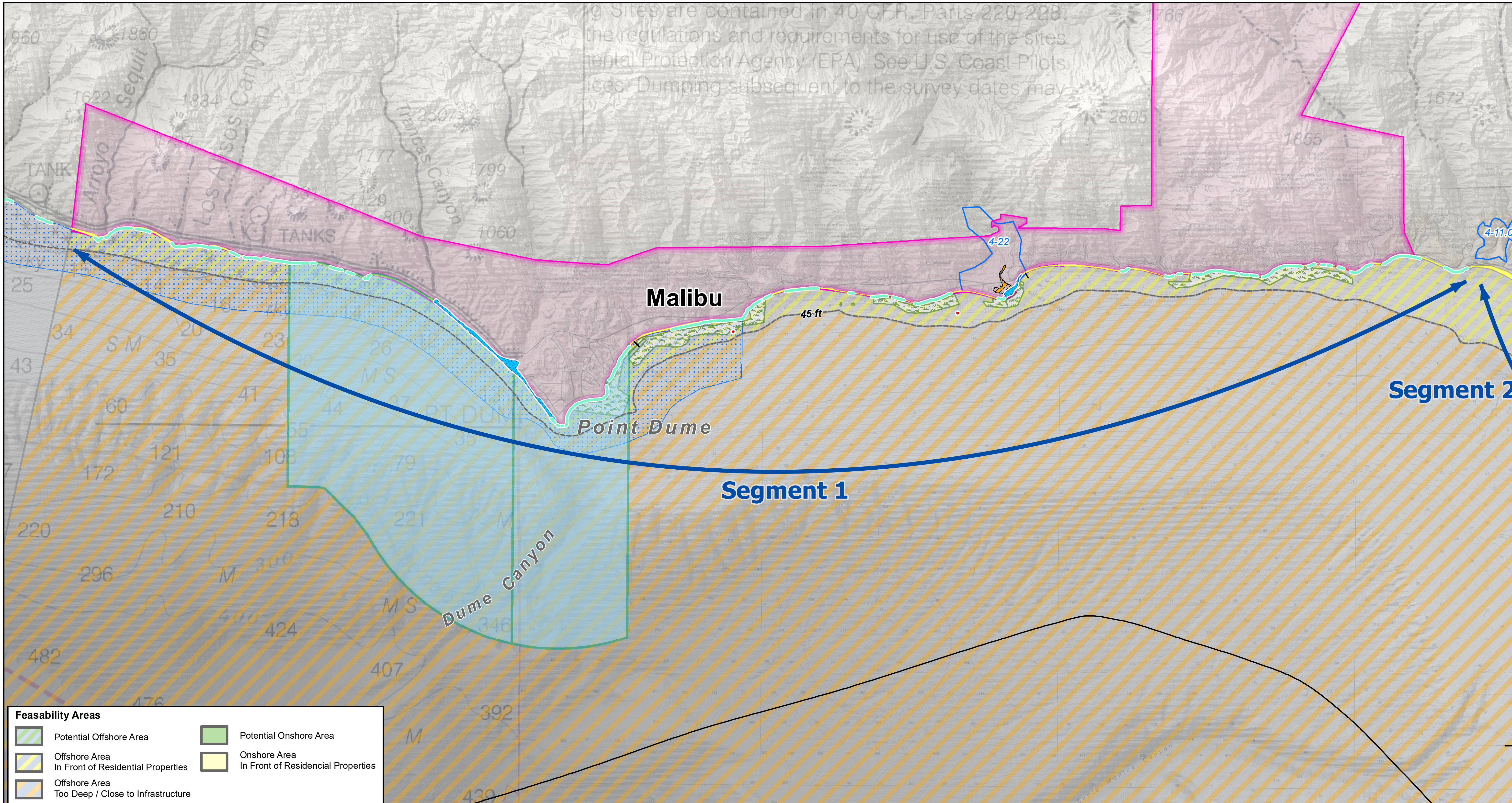

Legend

- Injection Barrier Well Location
- Pipes and Cables
- Approximate Beach Width
- Groundwater Basin
- Surf Grass
- Eel Grass
- Kelp Bed
- Estuaries
- California Marine Protected Areas
- Areas of Special Biological Significance
- West Basin Service Area
- Snowy Plover Critical Habitat
- Black Abalone Critical Habitat

Source:
Bathymetry and DEM: NOAA - https://maps.ngdc.noaa.gov
California Marine Protected Areas, Kelp Bed, Estuaries, Surf Grass, Eel Grass, and Areas of SBS: California Department of Fish and Wildlife - ftp://ftp.dfg.ca.gov/R7_MR/
Snowy Plover Critical Habitat - https://response.restoration.noaa.gov/maps-and-spatial-data/download-esi-maps-and-gis-data.html
Black Abalone Critical Habitat - National Marine Fisheries Service, Southwest Region

N

0 8,000 Feet

Constraints on SSI Feasibility, Segment 1

Alternative Site Evaluation
Proposed Desalination Facility
West Basin Municipal Water District

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Figure A-3

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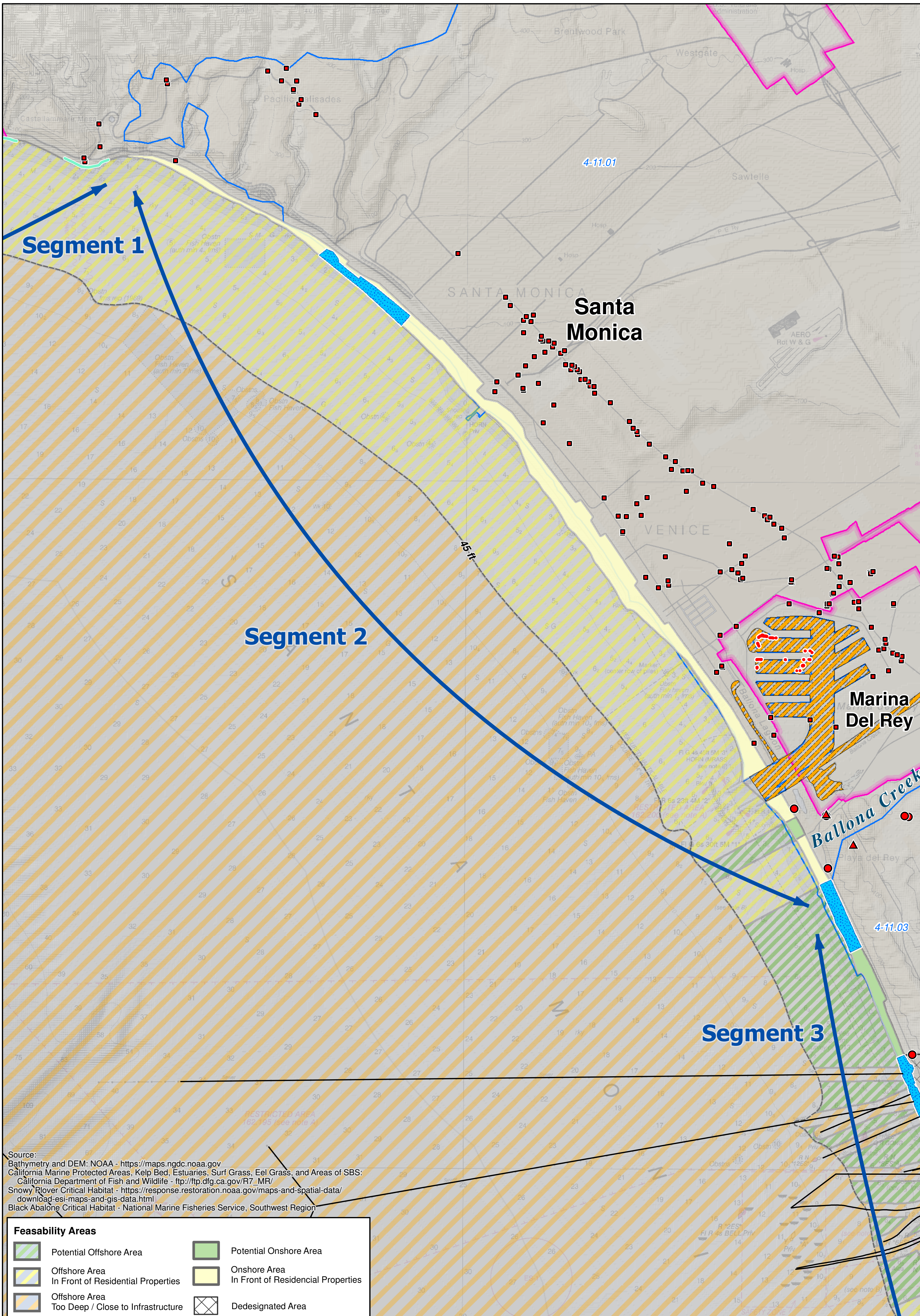

Legend

Injection Barrier Well Location
Pipes and Cables
Groundwater Basin

Sites with Contamination
Fuel
Solvent
Other

Surf Grass
Eel Grass
Kelp Bed
Estuaries

California Marine Protected Areas
West Basin Service Area
Snowy Plover Critical Habitat
Black Abalone Critical Habitat

N

0 4,000 Feet

Constraints on SSI Feasibility, Segment 2

Alternative Site Evaluation
Proposed Desalination Facility
West Basin Municipal Water District

Geosyntec consultants

Figure A-4

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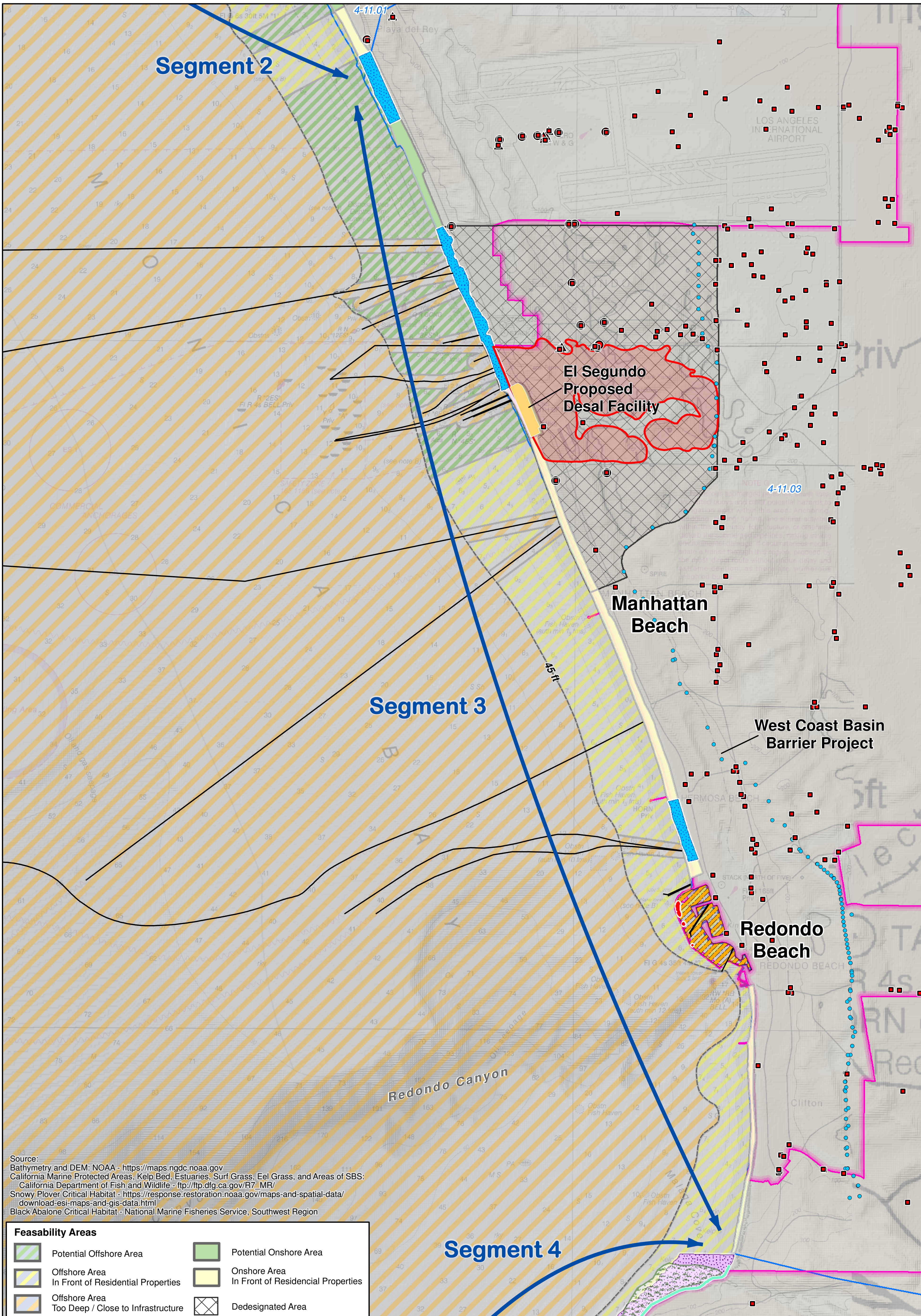

Legend

- Injection Barrier Well Location
- Pipes and Cables
- Proposed Desal Facility
- Groundwater Basin

Sites with Contamination

- Fuel
- Solvent
- Other
- Affected Area in Vicinity of Refinery

- Surf Grass
- Eel Grass
- Kelp Bed
- Estuaries
- California Marine Protected Areas
- West Basin Service Area
- Snowy Plover Critical Habitat
- Black Abalone Critical Habitat

N

0 4,000 Feet

Constraints on SSI Feasibility, Segment 3

Alternative Site Evaluation
Proposed Desalination Facility
West Basin Municipal Water District

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Figure A-5

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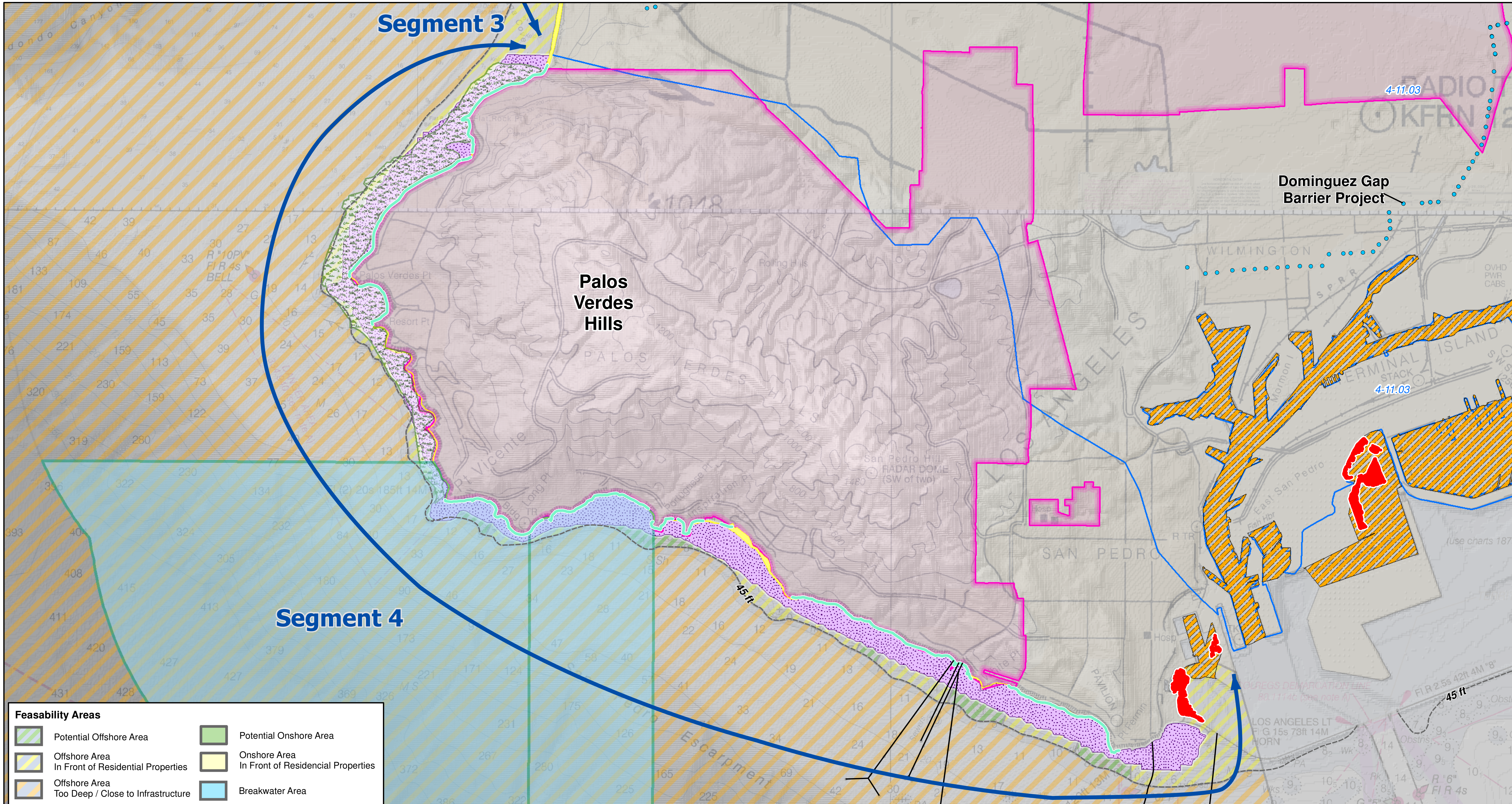

Legend

- Injection Barrier Well Location
- Pipes and Cables
- Approximate Beach Width
- Groundwater Basin
- Surf Grass
- Eel Grass
- Kelp Bed
- Estuaries
- California Marine Protected Areas
- West Basin Service Area
- Snowy Plover Critical Habitat
- Black Abalone Critical Habitat

Source:
Bathymetry and DEM: NOAA - https://maps.ngdc.noaa.gov
California Marine Protected Areas, Kelp Bed, Estuaries, Surf Grass, Eel Grass, and Areas of SBS: California Department of Fish and Wildlife - ftp://ftp.dfg.ca.gov/R7_MR/
Snowy Plover Critical Habitat - https://response.restoration.noaa.gov/maps-and-spatial-data/download-esi-maps-and-gis-data.html
Black Abalone Critical Habitat - National Marine Fisheries Service, Southwest Region

N

0 5,000 Feet

Constraints on SSI Feasibility, Segment 4

Alternative Site Evaluation
Proposed Desalination Facility
West Basin Municipal Water District

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Figure A-6

WR2596 | April 2019

P:\GIS\WestBasinMWD\Project\2019-03_updates\Fig3-4_SSI_Constraints_Segment_4.mxd 4/23/2019 12:29:47 PM

N

0 400 Feet

Notes:
Aerial Source: Google Earth Pro, 24 April, 2007.
The wider beach on the north side of the groin (jetty) is due to persistent southerly longshore current that transports sand along the coastal margin.
The aerial photo also shows evidence of strong currents stirring up the sea floor sediment.

Discontinuity of Beach Width at the Groin at El Segundo Beach

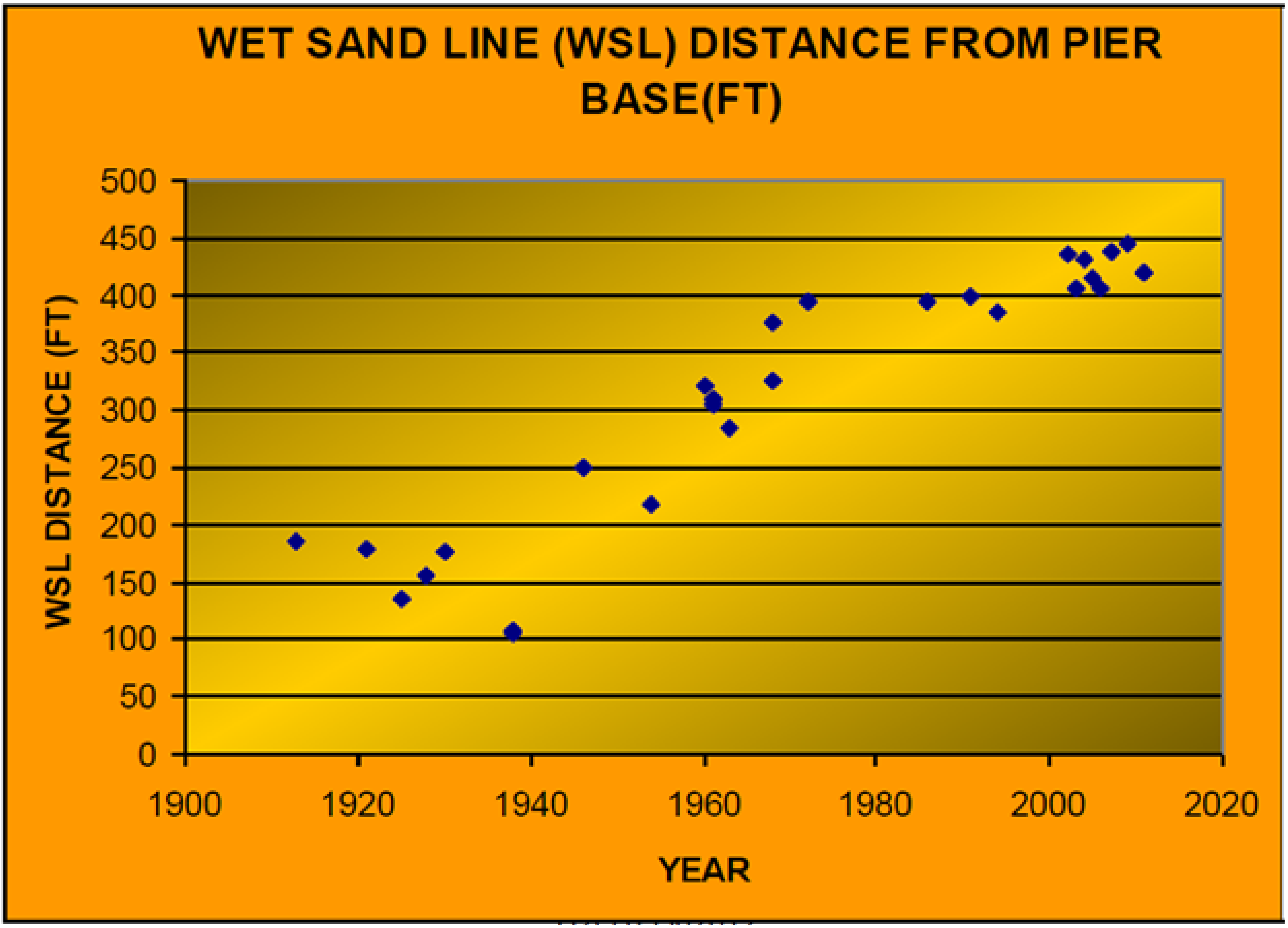
Alternative Site Evaluation
Proposed Desalination Facility
West Basin Municipal Water District

Geosyntec consultants

WR2596 | April 2019

Figure A-7

P:\GIS\WestBasinMWD\Project\2019-03_updates\Fig2-3_DiscontinuityOfBeachWidth.mxd 4/19/2019 1:27:49 PM



Source: Reppucci, 2012
http://hermosabeach.granicus.com/MetaViewer.php?view_id=4&clip_id=3118&meta_id=151400

Increase in Width of Manhattan Beach with Time Due to Beach Nourishment
Alternative Site Evaluation
Proposed Desalination Facility
West Basin Municipal Water District

Geosyntec consultants

WR2596 | April 2019

Figure A-8

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ATTACHMENT A-1

SSI Guidance Tool Input and Output Tables

Appendix A
Segments 1 and 4 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	Infeasible	Depth to bedrock (ft)	4	< 25 ft	4	High
		Cliff and beach width (ft)	Cliff and 50	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)	6,450	< 5875 ft	1	N/A
					6	Low
					10	Low
					12	Low
Available area	Potentially feasible	Available area needed (Sq Ft)	60,000	< 15000 Sq Ft	1	N/A
					7	Low
					11	Low
					12	Low

Appendix A
Segments 1 and 4 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	Infeasible	Depth to bedrock (ft) Cliff and beach width (ft) inlet	4 Cliff and 50 Inlet	< 100 ft Cliff and < 50 ft No inlet	4 2 and 5 3	High High and Medium High
Available Beach front	Potentially feasible	Length of beach front needed (ft)	6,450	< 6450 ft	1 6 10 12	N/A Low Low Low
Available area	Potentially feasible	Available area needed (Sq Ft)	60,000	< 60000 ft	1 7 11 12	N/A Low Low Low

Appendix A
Segments 1 and 4 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	Infeasible	Depth to bedrock (ft) Cliff and beach width (ft) inlet	4 Cliff and 50 Inlet	< 25 ft Cliff and < 50 ft No inlet	4 2 and 5 3	High High and Medium High
Available Beach front	Potentially feasible	Length of beach front needed (ft)	6,450	< 3763 ft	1 6 10 12	N/A Low Low Low
Available area	Potentially feasible	Available area needed (Sq Ft)	60,000	< 60000 Sq Ft	1 7 11 12	N/A Low Low Low

Appendix A
Segments 1 and 4 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	Infeasible	Depth to bedrock (ft)	4	< 10 ft	4	High
		Cliff and beach width (ft)	Cliff and 50	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)	6,450	< 1750 ft	1	N/A
					6	Low
					10	Low
					12	Low
Available area	Potentially feasible	Available area needed (Sq Ft)	2,000,000	< 2000000 Sq Ft	1	N/A
					8	Low
					11	Low
					12	Low

Beach Infiltration Gallery						
Fatal Flaw						
Fatal Flaw	**Feasibility**	**Criteria**	**Value**	**Threshold for infeasibility**	**Input**	**Data Quality**
Land type at construction site	Infeasible	Depth to bedrock (ft)	4	< 5 ft	4	High
		Cliff and beach width (ft)	Cliff and 50	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)	6,450	< 1389 ft	1	N/A
					6	Low
					10	Low
					12	Low
Available area	Potentially feasible	Available area needed (Sq Ft)	2,000,000	< 416667 Sq Ft	1	N/A
					7	Low
					11	Low
					12	Low

Appendix A
Segments 1 and 4 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	Infeasible	Depth to bedrock (ft)	4	< 5 ft	4	High
Available Beach front	N/A	Length of beach front needed (ft)	N/A	N/A	1 6 12	N/A Low Low
Available area	Potentially feasible	Available area needed (Sq Ft)	2,000,000	< 416667 Sq Ft	1 7 11 12	N/A Low Low Low

Appendix A
Segments 1 and 4 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	Infeasible	Depth to bedrock (ft)	4	< 5 ft	4	High	
		Cliff and beach width (ft)	Cliff and 50	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 Low Low	
Available area	Potentially feasible	Available area needed (Sq Ft)	2,000,000	< 46296 Sq Ft	1 7 12	N/A Low Low	

		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?**				
		500	ft	Medium	No
6)	**What is the length of the available beach front?**				
		46,500	ft	Medium	No
7)	**What is the area of available land onshore?**				
		26,000,000	sq ft	Medium	No
8)	**What is the area of available land offshore?**				
		208,000,000	sq ft	Medium	No
9)	**What is the available area for drilling, construction and staging?**				
		100,000	sq ft	Medium	Yes
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	0.2	MGD/well	Low	No
	Slant Wells	1	MGD/cluster of 3 wells	Low	No
	Radial Collectors	1	MGD/group of collectors	Low	No
	Horizontal Wells	0.6	MGD/drain	Low	No
	Beach Infiltration Gallery	0.02	gpm/sq ft	Low	No
	Seabed Infiltration Gallery	0.02	gpm/sq ft	Low	No
	Water Tunnel	0.4	gpm/ft	Low	No
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	30,000	gpd/ft	Medium	No
	Slant Wells	30,000	gpd/ft	Medium	No
	Radial Collectors	2,000	gpd/ft	Medium	No
	Horizontal Wells	1,000	gpd/ft	Medium	No
	Water Tunnel	2,500	gpd/ft	Medium	No
17)	**What is the leakance of the sediment overlying the planned SSI site?**				
	Vertical Wells	0.005	1/d	Medium	No
	Slant Wells	0.005	1/d	Medium	No
	Radial Collectors	0.01	1/d	Medium	No
	Horizontal Wells	0.03	1/d	Medium	No
	Water Tunnel	0.012	1/d	Medium	No

		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	40	ft	Medium	No
21)	**What is the distance of the depth of closure from the shore?**				
	Seabed Infiltration Gallery	5000	ft	Medium	No
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 A
Segment 2 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)	3000	< 25 ft	4	High
		Cliff and beach width (ft)	No Cliff and 500	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)	46,500	< 29875 ft	1	N/A
					6	Medium
					10	Low
					12	Low
Available area	Potentially feasible	Available area needed (Sq Ft)	26,000,000	< 75000 Sq Ft	1	N/A
					7	Medium
					11	Low
					12	Low

Appendix A
Segment 2 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)	100,000	> 50,000	10,000 - 50,000	< 10,000	9	Low	
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 Beach Width (ft) Depth to bedrock (ft)	No Cliff 500 3000	No Cliff > = 200 ft > = 50 ft	N/A N/A N/A	Cliff < 200 ft < 50 ft	2 5 4	High Medium High	
Operation (Intake) Challenges										
Geologic conditions	Highly Challenging	5	Transmissivity (gpd/ft) Leakance (1/d)	30,000 0.005	> 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	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 Turbidity (NTU)		< 0 < 10	0 - 1 10 - 25	> 1 > 25	31 28	Low Low	default is highly challenging
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	Medium	
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	Highly Challenging	1	% of number of units for existing systems	13%	> 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

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) Cliff and beach width (ft) inlet	3000 No Cliff and 500 Inlet	< 100 ft Cliff and < 50 ft No inlet	4 2 and 5 3	High High and Medium High
Available Beach front	Potentially feasible	Length of beach front needed (ft)	46,500	< 35250 ft	1 6 10 12	N/A Medium Low Low
Available area	Potentially feasible	Available area needed (Sq Ft)	26,000,000	< 300000 ft	1 7 11 12	N/A Medium Low Low

Appendix A
Segment 2 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)	100,000	> 50,000	10,000 - 50,000	< 10,000	9	Low	
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 500 3000	No Cliff > = 200 ft > = 200 ft	N/A N/A N/A	Cliff < 200 ft < 200 ft	2 5 4	High Medium High	
Operation (Intake) Challenges										
Geologic conditions	Highly Challenging	5	Transmissivity (gpd/ft)	30,000	> 88,000	25,000 - 88,000	< 25,000	16	Medium	
			Leakance (1/d)	0.01	> 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 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	Moderately Challenging	3	Saturation Index Turbidity (NTU)		< 0 < 10	0 - 1 10 - 25	> 1 > 25	31 28	Low Low	default is moderately
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	Medium	
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	2%	> 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

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)	3000	< 25 ft	4	High
		Cliff and beach width (ft)	No Cliff and 500	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)	46,500	< 20563 ft	1	N/A
					6	Medium
					10	Low
					12	Low
Available area	Potentially feasible	Available area needed (Sq Ft)	26,000,000	< 300000 Sq Ft	1	N/A
					7	Medium
					11	Low
					12	Low

Appendix A
Segment 2 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)	100,000	> 50,000	10,000 - 50,000	< 10,000	9	Low	
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 500 3000	No Cliff > = 200 ft > = 50 ft	N/A N/A N/A	Cliff < 200 ft < 50 ft	2 5 4	High Medium High	
Operation (Intake) Challenges										
Geologic conditions	Highly Challenging	5	Transmissivity (gpd/ft) Leakance (1/d)	2,000 0.01	> 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	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 Turbidity (NTU)		< 0 < 10	0 - 1 10 - 25	> 1 > 25	31 28	Low Low	default is moderately
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	Medium	
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 A
Segment 2 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)	3000	< 10 ft	4	High
		Cliff and beach width (ft)	No Cliff and 500	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)	46,500	< 12250 ft	1	N/A
					6	Medium
					10	Low
					12	Low
Available area	Potentially feasible	Available area needed (Sq Ft)	208,000,000	< 10000000 Sq Ft	1	N/A
					8	Medium
					11	Low
					12	Low

Appendix A
Segment 2 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)	100,000	> 50,000	10,000 - 50,000	< 10,000	9	Low	
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 500 3000	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)	1,000 0.03	> 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	Highly Challenging	1	% of number of units for existing systems	25%	> 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

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)	3000	< 5 ft	4	High
		Cliff and beach width (ft)	No Cliff and 500	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)	46,500	< 6875 ft	1 6 10 12	N/A Medium Low Low
Available area	Potentially feasible	Available area needed (Sq Ft)	208,000,000	< 2083333 Sq Ft	1 7 11 12	N/A Medium Low Low

Appendix A
Segment 2 Screening Tool Detailed Results
Beach Infiltration Gallery

Challenge	Challenge Score	Weight	Criteria	Value	Threshold: Not Challenging	Threshold: Moderately Challenging	Threshold: Highly Challenging	Input	Data Quality	Comments
Beach Infiltration Gallery – Signicant Challenges Scoring										
Construction Challenges										
Available area for construction equipment	Not Challenging	1	Available area (Sq Ft)	100,000	> 50,000	10,000 - 50,000	< 10,000	9	Low	
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 500 3000	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

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)	3000	< 5 ft	4	High	
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)	208,000,000	< 2083333 Sq Ft	1 7 11 12	N/A Medium Low Low	

Appendix A
Segment 2 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)	100,000	> 50,000	10,000 - 50,000	< 10,000	9	Low	
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)	3000	> = 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	Highly Challenging	3	Water depth at depth of closure (ft) Distance from the shore at depth of closure (ft)	40 5,000	< 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	Highly Challenging	1	% of number of units for existing systems	14%	> 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 A
Segment 2 Screening Tool Detailed Results
Deep Infiltration Gallery

Deep Iniftration 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)	3000	< 5 ft	4	High	
		Cliff and beach width (ft)	No Cliff and 500	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)	208,000,000	< 208333 Sq Ft	1 7 12	N/A Medium Low	

Deep Inifltration 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)	100,000	> 50,000	10,000 - 50,000	< 10,000	9	Low	
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 Beach Width (ft) Depth to bedrock (ft)	No Cliff 500 3000	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)	2,500	> 88,000	25,000 - 88,000	< 25,000	16	Medium	
			Leakance (1/d)	0.01	> 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 Mean sea lea level shoreline change (ft/year)	N/A N/A	N/A N/A	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 Turbidity (NTU)	 5	< 0 < 10	0 - 1 10 - 25	> 1 > 25	31 28	Low Low	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	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

		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?**				
		55,600	ft	Medium	No
7)	**What is the area of available land onshore?**				
		17,000,000	sq ft	Medium	No
8)	**What is the area of available land offshore?**				
		167,000,000	sq ft	Medium	No
9)	**What is the available area for drilling, construction and staging?**				
		100,000	sq ft	Medium	Yes
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	0.1	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

		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	40	ft	Medium	No
21)	**What is the distance of the depth of closure from the shore?**				
	Seabed Infiltration Gallery	5000	ft	Medium	No
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 A
Segment 3 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)	3000	< 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)	55,600	< 5875 ft	1	N/A
					6	Medium
					10	Low
					12	Low
Available area	Potentially feasible	Available area needed (Sq Ft)	17,000,000	< 15000 Sq Ft	1	N/A
					7	Medium
					11	Low
					12	Low

Appendix A
Segment 3 Screening Tool Detailed Results
Vertical Wells

Challenge	Challenge Score	Weight	Criteria	Value	Threshold: Not Challenging	Threshold: Moderately Challenging	Threshold: Highly Challenging	Input	Data Quality	Comments
Vertical Wells										
Signicant Challenges Scoring										
Construction Challenges										
Available area for construction equipment	Not Challenging	1	Available area (Sq Ft)	100,000	> 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 Beach Width (ft) Depth to bedrock (ft)	No Cliff 400 3000	No Cliff > = 200 ft > = 50 ft	N/A N/A N/A	Cliff < 200 ft < 50 ft	2 5 4	High Medium 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 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	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 Turbidity (NTU)		< 0 < 10	0 - 1 10 - 25	> 1 > 25	31 28	Low Low	default is highly challenging
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

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)	3000	< 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)	55,600	< 6450 ft	1	N/A
					6	Medium
					10	Low
					12	Low
Available area	Potentially feasible	Available area needed (Sq Ft)	17,000,000	< 60000 ft	1	N/A
					7	Medium
					11	Low
					12	Low

Appendix A
Segment 3 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)	100,000	> 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 3000	No Cliff > = 200 ft > = 200 ft	N/A N/A N/A	Cliff < 200 ft < 200 ft	2 5 4	High Medium 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 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	Moderately Challenging	3	Saturation Index Turbidity (NTU)		< 0 < 10	0 - 1 10 - 25	> 1 > 25	31 28	Low Low	default is moderately
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

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) Cliff and beach width (ft) inlet	3000 No Cliff and 400 Inlet	< 25 ft Cliff and < 50 ft No inlet	4 2 and 5 3	High High and Medium High
Available Beach front	Potentially feasible	Length of beach front needed (ft)	55,600	< 3763 ft	1 6 10 12	N/A Medium Low Low
Available area	Potentially feasible	Available area needed (Sq Ft)	17,000,000	< 60000 Sq Ft	1 7 11 12	N/A Medium Low Low

Appendix A
Segment 3 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)	100,000	> 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 3000	No Cliff > = 200 ft > = 50 ft	N/A N/A N/A	Cliff < 200 ft < 50 ft	2 5 4	High Medium 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 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	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 Turbidity (NTU)		< 0 < 10	0 - 1 10 - 25	> 1 > 25	31 28	Low Low	default is moderately
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 A
Segment 3 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)	3000	< 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)	55,600	< 1750 ft	1 6 10 12	N/A Medium Low Low
Available area	Potentially feasible	Available area needed (Sq Ft)	167,000,000	< 2000000 Sq Ft	1 8 11 12	N/A Medium Low Low

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)	100,000	> 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 3000	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

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)	3000	< 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)	55,600	< 1375 ft	1 6 10 12	N/A Medium Low Low
Available area	Potentially feasible	Available area needed (Sq Ft)	167,000,000	< 416667 Sq Ft	1 7 11 12	N/A Medium Low Low

Appendix A
Segment 3 Screening Tool Detailed Results
Beach Infiltration Gallery

Challenge	Challenge Score	Weight	Criteria	Value	Threshold: Not Challenging	Threshold: Moderately Challenging	Threshold: Highly Challenging	Input	Data Quality	Comments
Beach Infiltration Gallery										
Signicant Challenges Scoring										
Construction Challenges										
Available area for construction equipment	Not Challenging	1	Available area (Sq Ft)	100,000	> 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 3000	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

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)	3000	< 5 ft	4	High
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)	167,000,000	< 416667 Sq Ft	1 7 11 12	N/A Medium Low Low

Appendix A
Segment 3 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)	100,000	> 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)	3000	> = 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	Highly Challenging	3	Water depth at depth of closure (ft) Distance from the shore at depth of closure (ft)	40 5,000	< 10 ft < 1,000 ft	10 - 20 ft OR 1,000 - 2,000 ft	> 20 ft OR > 2,000 ft	20 21	Medium 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	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 A
Segment 3 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)	3000	< 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)	167,000,000	< 46296 Sq Ft	1 7 12	N/A Medium Low	

Appendix A
Segment 3 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)	100,000	> 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 Beach Width (ft) Depth to bedrock (ft)	No Cliff 400 3000	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)	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 Mean sea lea level shoreline change (ft/year)	N/A N/A	N/A N/A	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 Turbidity (NTU)	 5	< 0 < 10	0 - 1 10 - 25	> 1 > 25	31 28	Low Low	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	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 13B
Supplemental HDD Evaluation

ESA

Prepared for

West Basin Municipal Water District
17140 South Avalon Blvd, Suite 210
Carson, California 90746

SUPPLEMENTAL EVALUATION OF FEASIBILITY OF HORIZONTAL DIRECTIONALLY DRILLLED SUBSURFACE INTAKES

PROPOSED DESALINATION FACILITY EL SEGUNDO, CALIFORNIA

Prepared by

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Project Number: WR2596-01

15 May 2019

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ACRONYMS AND ABBREVIATIONS

BIG	Beach Infiltration Gallery
CEQA	California Environmental Quality Act
CPT	Cone Penetrometer Testing
CPUC	California Public Utilities Commission
Desal PMP	Ocean Water Desalination Program Master Plan
DIG	Deep Infiltration Gallery (also called Water Tunnel)
DWR	California Department of Water Resources
EIR	Environmental Impact Report
HDPE	high-density polyethylene
HDD	Horizontal Directionally Drilled
ISTAP	Independent Scientific Technical Advisory Panel
MGD	million gallons per day
N/A	Not Applicable
NOAA	National Oceanic and Atmospheric Administration
NRG Facility	NRG Generating Station site in El Segundo
desal	ocean water desalination
SIG	Seafloor Infiltration Gallery
SSI	Subsurface Seawater Intake
UWMP	Urban Water Management Plan
West Basin	West Basin Municipal Water District

Geosyntec
consultants

CERTIFICATION

Hydrogeologic, geologic, and engineering information and findings presented in this document have been prepared under the supervision of and reviewed by a California registered Professional Geologist and Engineer.

______________________________ 15 May 2019

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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 aims to reduce dependence on imported water from 57% in 2015 to 43% by 2025 (West Basin, 2015). 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).

To identify the 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). The Desal PMP identified an Environmental Impact Report (EIR) as key next step. As a component of the EIR process, West Basin conducted an evaluation of the feasibility of subsurface seawater intakes (SSIs) in compliance with the California State Water Board’s updated Ocean Plan (2015). Because screened ocean intakes can impact marine life, the Ocean Plan requires the use of SSIs for extraction of ocean water when “feasible” as opposed to direct ocean intakes. The definition of feasibility is based in part on the analyses required under the California Environmental Quality Act (CEQA).

The SSI feasibility study (Gesoyntec, 2016) was conducted for the vicinity of the NRG Facility location on the coastal margin of Santa Monica Bay in El Segundo. The design production capacity of 20 million gallons per day (MGD)[1] would require an ocean water intake (feed water) capacity of approximately 40 MGD.[2] The study considered site-specific geotechnical data, hydrogeology of the coastal margin, 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, consistent with the factors outlined in the 2015 Ocean Plan.

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[1] 20 MGD is considered the minimum capacity for the project per analysis of the need for desalinated water based on West Basin’s 2010 Urban Water Management Plan (UWMP) (RMC, 2011) and the Desal PMP.

[2] Use of the Sea Water Reverse Osmosis process produces a yield of approximately 50% of the water extracted from the ocean.

The following seven SSI technologies, which have been used at least once in desalination projects around the world, were evaluated (see Geosyntec, 2016 – Appendix B for detailed descriptions):

1. Vertical wells
2. Slant wells
3. Radial (Ranney) collector wells
4. Horizontal directional-drilled (HDD) wells (sometimes called drains)
5. Seabed infiltration gallery (SIG)
6. Beach (surf zone) infiltration gallery (BIG)
7. Deep infiltration gallery (DIG, also called water tunnel)

Analysis determined that none of the seven SSI technologies are feasible at El Segundo for the design intake rate of 40 MGD (Geosyntec, 2016) as summarized below.

Vertical, Slant, and Radial Collector Wells

Detailed analysis for vertical wells, slant wells and radial collector wells indicated that 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. Moreover, the pumping would impact the performance of the West Coast Basin Injection Barrier.

Based on groundwater modeling, the estimated maximum sustainable production capacity for vertical wells, slant wells and radial collector wells at the El Segundo NRG Facility is below 20 MGD, significantly less than the design intake rate of 40 MGD. More wells potentially could be located outside the NRG Facility to increase capacity, but they 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.

Beach Infiltration gallery (BIG)

BIGs are constructed in the surf zone, so that they are cleaned by the turbulence caused by breaking waves. A sustainable BIG requires a beach that is stable, with minimal erosion and deposition cycles. The high energy coastal environment at El Segundo that is exposed to long period swells from the Gulf of Alaska winter storms, can lead to long-term patterns of coastal erosion. The erosion is 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). BIGs have not been constructed in high-energy unstable beach settings such as at El Segundo and rest of Santa Monica Bay, and would not be sustainable.

Deep Infiltration Gallery (Water Tunnel)

DIGs or water tunnels are a range of conceptual offshore subsurface seawater collector systems. 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. Because of the extreme construction complexity coupled with high technical risks and lack of precedence for comparable conditions, DIGs were deemed infeasible for the proposed El Segundo Desal Facility (Geosyntec, 2016), and for the same reasons are not viable for the entire coastline of Santa Monica Bay.

Seafloor Infiltration Gallery (SIG)

A seabed infiltration gallery was determined to be potentially technically feasible but economically not feasible. Cost analysis of a seabed infiltration gallery supported this conclusion (Geosyntec, 2017a).

Horizontal Wells

Two main factors that contributed to the reported finding that HDD wells are not feasible for SSIs for the proposed desal facility at El Segundo include

1. the presence of a low permeability clayey layer approximately 20 feet below the seabed, that would limit the hydraulic connection between the ocean and HDD SSIs installed below the clay layer, and
2. challenges associated with installation of shallow HDD wells within 20 ft of seafloor above the low-permeability clayey layer in the presence of cobbles and gravel.

An alternative construction method was identified for installing horizontal wells in the seabed above the low-permeability layer that would consist of trenching and laying down micro-porous pipes from offshore trestles instead of by HDD. This “seabed wells” alternative is likely technically feasible; however it would require major offshore construction for which Geosyntec conducted a cost analysis (Geosyntec, 2017b).

The Water Board has requested supplemental consideration of feasibility of SSIs installed by HDD at El Segundo. This report presents further evaluation of the feasibility of HDD SSIs at El Segundo based on additional review of literature, further consideration of site-specific conditions, and input from HDD experts.

1.1 Report Organization

This remainder of the report is organized as follows:

Section 2 is an overview of Horizontal Directionally Drilled (HDD) Wells.

Section 3 presents a discussion of offshore subsurface conditions in the vicinity of El Segundo and considerations for feasibility of HDD Wells.

Section 4 presents conclusions.

Section 5 is a list of references.

Five figures follow the reference list.

Appendix A is a location map and logs borings used for the geologic cross-section.

Appendix B documents input from HDD experts regarding the feasibility of shallow HDD wells beneath the seafloor at El Segundo.

2. HDD OVERVIEW

Horizontal Directionally Drilled (HDD) wells have been used for installation of utilities since the 1970s for underground pipes, conduits, and cables, including crossings beneath water bodies (e.g. Pankratz, 2015; Bennett and Ariaratnam, 2017).

Typical HDD installations begin with a guided pilot boring drilled from an excavated entry pit to contain drilling fluids. Usually another pit is excavated at the exit point to contain drilling fluids and facilitate entry of the pipeline, which normally is pulled back through the boring. Prior to, or concurrent with pulling the product pipe in from the exit point, the pilot boring is reamed to the final diameter. Figure 1 illustrates the typical HDD drilling, reaming, and pipeline installation process (e.g. CAPP, 2004).

Shallow HDD wells, sometimes called drains, potentially can provide better hydraulic connection to the ocean than deeper subsurface seawater intakes (SSIs) because HDD wells can be installed at relatively shallow depths and to greater distances offshore. Groups of HDD wells can fan out from a common location inland of the beach. Figure 2 is a schematic cross-section illustration of an HDD SSI (IntakeWorks, 2017) and a system of HDD SSIs for desal facility (Missimer, 2013).

Installation of HDD wells beneath the seafloor normally requires exit points on the seafloor to pull the casing and well screen into each boring from offshore. As shown by Figure 2, the exit points can be completed as permanent access ports on the seafloor to facilitate construction and maintenance. However, an exit point on the seafloor requires offshore construction activity and increases the amount of environmental impact compared to other SSI wells (e.g. Pankratz, 2015).

Drilling fluids, which are pumped in through the drill pipe and flow back through the borehole annulus, carry the cuttings out of the boring, keep the borehole from collapsing, cool the cutting tools, and lessen friction between the subsurface and drill stem or product pipe.

HDD well technology has advanced in the last 20 years. In recent years, pipelines with diameters as large as 65 inches have been installed, and lengths of HDD installations have reached 10,000 feet. The maximum length of an HDD boring and pipeline installation is usually controlled by the drill-rig fluid requirements, pullback and torque capabilities, and subsurface ground conditions. Most installations are between 2 and 36-inches in diameter, and less than 3,000 feet long (Bennett and Ariaratnam, 2017; Netwas Group Oil, 2017).

Newer HDD technologies are reportedly being developed to facilitate installation of SSIs with single on-shore entry points (i.e. without an exit pit, also called “blind completions”), which would lessen impacts to the coastal marine environment. One type of HDD well technology utilizes a micro-porous polyethylene casing (e.g., Neodren®). Very limited published data are available on the long-term performance of Neodren® intake systems (e.g. Maliva and Missimer, 2015).

3. SUBSURFACE CONDITIONS AND CONSIDERATIONS

The technical feasibility of HDD well installations is largely dependent on the subsurface conditions.

The HDD method is well-suited for soft soils such as clays and compacted sands. Cohesive soils, such as clays, silty or clayey silts are commonly self-supporting and often can maintain an open borehole. Also, with the use of drilling mud, an open borehole normally can be supported and maintained in clayey sands and cohesionless sandy material (e.g. CAPP, 2004; Carlin, 2014; Bennett and Ariaratnam, 2017).

3.1 Site-specific Geology at El Segundo Coastal Margin

Seafloor conditions at El Segundo pose significant limitations and challenges for HDD wells:

1. A low-permeability clayey layer approximately 20 feet below the seabed would limit the hydraulic connection between the ocean and HDD wells beneath the clay layer.
2. Due to inadequate overburden, attempts using standard methods to drill and install HDDs within the shallow sediments in the upper 20 feet of the seafloor would likely result in loss of drilling mud circulation, leakage of drilling mud into the sea, and collapse of the boring.
3. Presence of cobbles and gravel in the shallow sediments make leakage and loss of circulation more likely and may result in difficulty in controlling the location of HDD borings, refusal, and casing becoming stuck in the sediment.

The stratigraphy of the shallow sediment on and offshore in the vicinity of the NRG Facility that is relevant to the feasibility of HDD SSIs is based on boring logs, cone penetrometer testing (CPTs), an offshore seismic reflection geophysical survey, and previous reports, including:

- 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);

- Boring logs for onshore monitoring and extraction wells available from the Water Board Geotracker files for the Chevron El Segundo Refinery, (Geotracker Site # SL372482441).
- CPTs in the NRG Facility to characterize the subsurface stratigraphy, and pore-pressure dissipation testing to measure permeability of the subsurface sediments (Geosyntec, 2016);
- Offshore sub-bottom profiling and multi-channel seismic reflection geophysical surveys to characterize the shallow offshore stratigraphy, including the extent and continuity of the clay interval (Geosyntec, 2016).
- Previous reports on the stratigraphy (e.g. California State Lands Commission, 2010; Appendix E, MWH, 2007; Geosyntec, 2016)

Figure 3 shows the investigation locations and Figure 4 is a cross-section illustrating the stratigraphy near the coastal margin of the NRG Facility at El Segundo. Boring logs on which the cross-section is based are provided in Appendix A.

Based on the offshore geophysical survey (Geosyntec, 2016), the upper clay layer appears to be nearly horizontal and continuous to a distance of approximately 2,200 feet offshore. Beyond 2,200 feet offshore, the interpreted geophysical profiles show the upper clay layer truncated by the overlying shallow sandy sediments, likely due an erosional unconformity.

As illustrated by the cross section (Figure 4), the shallow 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 the clayey layer is 5 to 10 feet thick. The vertical hydraulic conductivity of the clayey interval is expected to be at least 100 to 1,000 times lower than the horizontal hydraulic conductivity of the overlying very fine sand, which was estimated to be in the order of 1 to 50 ft/d. Based on CPT data, the vertical hydraulic conductivity of this fine-grained material is estimated to be in the range of 0.005 to 0.01 ft/day (Geosyntec, 2016).

3.2 <u>Unconsolidated coarse sediments present challenges for HDD</u>

Unconsolidated coarse-grained sediments (e.g. sands with gravel or cobbles) can present serious limitations to the feasibility of HDD and can result in

- bore instability or collapse during drilling of the pilot hole or subsequent reaming passes, which can result in the drill string or product pipe becoming stuck;
- difficulty of removal of the gravel and cobble with the circulating drilling mud;
- loss of drilling fluids to the formation; and
- release of drilling fluids to the environment.

Cobbles can remain in the drilled path and present an obstruction to a bit, reamer, or pipeline. Coarse material can also migrate to low spots on the drilled path, forming impenetrable obstructions (e.g. CAPP, 2004; Carlin, 2014; Bennett and Ariaratnam, 2017).

Difficulties of installing HDD wells in loose sediments with cobbles and boulders sediments is documented 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).

3.3 Overburden must exceed drilling mud pressure

The depth of the HDD borehole beneath the ground surface or seafloor is a key factor for feasibility and design of HDD wells. The depth needs to be sufficient so the overburden pressure exceeds the necessary drilling mud pressure in the annulus of the borehole. Otherwise, hydraulic fracturing[3] of the soil (frac-out) and loss of drilling fluid is likely to occur, which can lead to collapse of the borehole, a stuck drill stem or product pipe, and failure of the HDD installation. HDD beneath water bodies with insufficient overburden pressure can result in leakage of drilling mud into the water body and environmental impacts (CAPP, 2004; Placido et al., 2009; Carlin, 2014; Bennett and Ariaratnam, 2017). The minimum design depth for a large HDD project is typically 40 ft or more (Kezdi, 2015). A site-specific scour analysis and hydrofracture risk evaluation can be important for feasibility assessment and design of HDD projects beneath a river or sea shore (e.g. Bennett and Ariaratnam, 2017). A site-specific hydrofracture analysis follows, and site-specific stability of the beach seafloor is discussed further in Section 3.4.

3.3.1 Site-Specific Hydrofracture Analysis for Shallow HDD SSIs

A site-specific analysis of the potential for hydrofracture during HDD offshore of El Segundo Beach was conducted using the cavity expansion model to calculate maximum allowable pressure and the Bingham-Plastic model to calculate the minimum required pressure for the drilling mud (e.g., see Bennett and Ariaratnam, 2017, Section 5.2). Based on discussions with HDD experts it was assumed a pilot boring using a 5-inch diameter pipe would be used to drill an 8-inch diameter boring at a depth of 18 feet below ground or seafloor surface (i.e., above the clay layer at approximately 20-feet depth) to a distance of 2,000 feet off-shore. The following typical values for drilling mud were used: unit weight = 9.5 lb/gal, viscosity = 14 centipose (cP), yield point 28 lb/100ft^2, and a flow rate of 300 gpm. The following mid-range values for a loose sand were assumed: cohesion = 0, unit weight = 120 lbs/ft^3, internal friction angle = 32 degrees, and shear modulus = 150,000 lbs/ft^2 (Asperger & Bennett, 2011, Table 1). The unit weight of seawater was taken as 64 lbs/ft^3.

Results of the calculations are presented in Figure 5 and indicate that the maximum allowable pressure would likely be exceeded by the drilling mud pressure beyond approximately 800 feet, and that hydrofracture would likely occur resulting in leakage of drilling mud into the ocean and potential failure of the installation.

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[3] Note that leakage of drilling mud out of an HDD boring during drilling in unconsolidated sediments of soil, such as the loose sandy sea floor at El Segundo Beach, due to exceedance of overburden pressure by the drilling mud pressure is also referred to as "hydrofracture" although the unconsolidated sandy material would not actually fracture as consolidated material can.

Note that the results of these analyses depend on the properties of the sandy seafloor, and additional measurements and investigations could be conducted to confirm or refine the estimates used. However, practical measurements of cavity pressure during drilling indicate that hydrofracture and inadvertent returns of drilling mud may occur at substantially lower pressures than calculated by the cavity expansion model. Specifically, Staheli et al., (2010) noted inadvertent returns of drilling mud occurred at pressures as low as 55 psi, when the cavity expansion model predicted permissible pressures as high as 314 psi. This indicates that the calculations may not be conservative and an additional factor of safety should be applied when interpreting the results in Figure 5. This is consistent with Xia (2009) who recommends a factor of safety of at least 2.5.

3.4 Seafloor and beach stability (erosion/deposition)

Seafloor instability can pose a threat to sustainability of shallow SSI infrastructure including HDD wells. High sedimentation rates, generally associated with discharges from rivers, streams or sewer outfalls can result in deposition of fine-grained material (silt and clay) on the seabed and decrease hydraulic connection between HDD wells and the ocean (e.g. Missimer et al., 2013). Elevated sedimentation rates of fine-grained sediments have been documented in Santa Monica Bay that are associated with wastewater outfalls such as Hyperion Water Reclamation Plant and discharge to the ocean of mud from Ballona Creek during flood events (e.g. Farnsworth and Warrick, 2007; Inman and Jenkins, 1999; Jenkins, 2015b—Appendix K in Geosyntec, 2016).

Erosion of the seafloor, which is exacerbated during extreme winters by large waves associated with El Nino, can exhume and damage shallow SSI infrastructure beneath the seafloor (California State Lands Commission, 2010; Water Research Foundation, 2011; Geosyntec, 2016). 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, 2015b, Appendix K of Geosyntec 2016)[4]. The closure depth, which is an important parameter in construction feasibility

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[4] Profiles of seafloor bathymetry for different times typically would converge at the depth of closure. However, some of the bathymetric profiles offshore of El Segundo shown on Figures 4.7 and 4.8 of Jenkins, 2015b 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.

and sustainability of SSIs, represents the closest point to the shoreline where a stable seabed occurs. Shallow offshore SSIs inside the closure depth are vulnerable to seafloor instability.

The thickness of the critical mass[5] envelope based on compilation of historical bathymetric profiles provides an indication of the depth below the beach and seafloor for pipelines to be safe from exposure by erosion. Analysis at El Segundo indicates a depth of up to approximately 10 feet of sand erosion and deposition cycles to approximately 800 ft offshore (Figures 5.4 and 5.5 in Jenkins 2015b, Appendix K of Geosyntec, 2016). However, the Jenkins analysis was based upon measurements in 1991, 1992, 1993, 1995, 1996, and 1997, which did not include large El Nino storm years (e.g., 1983 or 1998). Accordingly, 10 feet may not encompass the full range of seafloor elevation, so deeper installation may be necessary to ensure sustainability of subsurface pipelines or intakes. Moreover, stability of the beach width and sand thickness at El Segundo is dependent on beach nourishment programs. Without continued beach nourishment major erosion of the Santa Monica Bay beaches will occur as a consequence of the persistent southward littoral transport (Reppucci, 2012; Jenkins 2015b-- Appendix K of Geosyntec, 2016).

3.5 <u>Clogging</u>

Clogging (also referred to as plugging) of HDD SSIs results in decreased intake capacity, loss of performance, and would require rehabilitation of the intake (e.g. ISTAP, 2014). Deposition of fine-grained, low-permeability sediments on the sea floor would impede the hydraulic connection between the ocean and HDD SSIs and thus reduce the intake rates of feed water to the desal facility (e.g. Missimer et al., 2013). Sedimentation rates in Santa Monica Bay are relatively high because of discharge from wastewater outfalls such as Hyperion Water Reclamation Plant and from Ballona Creek following flood events (Farnsworth and Warrick, 2007; Jenkins 2015b—Appendix K in Geosyntec, 2016).

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[5] "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." Jenkins, 2015b—Appendix K of Geosyntec, 2016.

3.6 Existing Buried Infrastructure

A variety of buried offshore infrastructure is present near the proposed desal facility at El Segundo, including sewer lines, oil pipelines, and fiber optic cables (Figure 3). Existing subsurface infrastructure pose significant potential technical risks during HDD construction, including delays and cost overruns due to encountering the infrastructure. Furthermore, due to the abundance of oil pipelines in the area there is a risk of leaking subsurface pipes introducing oil to SSIs via seepage through sand.

Vulnerable subsurface infrastructure is also present onshore, including a 36-inch gas line running parallel to the western boundary of the NRG Facility. This may complicate construction for SSIs such as the installation of a system of HDD wells.

3.7 Maintenance

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

The frequency of maintenance activities that would be required depends on both the SSI technology and site-specific conditions. HDD Neodren® and other micro-porous intake wells are expected to be challenging to maintain and have a high clogging potential. Rehabilitation of HDD wells that extend a long distance from the shoreline would require specialized equipment and damaging the intakes could occur during maintenance efforts (Water Research Foundation, 2011; Missimer et al., 2013).

3.8 Other Risk Factors and Uncertainties

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

3.8.1 Precedence

Lack of precedence of intake systems operating in similar settings and at similar capacity increases the risk of performance and reliability. It also means that the ability to find contractors capable of designing, constructing, and maintaining the intake system might be limited.

No HDD SSI intake systems exist in shallow unconsolidated sediments with gravel and cobbles in a high energy setting. However, a desal facility exists in San Pedro de Pinatar, Spain with an intake capacity of approximately 40 mgd using 19 Neodren® micro porous horizontal intake wells installed in a 16-feet-thick lithified calcarenite beneath the seafloor[6]. Moreover, illustrations of the HDD SSIs at the facility in Spain show that they were constructed with exit points on the seafloor (e.g. Bartak et al., 2012).

Limited data are available to assess actual performance and long-term operating efficiency for the existing HDD SSI systems. However, some Neodren® HDD wells have been reported to have water quality problems and lower capacity than expected (Rachman et al., 2014).

3.9 Input from HDD Experts

As part of this supplemental evaluation of HDD SSIs, Geosyntec contacted nine HDD experts and requested their input on the feasibility of shallow HDD well installations beneath the seafloor at El Segundo. Five of the HDD experts provided input.

None of the experts were aware of examples of single-entry HDD SSIs beneath the seafloor. Jeremy King with The HDD Company indicated that technology was being developed for single-entry HDD SSIs but has not yet been implemented.

All of the experts expressed concern about the feasibility of installing SSIs with HDD in unconsolidated sediments with gravel and cobbles within 20 feet of the seafloor. Some said that attempting HDD at the shallow depth would certainly result in "fracing-out" of the drilling fluid on the seafloor.

A few of the HDD experts suggested that by using the Direct Pipe® method[7], installation of shallow SSIs would likely be possible for the conditions at El Segundo

[6] Note that the reported number of HDD Neodren® intake wells at the facility in San Pedro de Pinatar Spain is not consistent between publications. Also, Bartak et al., 2012 report that the Neodren® HDDs at this facility are completed in a "solid calcarenite", which presumably means lithified. Other publications report that the HDDs at San Pedro de Pinatar are completed in unconsolidated sediment (e.g. Rachman et al. 2015).

[7] Description and examples of the Direct Pipe® method can be found at the following websites: https://www.laneydrilling.com/direct-pipe/ http://jdhair.com/services https://www.michels.us/oil-gas/direct-pipe/

with much lower risk of escape of drilling mud into the ocean but would require exiting the seafloor and associated offshore construction. Maureen Carlin with Laney Directional Drilling indicated that work is in progress to develop a specialized modification of Direct Pipe® that would facilitate installation of an SSI with a single entry (blind completion).

Apparently, the minimum size of a pipeline installation with the Direct Pipe® is 36-inches in diameter, and it is likely twice the cost of HDD.

Appendix B lists the experts contacted, and documents information provided to the experts and their input.

4. CONCLUSIONS

Based on additional review of literature, further consideration of site-specific conditions, and input from horizontal directional drilling (HDD) experts, installation of shallow subsurface seawater intakes (SSIs) beneath the seafloor at El Segundo is not feasible using established HDD technology.

In the vicinity of the proposed desal facility at El Segundo, for an effective hydraulic connection between SSIs and the ocean would require installation of the SSIs within 20 feet of the seafloor because of the presence of a low-permeability clayey layer at a depth of approximately 20 feet. The upper 20 feet beneath the seafloor consists of unconsolidated sand with significant amounts of gravel and cobbles. The presence of gravel and cobbles can deflect an HDD boring and obstruct the reaming pull-back of the intake pipe.

For established HDD technology, drilling mud is pumped in through the drill stem pipe and flows back through the annulus between the walls of borehole and the drill stem. The pressurized circulating drilling mud removes the cuttings from the borehole, supports the borehole to keep it from collapsing, cools the cutting tools, and lessens friction between the subsurface and drill stem or product pipe. At depths of less than 20 feet within unconsolidated sands with gravel and cobbles beneath the seafloor there is insufficient overburden confining pressure to contain the drilling mud within the borehole. Consequently, the probability is high that the drilling mud would escape and flow into the ocean and the borehole would collapse.

There is no precedence for SSIs installed by HDD without exiting the seafloor during the drilling and installation procedure, which would impact the coastal marine environment. Moreover, there are no Neodren® SSIs in California and the sustainability of Neodren® intakes in Santa Monica Bay is a concern due to potential for clogging and vulnerability to erosion. Limited data are available to assess actual performance and long-term operating efficiency for the existing HDD Neodren® SSI systems.

A few of the directional drilling experts contacted have suggested that Direct Pipe® technology would likely be possible to install shallow SSIs for the conditions at El Segundo with lower risk of escape of drilling mud into the ocean than HDD but would require exiting the seafloor and associated offshore construction. Also, pipeline installation using the Direct Pipe® method is reportedly more than twice the cost of the HDD method. Apparently, work is in progress to develop a specialized modification of the Direct Pipe® technology that would facilitate installation of an SSI with a single onshore entry on the shore. However, the technology does not exist; it is a novel concept with no precedence.

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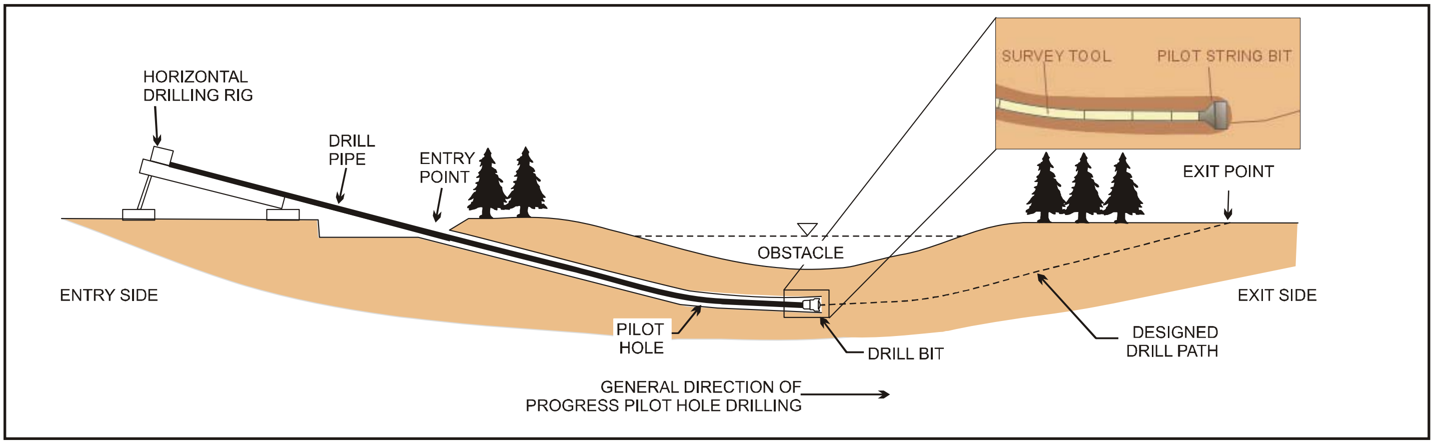
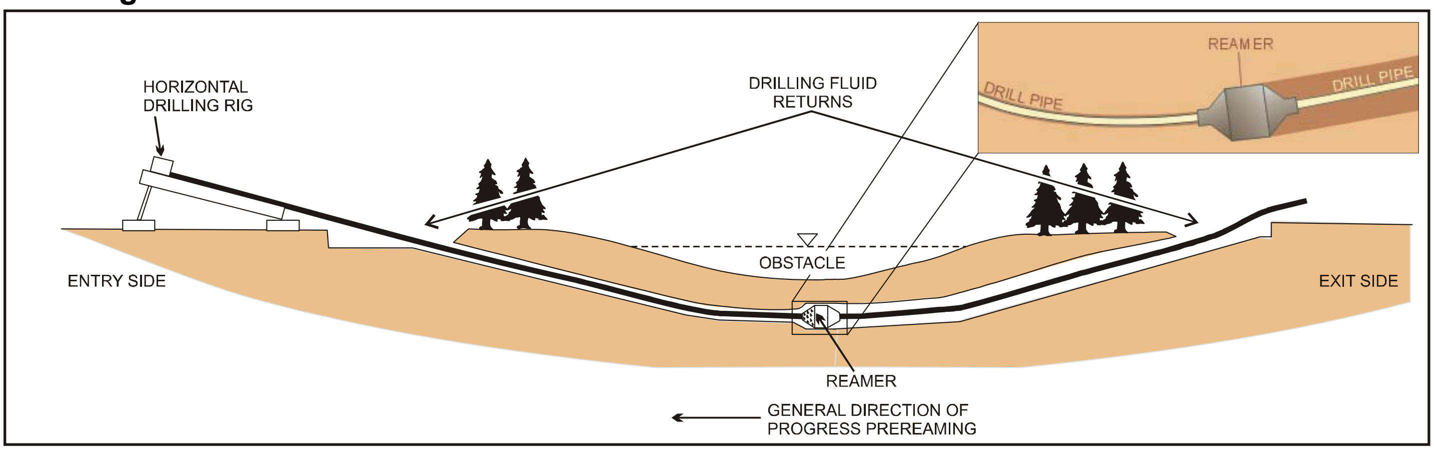
FIGURES

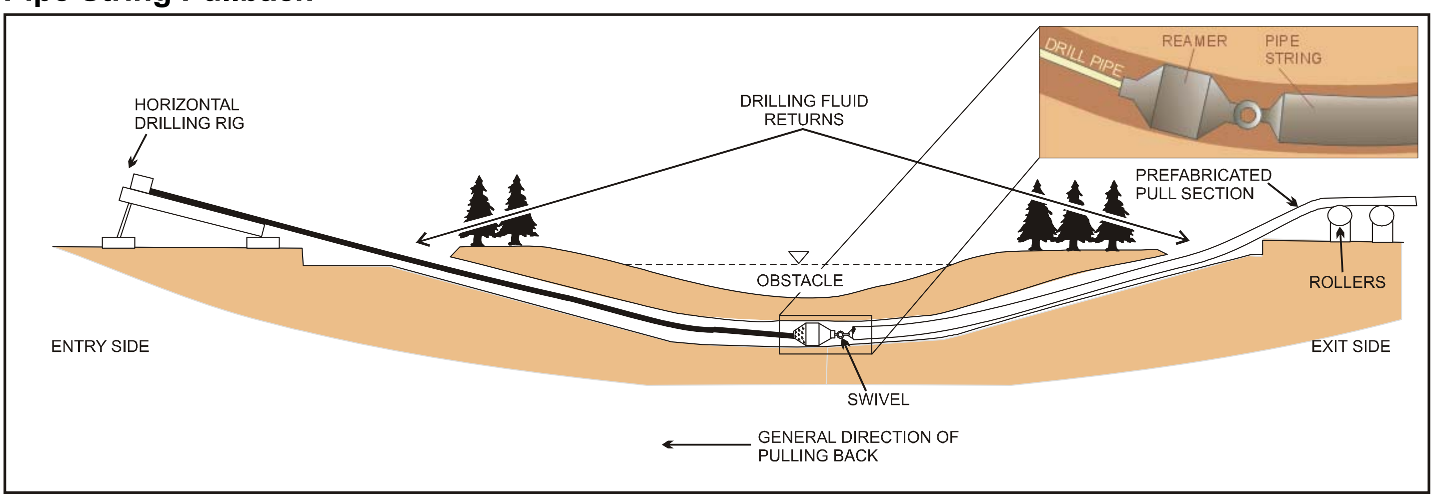
Drilling the Pilot Hole



Reaming of the Pilot Hole



Pipe String Pullback



Note:
Adapted from CAPP, 2004
Not to scale

Illustration of HDD Process

HDD Feasibility Evaluation
West Basin Municipal Water District

Geosyntec consultants

WR2596 | April 2019

Figure 1

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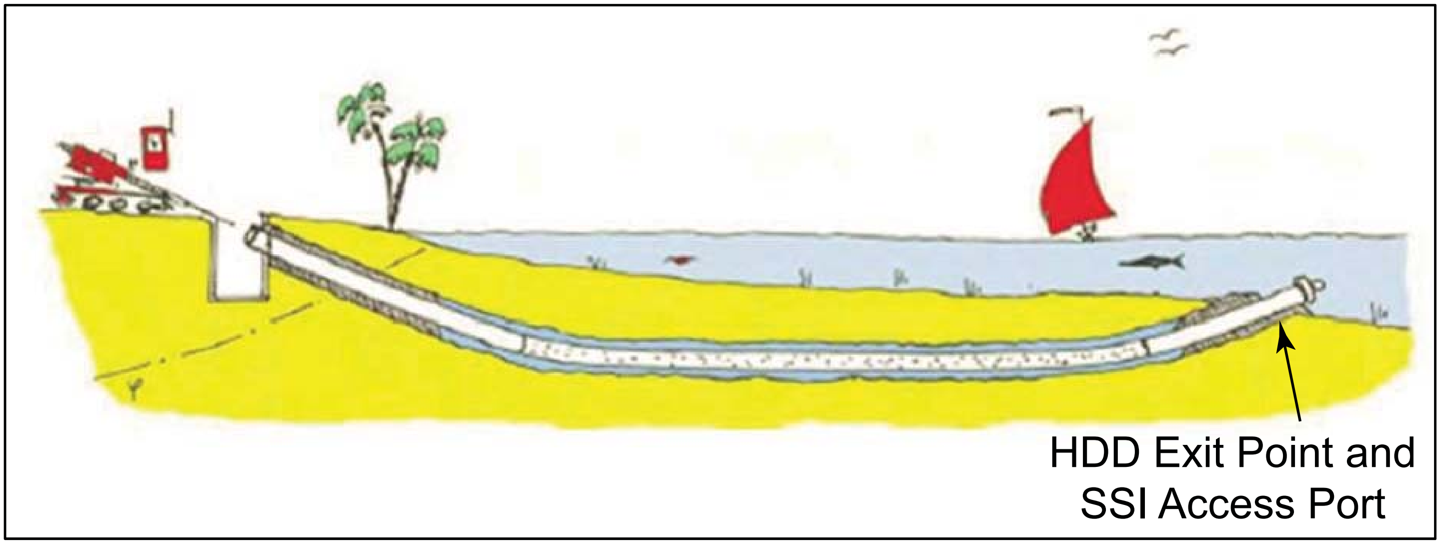
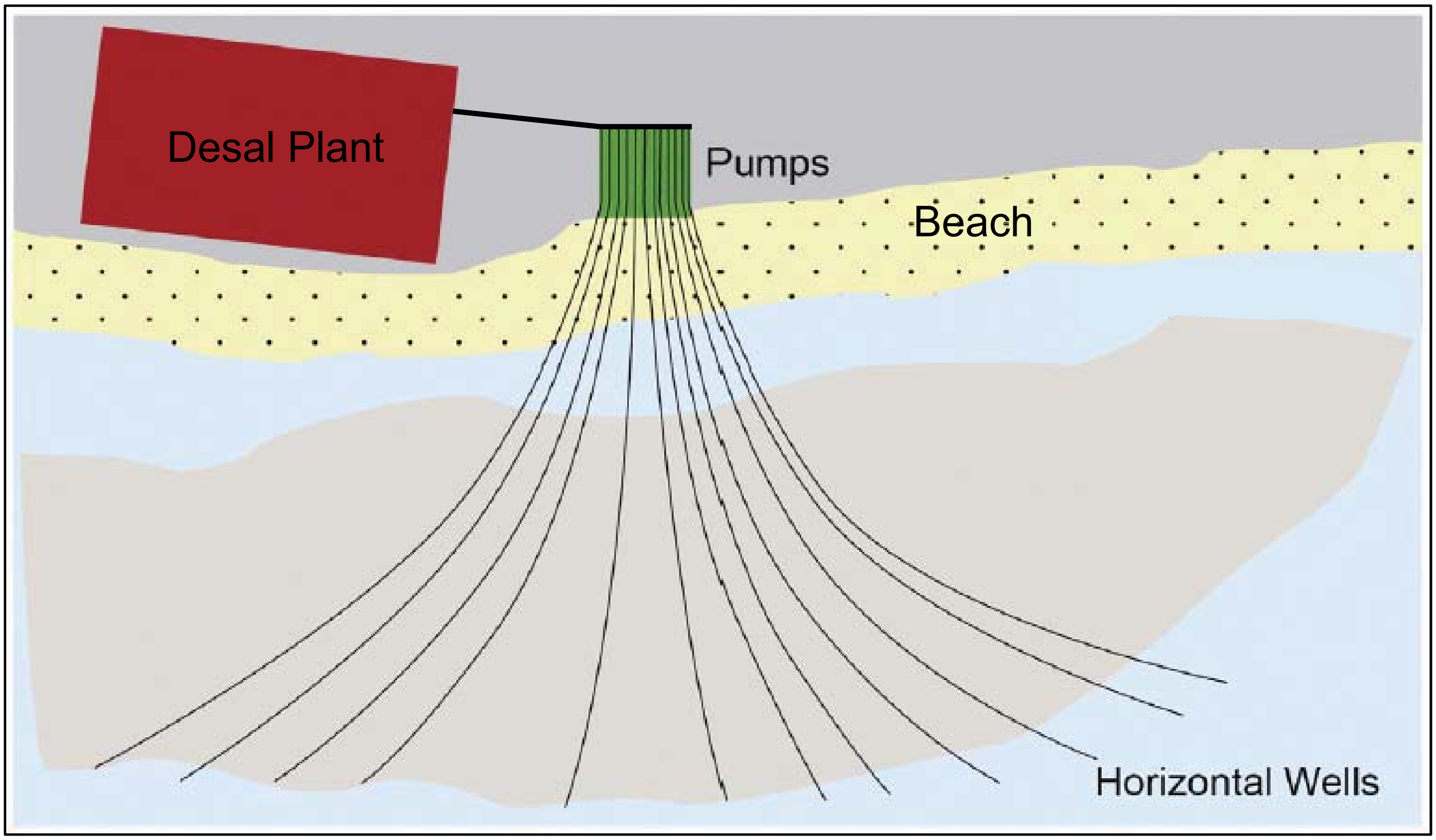
Cross-Section of an HDD SSI



Plan View of Conceptual HDD SSI System



Note:
Adapted from Missimer et al., 2013
IntakeWorks, 2017

Representation of a Conceptual HDD Subsurface Intake System

HDD Feasibility Evaluation
West Basin Municipal Water District

Geosyntec consultants

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Figure 2

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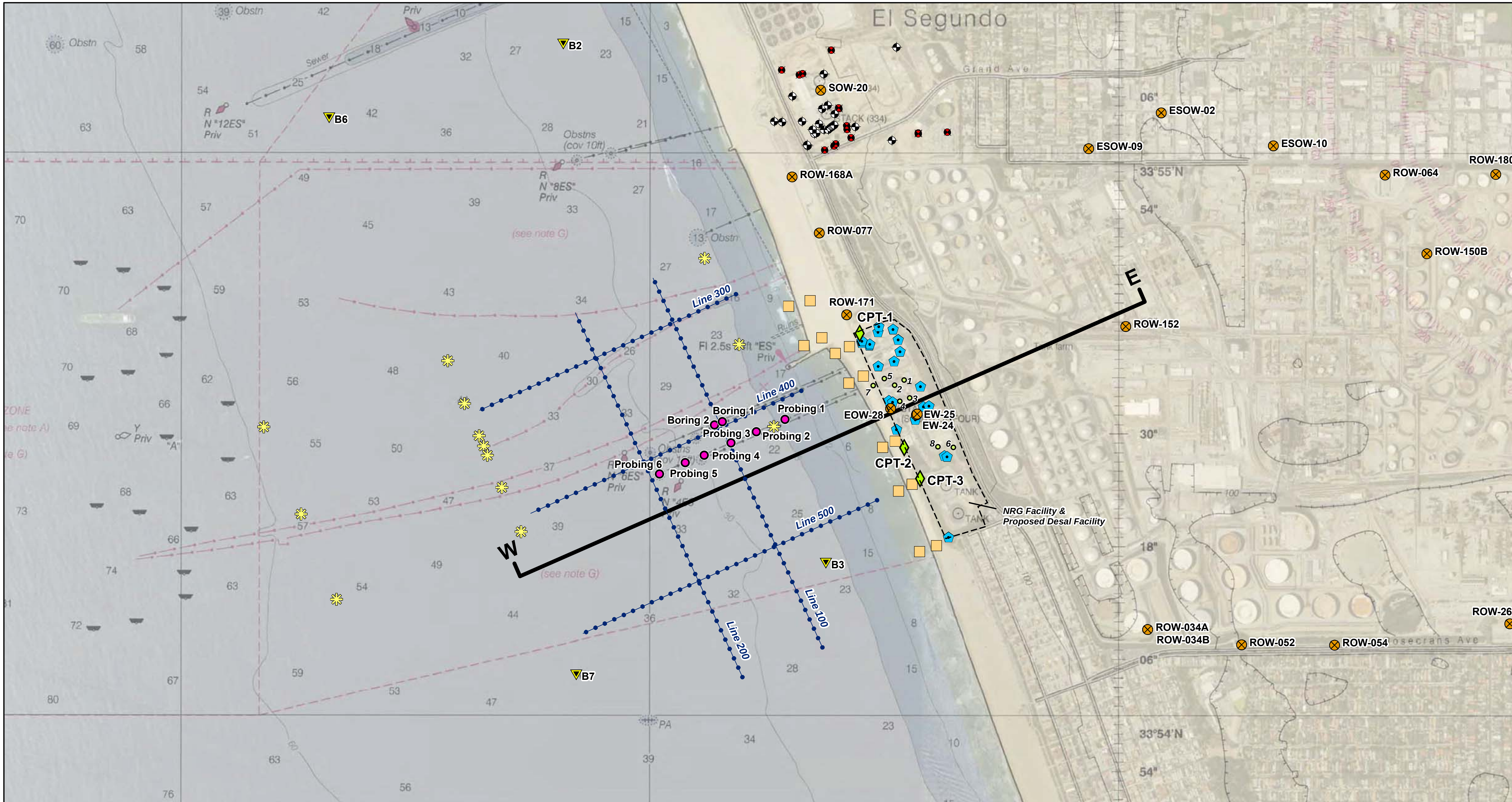

Legend

- Offshore Seafloor Sediment Sample Location *(State Lands EIR, Chevron El Segundo Refinery, 2010; Fugro West 2004, 2007.)*
- Beach and Surf-Zone Sand Sample (Geosyntec, 2016)
- CPT Location (Geosyntec, 2016)
- Seismic Reflection Lines (Geosyntec, 2016)
- **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

Sources:
* 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
Stratigraphy: California State Lands Commission, 2010
Topography and Bathymetry based on elevations included on maps and boring logs cited above, and detailed topography maps (e.g. Brinderson, 2006, Ninyo and Moore, 2007) and bathymetry map by NOAA (2008).

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Investigation Locations, El Segundo Vicinity

HDD Feasibility Evaluation
West Basin Municipal Water District

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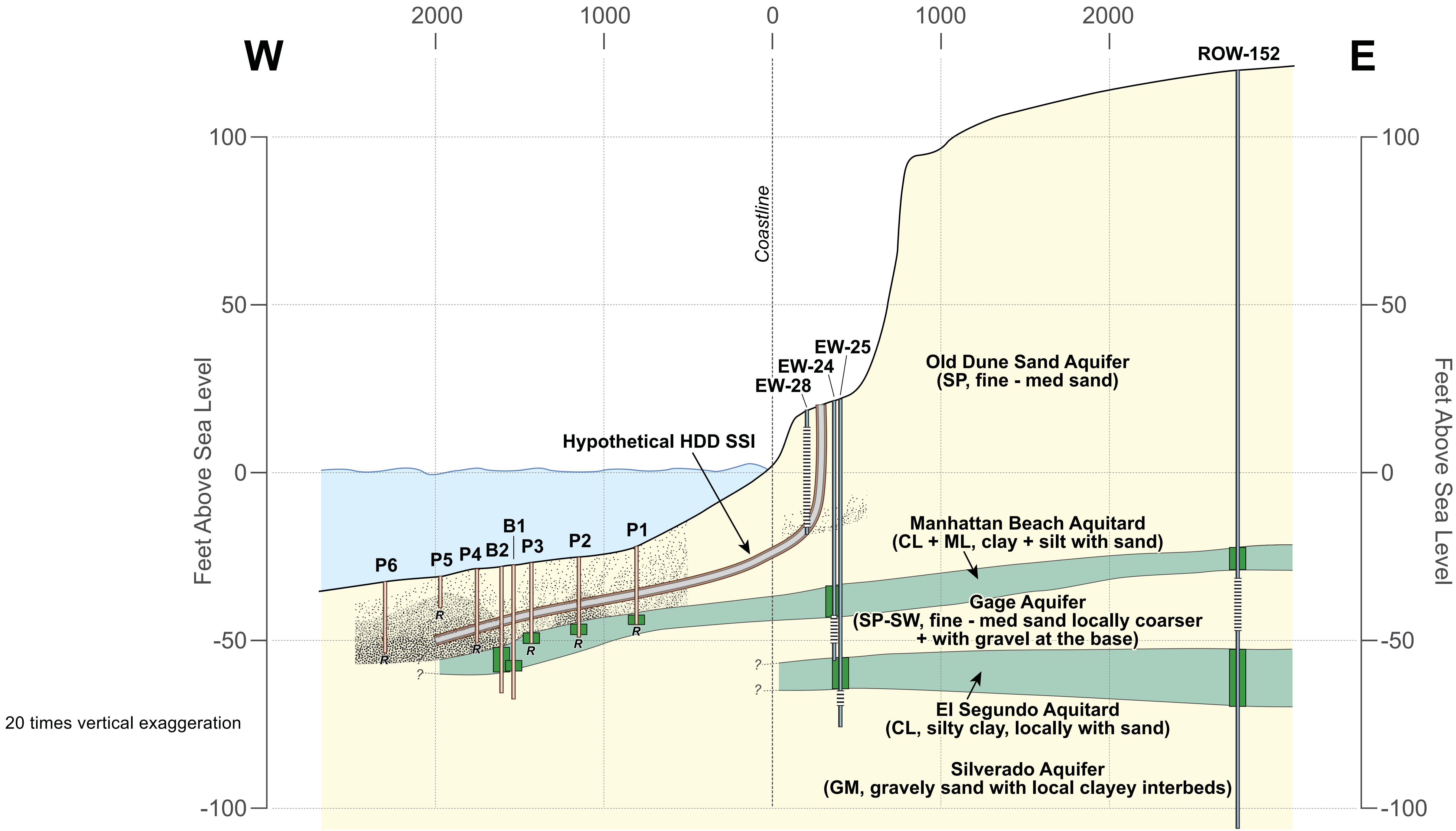
Figure 3



Legend

- Coarse Grained Material
- Fine Grained Material
- Gravel
- Cobbles

P2
- Soil Boring
- Soil Log Indicating Fine Grained Material
- *R* = Boring Refusal

EW-24
- Extraction Well
- Well Screen

Sources:
Offshore borings and probings: Dames and Moore, 1954 and 1962 in Appendix G of El Segundo Power, 2000
Onshore wells: Geotracker, Chevron El Segundo Refinery, Site # SL372482441
Stratigraphy: California State Lands Commission, 2010
Topography and Bathymetry based on elevations included on maps and boring logs cited above, and detailed topography maps (e.g. Brinderson, 2006, Ninyo and Moore, 2007) and bathymetry map by NOAA (2008).

Note:
Cross-section location shown on Figure H-2

Cross-Section,
El Segundo Vicinity

HDD Feasibility Evaluation
West Basin Municipal Water District

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Figure
4

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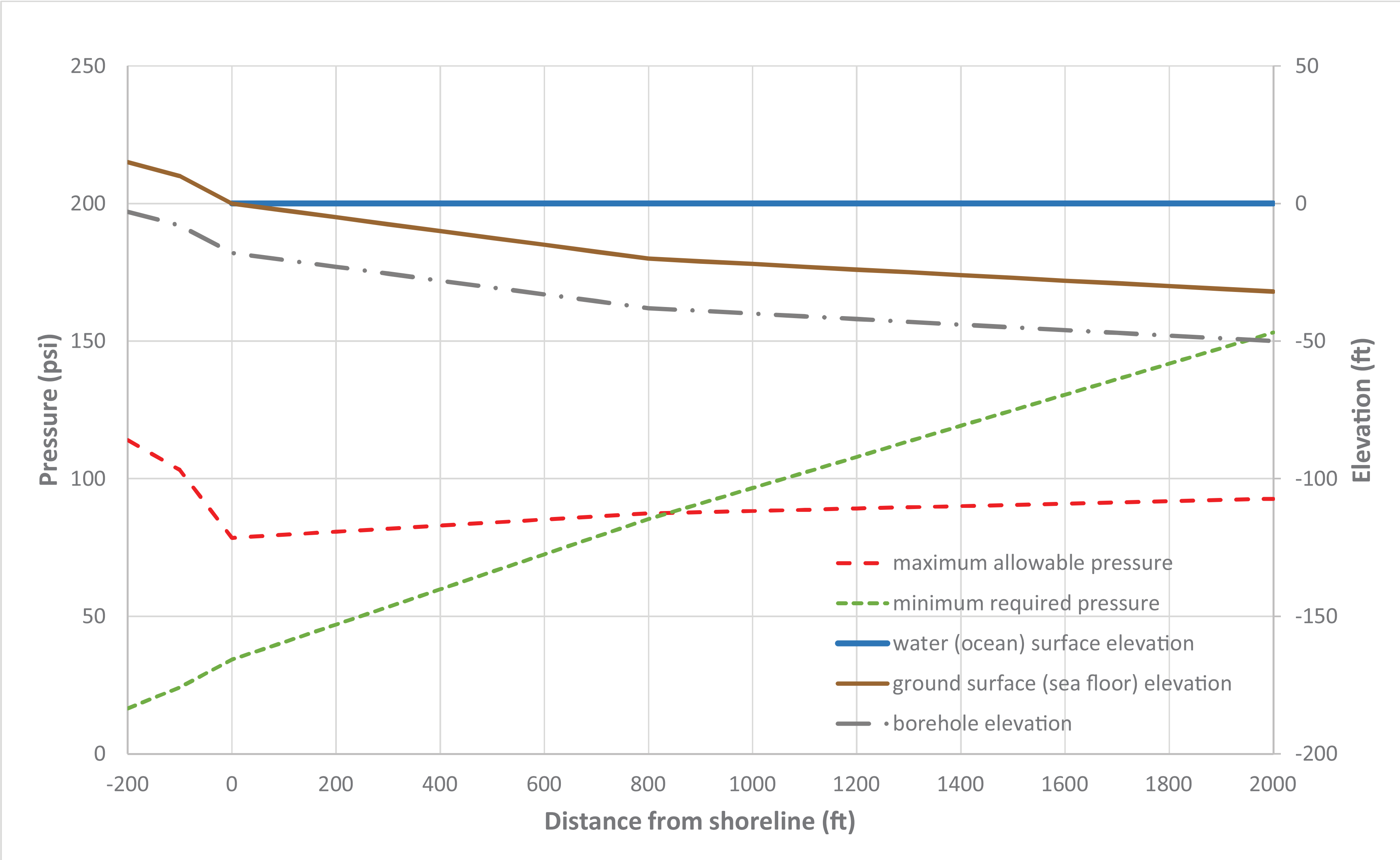

Parameter values:
8-inch-diameter pilot boring drilled with a 5-inch-diameter pipe. Depth of 18 feet below ground surface or seafloor.
Drilling mud: 9.5 lb/gal, viscosity = 14 centipoise, yield point 28 lb/100ft2, flow rate of 300 gpm.
Subsurface properties (loose sand): cohesion = 0, unit weight = 120 lbs/ft3, internal friction angle = 32 degrees, and shear modulus = 150,000 lbs/ft2
Weight of seawater: 64 lbs/ft3
As illustrated by the graph, the calculations indicate that the maximum allowable pressure would be exceeded by the drilling mud pressure beyond approximately 800 feet, and "hydrofracture" would likely occur resulting in leakage of drilling mud into the ocean and potential failure of the borehole.

Hydrofracture Risk Analysis for Shallow HDD

HDD Feasibility Evaluation
West Basin Municipal Water District

Geosyntec consultants

WR2596 | April 2019

Figure 5

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APPENDIX A

Location Map and Logs of Borings for the Geologic Cross Section

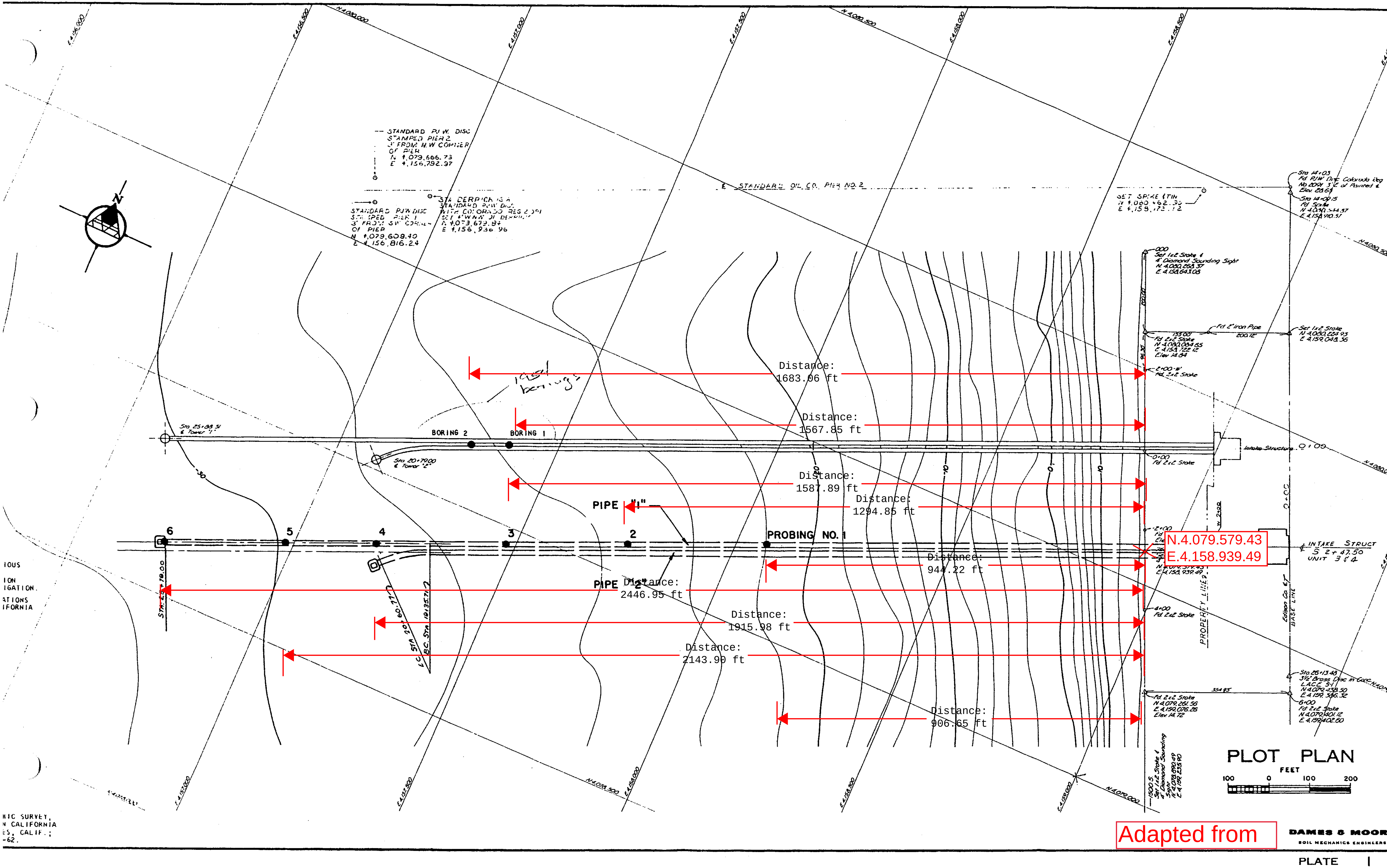
Sources:

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

Note:

The borings, for which logs are included in this appendix, are shown on the cross-section (Figure 3 of this report)


STANDARD P.I.W. DISC STAMPED PIER 2 3' FROM N.W CORNER OF PIER N 4,079,666.73 E 4,156,792.97
STANDARD P.I.W. DISC STAMPED PIER 1 3' FROM SW CORNER OF PIER N 4,079,609.40 E 4,156,816.24
STANDARD OIL CO. PIER NO. 2
BORING 2
BORING 1
PIPE "1"
PIPE "2"
PROBING NO. 1
6
5
4
3
2
Distance: 1683.06 ft
Distance: 1567.85 ft
Distance: 1587.89 ft
Distance: 1294.85 ft
Distance: 944.22 ft
Distance: 2446.95 ft
Distance: 1915.98 ft
Distance: 2143.90 ft
Distance: 906.65 ft
N.4.079.579.43
E.4.158.939.49
Intake Structure
INTAKE STRUCT
PROPERTY LINE
PLOT PLAN
FEET
100 0 100 200
Adapted from
DAMES & MOORE
SOIL MECHANICS ENGINEERS
PLATE 1

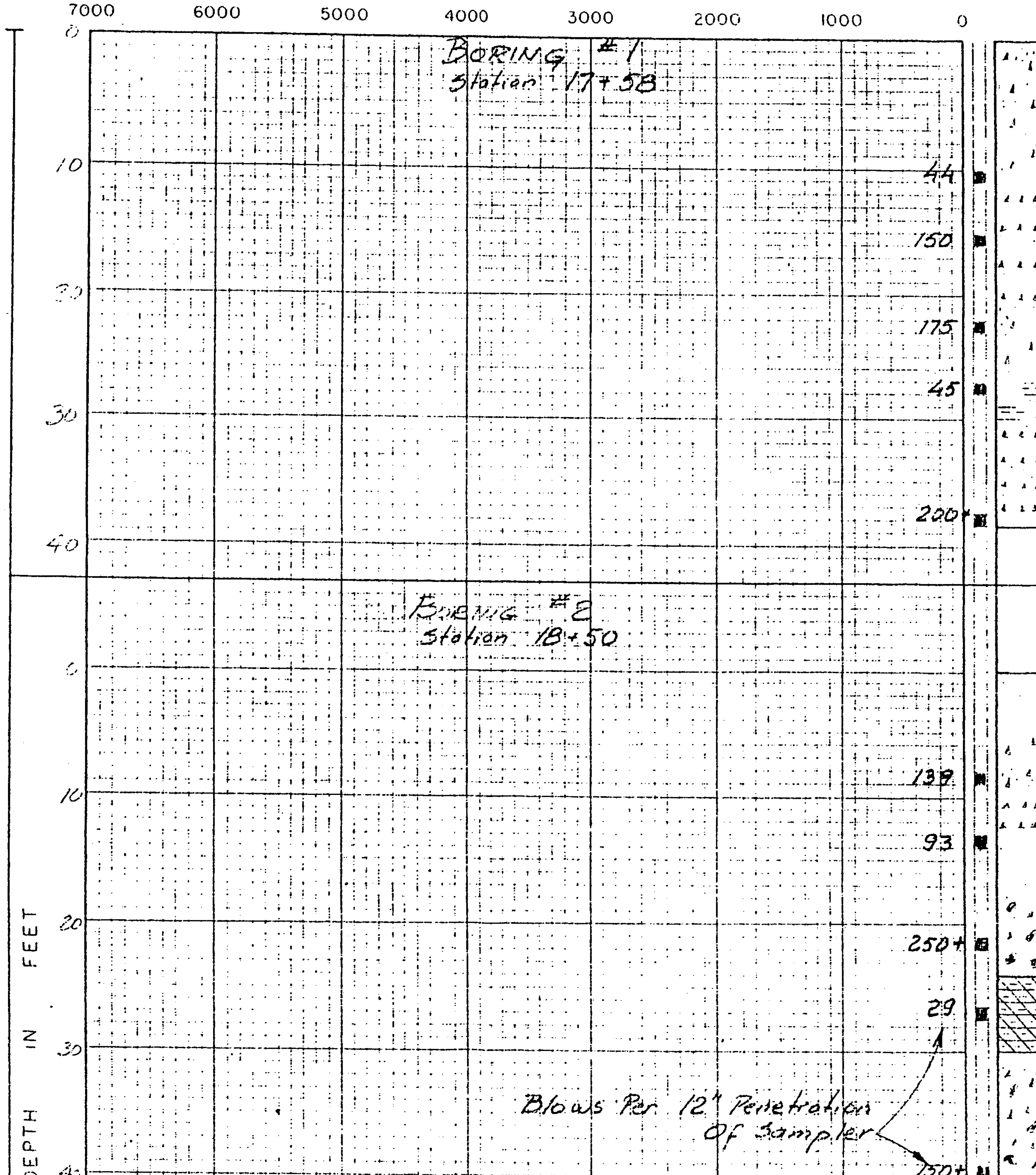
SHEET ____
OF ____ SHEET

LOG OF BORING 1#2

PLOTTED BY ____ DATE ____
CHECKED BY ____ DATE ____

JOB NUMBER 572-V
JOB NAME [illegible]

SHEARING STRENGTH AND FRICTIONAL RESISTANCE
IN POUNDS PER SQUARE FOOT



ELEVATION -27'

LIGHT BROWN [illegible] GRAVEL (SHELLS)

GRADING TO LIGHT [illegible] WITH [illegible] OF GRAVEL

GRADING TO GREY MEDIUM TO COARSE SAN[illegible]

LENSES OF BLUISH GREY SILTY [illegible]

GRADING [illegible] OF [illegible] 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

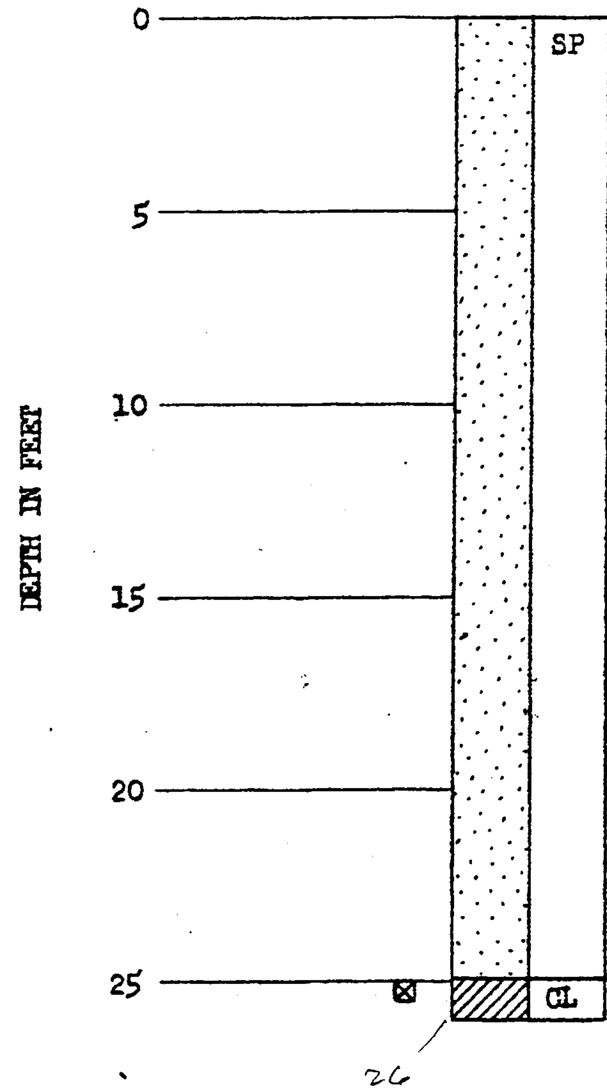
REVISIONS BY ______ DATE ______

FILE 377-027 Calif. Edison Co.

BY U.A.M. DATE 1-17-62 CHECKED BY ______

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:

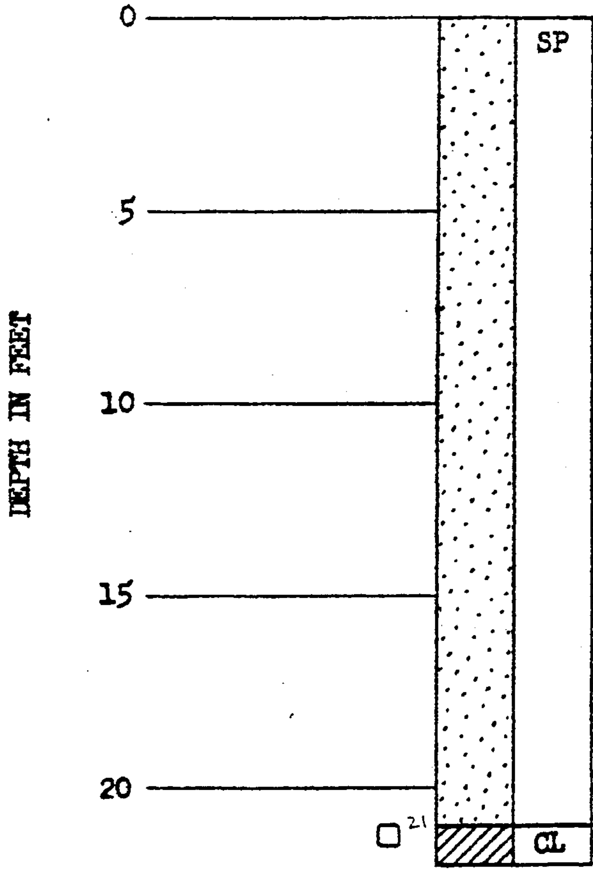
⊠ INDICATES DEPTH OF DISTURBED SAMPLE

☐ INDICATES DEPTH OF SAMPLING ATTEMPT WITH NO RECOVERY

ELEVATIONS REFER TO M.L.L.W. DATUM

DAMES & MOORE
APPLIED EARTH SCIENCES

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

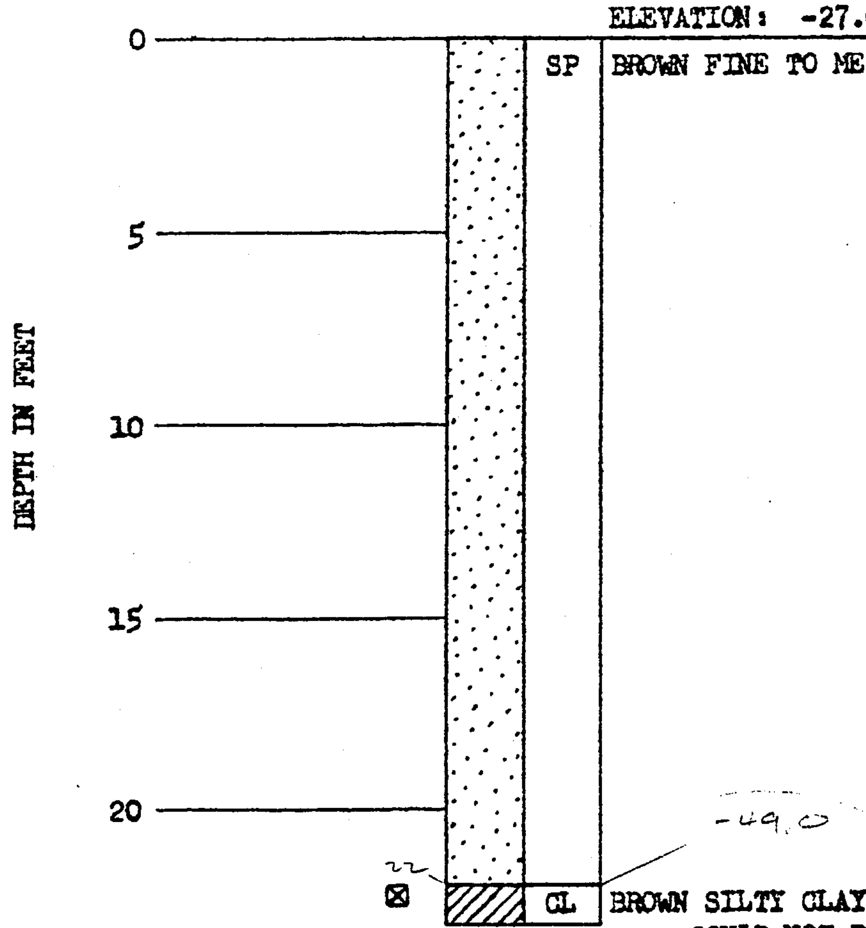
REVISIONS BY ______ DATE ______

FILE 377-027 Calif Edison Co.

BY D.A.M. DATE 7-17-62
CHECKED BY ______

PROBING NO. 3

ELEVATION: -27.0 FEET



SP BROWN FINE TO MEDIUM SAND WITH SOME GRAVEL

CL BROWN SILTY CLAY (FIRM)
COULD NOT PROBE BELOW 23'

BORING COMPLETED - 7/10/62

LOG OF PROBING

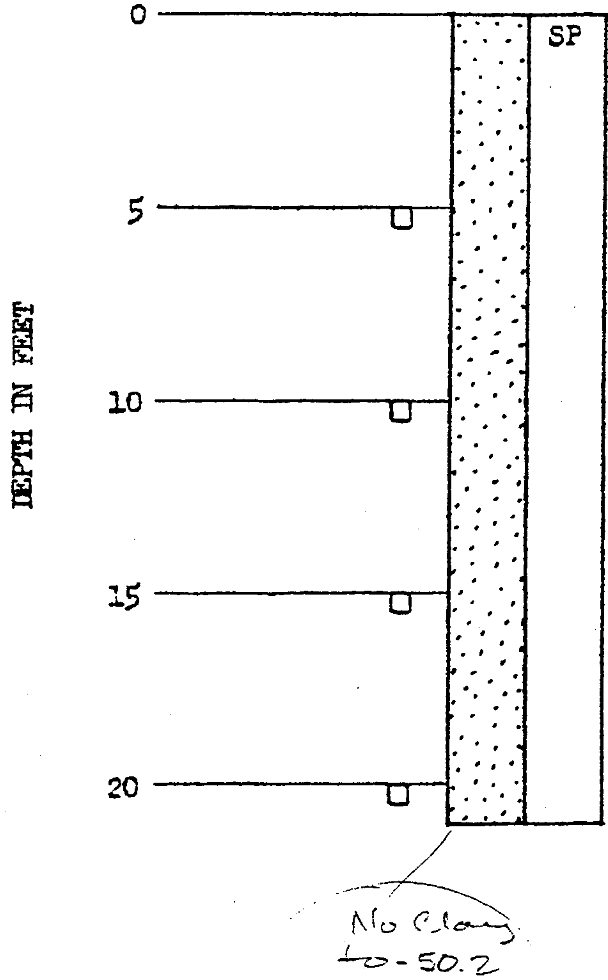
REVISIONS BY ______ DATE ______

FILE 377-027 Calif Edison Co.

BY D.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

L O G   O F   P R O B I N G

REVISIONS BY ______ DATE ______

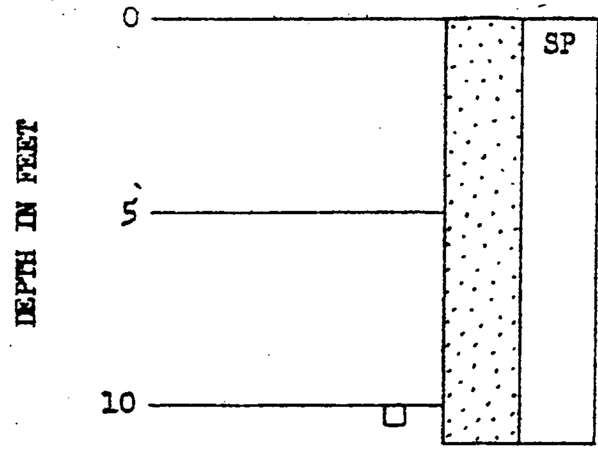
FILE 377-027 Calif Edison Co.

BY R.A.M. DATE 7-17-62

CHECKED BY ______

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

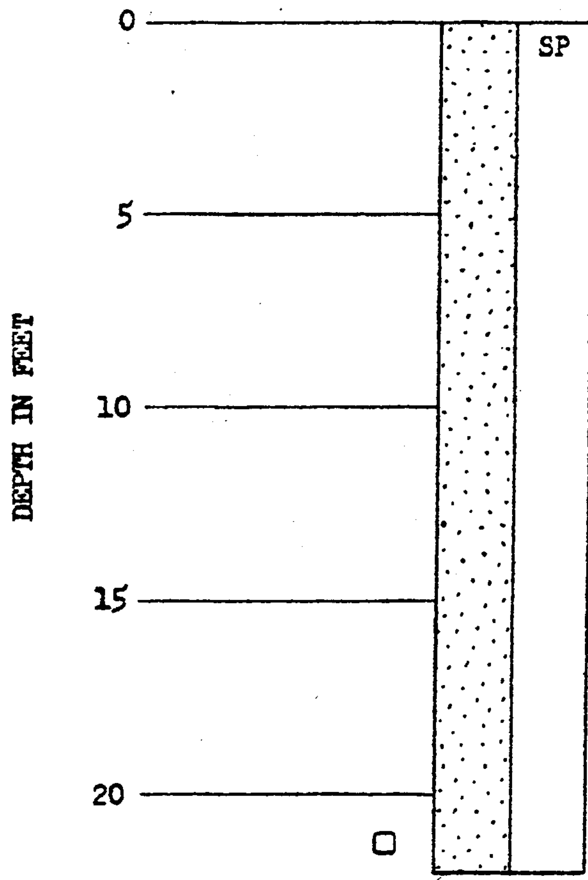
LARGE GRAVEL DROPPING TO BOTTOM OF PROBING AS SAND IS WASHED OUT BY JET

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

REVISIONS BY ______ DATE ______

CALIF. EDISON CO.

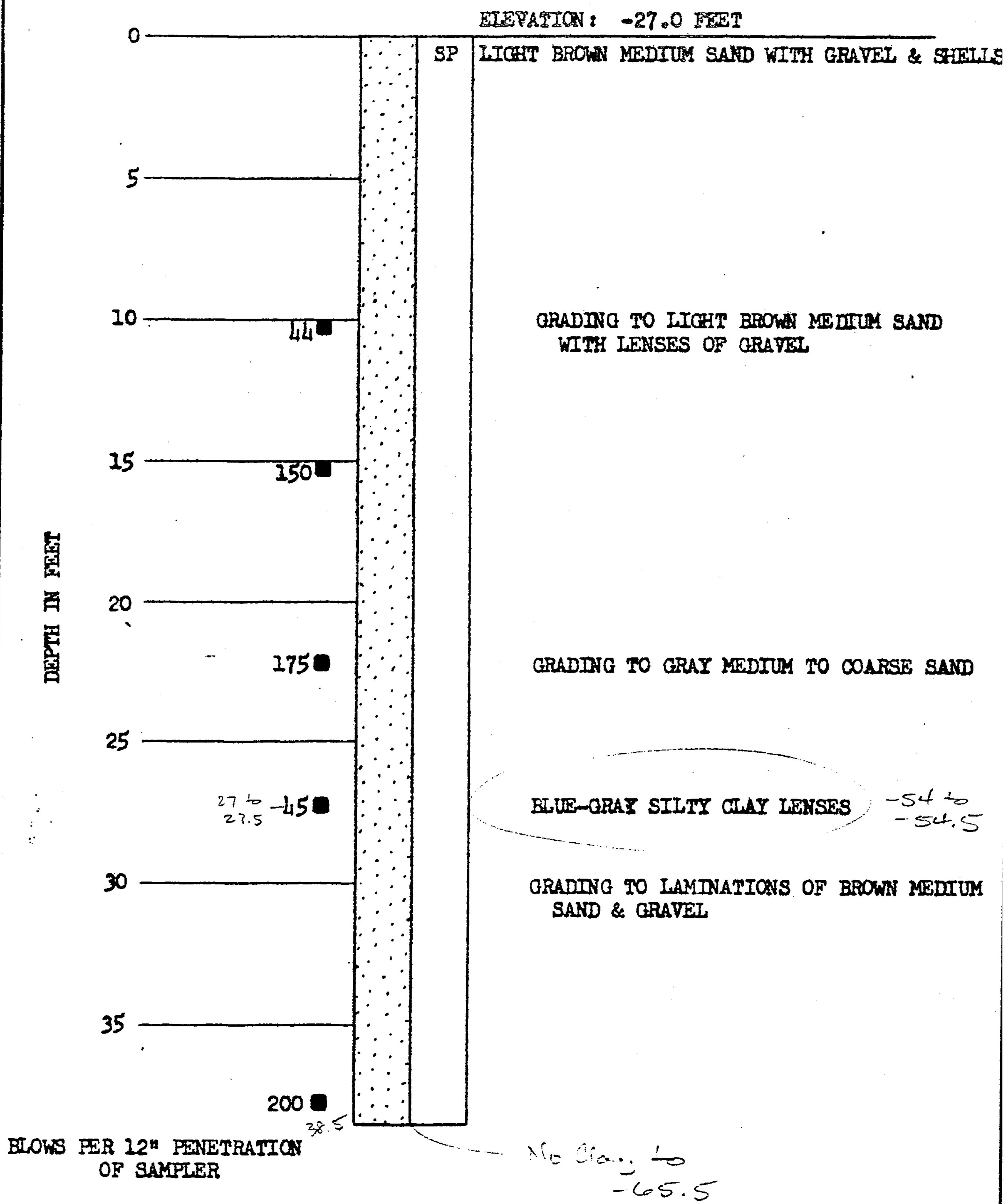
FILE 377-027

BY D.A.M. DATE 7-17-62

CHECKED BY ______

DAMES & MOORE
APPLIED EARTH SCIENCES

1954 BORING NO. 1



LOG OF BORING

DAMES & MOORE
APPLIED EARTH SCIENCES

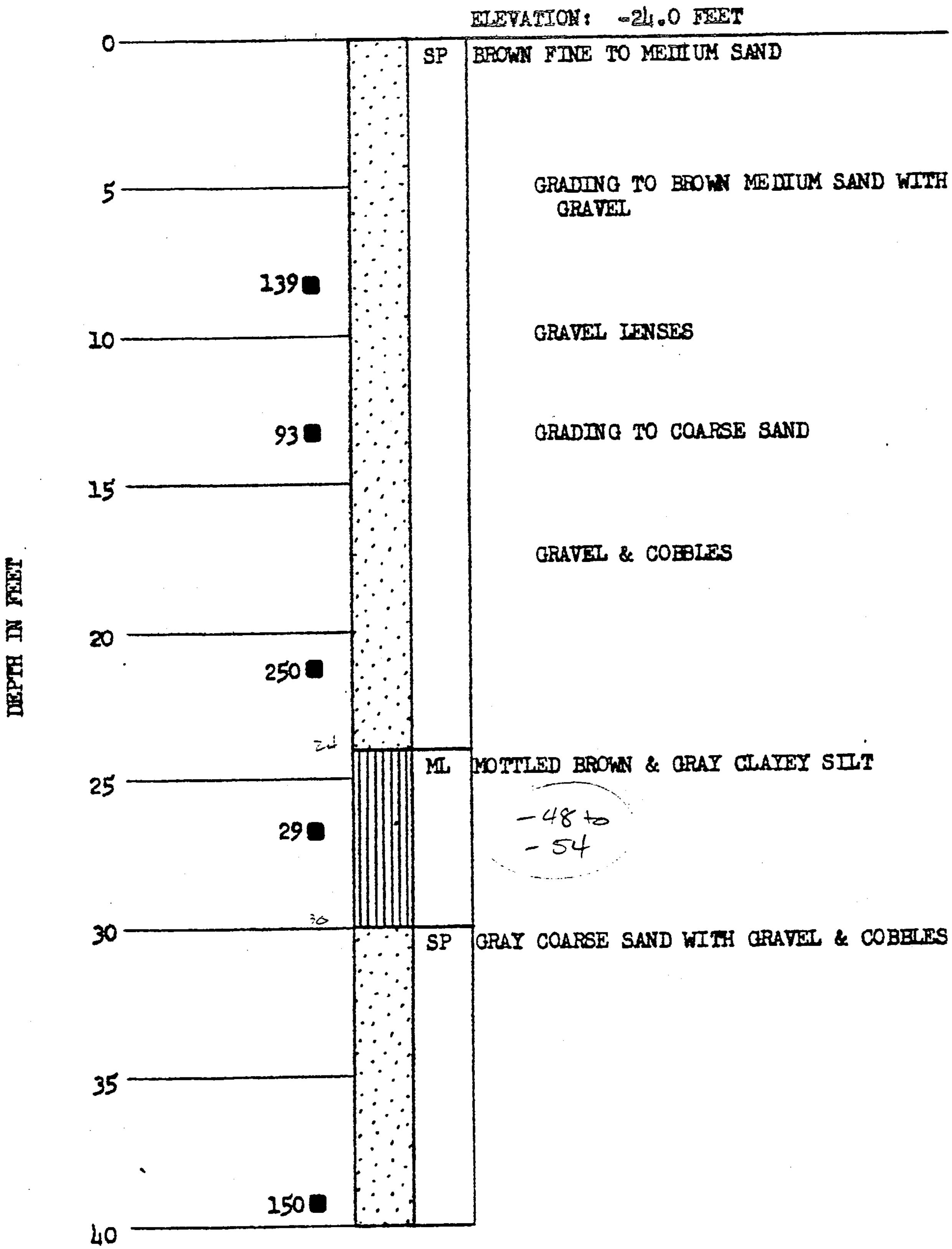
PLATE 3A

REVISIONS BY ______ DATE ______

FILE 2377-027 Calif Edison Co.

BY J.A.M. DATE 1-24-62 CHECKED BY ______

1954 BORING NO. 2



LOG OF BORING

REVISIONS BY ______ DATE ______

FILE 0377-027 Calif. Edison Co.

BY D.A.M. DATE 7-24-62

CHECKED BY ______

DAMES & MOORE
APPLIED EARTH SCIENCES

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, HELID CONDITIONER.

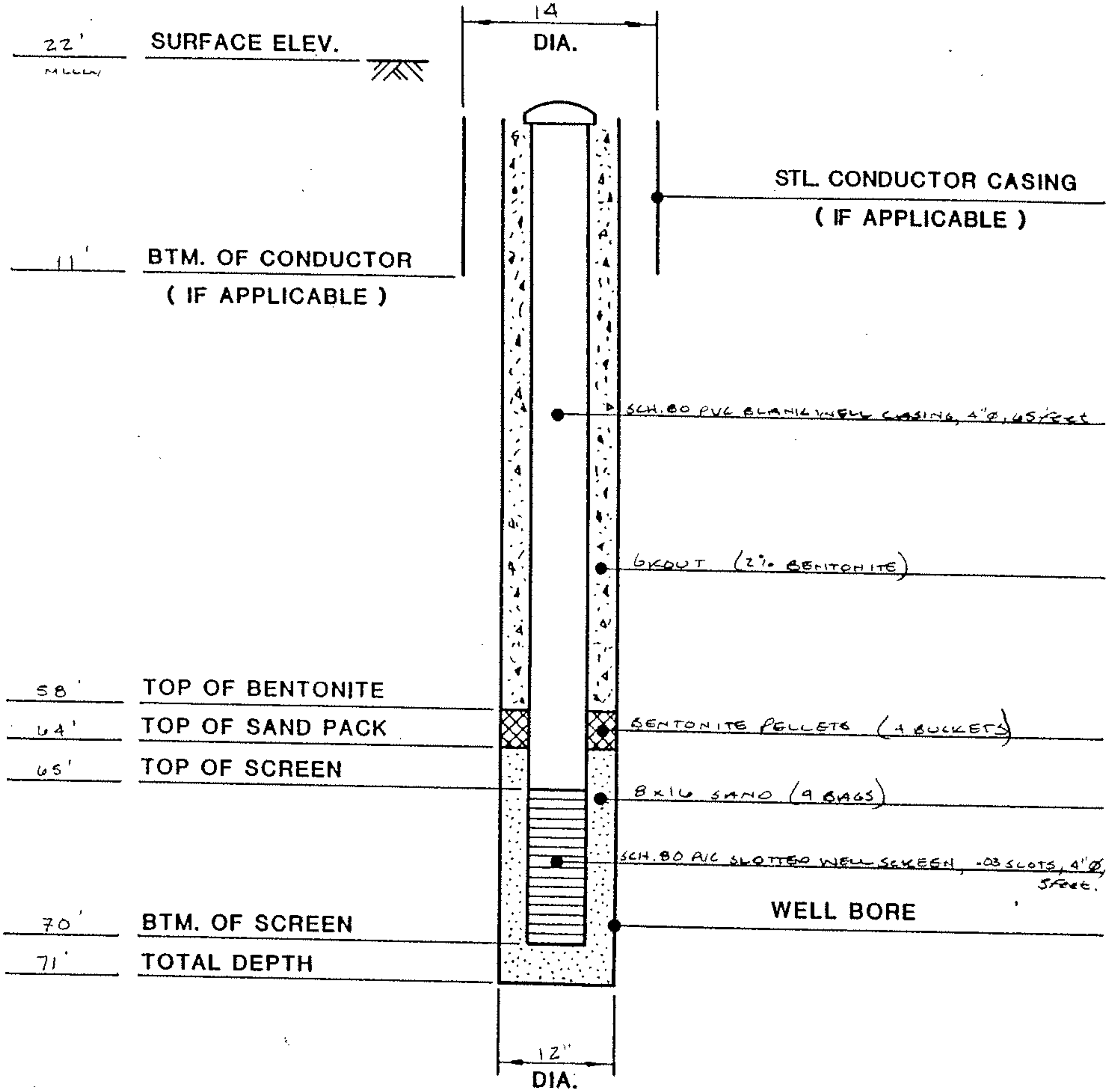
* PLEASE SUBMIT COMPLETED FORM(S) TO C.H.ETTER BY 7:00 AM THE DAY AFTER DRILLING ACTIVITY

che:wellstat

WELL NUMBER : EW-4

DRILLING METHOD : MUD ROTARY

DATE : 03/18/86



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: 03/18/86
Geologist: R. Graff
ty 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 obtained. Conductor pipe to 11 feet.
					2	
					3	
					4	
					5	
					6	
					7	
					8	
					9	
					10	
					11	Light brown, subrounded, medium sand with a trace well rounded coarse.
					12	
					13	
					14	
					15	
					16	
					17	
					18	
					19	Greyish brown, medium, subangular to subrounded. sand with shell fragments. 12 - 15% black (basaltic) rock fragments. HC visible in cuttings.
					20	
					21	
					22	
					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 well rounded fine gravel (5-10mm).
					33	
					34	
					35	
					36	
					37	
					38	
					39	[SM] Greyish brown, silty, fine sand with a trace medium. 12-18% muscovite.
					40	
					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 Number: 8210-EW
Well #: 24
Surface Elevation: 34.1[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	
					46	Grading to a trace rounded coarse.
					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 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 …NUE, LOS ANGELES, CA 90007, ROOM 604

…OUNTY OF LOS ANGELES DEPARTMENT OF HEAL… …RVICES

DATE: May 21, 1986

DESCRIPTION

TYPE OF PERMIT (CHECK)

- [x] NEW WELL CONSTRUCTION
- [ ] RECONSTRUCTION OR RENOVATION
- [ ] DESTRUCTION

TYPE OF WELL

- [ ] PRIVATE DOMESTIC
- [ ] PUBLIC DOMESTIC
- [ ] IRRIGATION
- [x] OBSERVATION/MONITORING
- [ ] CATHODIC
- [ ] INDUSTRIAL
- [ ] 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
-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)

- [x] 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 Secti…

WELL DRILLING STATUS

DATE: 03/20/86

WELL NUMBER Gd-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 PVC SLOTTED WELL SCREEN, .03 SLOTS, 4" Ø, 5 feet.

COMMENTS,PROBLEMS,ETC:

DRILLED MUD ROTARY, VARIFLOW MUD, HELD CONDITIONER.

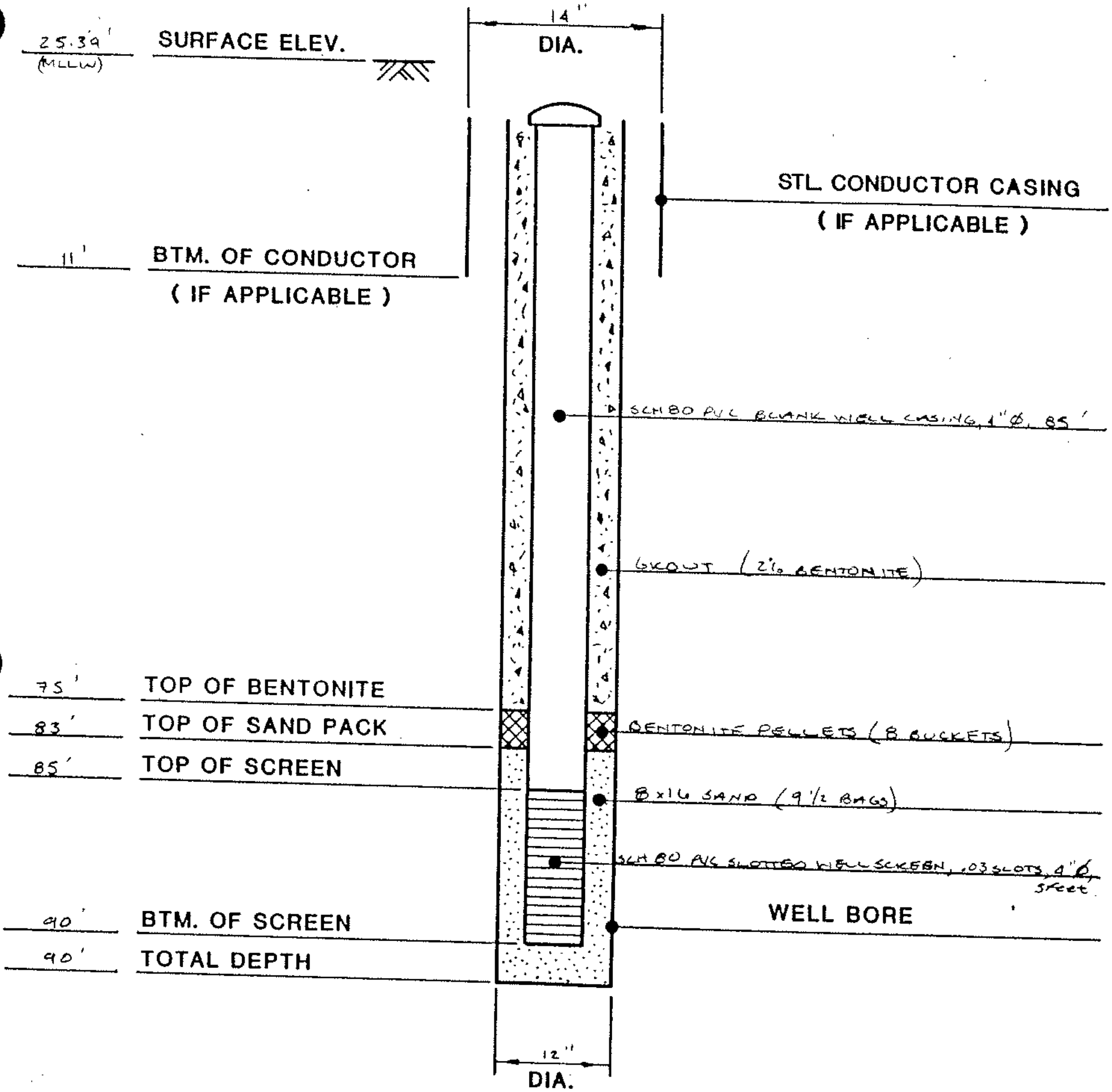
PLEASE SUBMIT COMPLETED FORM(S) TO C.H.ETTER BY 7:00 AM THE DAY AFTER DRILLING ACTIVITY

che:wellstat

WELL NUMBER : E1 -25

DATE : 03/20/86

DRILLING METHOD : MUD ROTARY



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-
					2	angular, medium sand with a trace well rounded
					3	coarse, shell fragments.
					4	Slight HC odor.
					5	Light brown, moist, subangular, fine to medium
					6	sand with shell fragments.
					7	
					8	
					9	
					10	
					11	Grading to some well rounded coarse.
					12	
					13	
					14	
					15	
					16	Greyish brown, medium, subangular to subrounded,
					17	sand with shell fragments.
					18	12-15% black(basaltic?) rock fragments.
					19	Slight HC odor, HC visible in cuttings.
					20	
					21	
					22	
					23	
					24	Grading to a fine to medium sand, lower % black
					25	rock fragments.
					26	
					27	
					28	
					29	
					30	[SW] [SP] grading to a fine to coarse with a trace well
					31	rounded fine gravel(5-10mm).
					32	
					33	
					34	
					35	
					36	
					37	
					38	[SM] Greyish brown, silty, subangular, very fine to
					39	fine sand with a trace medium, 12-18% muscovite.
					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	[GM] 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)

- [x] NEW WELL CONSTRUCTION
- RECONSTRUCTION OR RENOVATION
- [ ] DESTRUCTION

TYPE OF WELL

- [ ] PRIVATE DOMESTIC
- [ ] PUBLIC DOMESTIC
- [ ] IRRIGATION
- [x] 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
-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)

- [x] 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

WELL DRILLING STATUS

DATE: 4/8/86

WELL NUMBER EW-28

CASING & SCREEN TOTAL DEPTH 35'

HI PPM LEL 39% AT 30' (ft) WITH ________ (TLV,OVA,??)

LIQUID HYDROCARBON (Y/N) Y

NOTE: Please attach "as built" well diagram.

STATUS:

Well completed

Screened interval: 35'-5'

Blank interval: 5'-surface

Total Sand Used: 11 Bags

Total Bentonite used: 1-50 Lb bucket

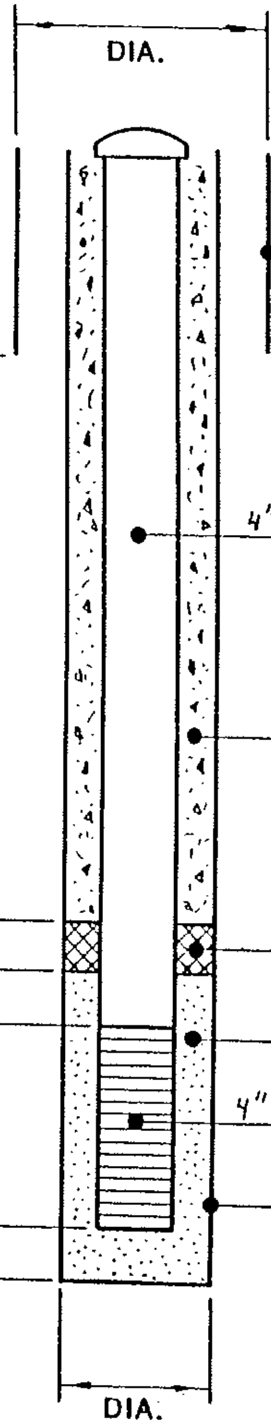
COMMENTS,PROBLEMS,ETC:

WELL NUMBER : EW-28

DATE : 4/8/86

DRILLING METHOD : Ho. , Stem Auger

≈19.5′	SURFACE ELEV.
NA	BTM. OF CONDUCTOR (IF APPLICABLE)
2.5′	TOP OF BENTONITE
4′	TOP OF SAND PACK
5′	TOP OF SCREEN
35′	BTM. OF SCREEN
36′	TOTAL DEPTH



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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: EL SEGUNDO REFINERY
Date Drilled: 04/08/86
Geologist: M. BYRNES
Safety Officer: M. TAYLOR
Driller: BEYLIK DRILLING

Job Number: 8210-EW
Well #: 28
Surface Elevation: 19.5
Total Depth: 36'
Depth To Fluid: 14.25'
Drilling Method: AUGER

% LEL	PPM Draeger	PPM OVA	Sample Depth	Sample Type	Feet	Visual Classification
					1	[SW] Light to medium gray sand, medium grained, moderately well sorted, trace pebbles and chert, subrounded grains, dry, no odor.
					2	
					3	
					4	
					5	
					6	
					7	Orange-brown sand, medium grained, moderately well sorted, trace chert, subrounded grains, moist, slight odor.
					8	
					9	
					10	
					11	
					12	[SP] Light to medium gray sand, medium grained, well sorted, trace chert, moist, strong odor.
					13	
					14	
					15	
					16	
					17	
					18	
					19	
					20	
					21	
					22	
					23	
					24	Medium to dark gray sand, medium grained, well sorted, trace of pebbles, chert, and shell fragments, saturated, strong odor.
					25	
					26	
					27	
					28	
					29	[SW] Medium to dark gray sand, medium grained, moderately well to poorly sorted, minor shell fragments and pebbles, trace chert, saturated, strong odor.
					30	
					31	
					32	
					33	
					34	[GW] Medium gray sandy gravel, poorly sorted, well rounded clasts, saturated, strong odor.
					35	
					36	

Client: Chevron
Job Location: El Segundo Refinery
Date Drilled: 04/01/85
Geologist: R. Graff
Safety Officer: R. Graff
Driller: Bevlik Drilling

Job Number: 8219-ROW
Well #: 152
Surface Elevation:
Total Depth: 225'
Depth To Fluid:
Drilling Method: Mud Rotary

% LEL	PPM (Draeger)	Blow Count	Sample Depth	Sample Type	Feet	Visual Classification
					2	[SP] Conductor to 11 feet, black- brown, medium, tar
					4	stained sand.
					6	
					8	Grey brown, subangular to subrounded, fine sand with
					10	with shell fragments.
					12	HC sheen on basin, slight HC odor.
					14	Grading to a trace silt.
					16	Occassional tar-sand stringer.
					18	
					20	Grading to grey.
					22	
					24	[SM] Grading to some silt.
					26	
					28	
					30	
					32	
					34	
					36	Tar-sand stringers.
					38	
					40	
					42	Wood fragments.
					44	
					46	Grading to a trace medium.
					48	
					50	
					52	
					54	
					56	
					58	Wood fragments.
					60	Grading to a greyish brown with some medium.
					62	
					64	Wood fragments.
					66	
					68	
					70	
					72	
					74	
					76	[SM] Grading to a grey, silty, subangular, fine sand
					78	with a trace medium and shell fragments.
					80	
					82	Wood fragments.
					84	

Log Continued on Next Page

Client: Chevron
Job Location: El Segundo Refinery
Date Drilled: 04/01/86
Geologist: R. Graff
Safety Officer: R. Graff
Driller: Beylik Drilling
:
:

Job Number: 8210-ROW
Well #: 152
Surface Elevation: 123.2
Total Depth: 225'
Depth To Fluid:
Drilling Method: Mud Rotary
:
:

% LEL	PPM Draeger	Blow Count	Sample Depth	Sample Type	Feet	Visual Classification
					86	
					88	
					90	
					92	
					94	
					96	
					98	
					100	[GM] Gravelly lense.
					102	
					104	[SM] Grey, silty, subangular, fine sand with a trace medium and shell fragments.
					106	
					108	
					110	
					112	
					114	Grading to a brown, silty, subangular, fine sand with a trace medium.
					116	
					118	
					120	
					122	
					124	
					126	
					128	
					130	Interbedded grey/brown silty sand layers.
					132	
					134	Wood fragments.
					136	
					138	FeO stained sand stringers.
					140	[ML] Grey, interbedded silty sand-silty sandy clay with FeO stained sand stringers.
				mB	142	
					144	
					146	[SP] Grey, angular to subangular, fine to medium sand with a trace coarse, trace silt.
					148	
					150	
					152	
				Bag	154	
					156	
					158	[SW] Grading to some coarse.
					160	
					162	
					164	[SW] Grading to a gravelly sand.
					166	
					168	

Log Continued on Next Page

Client: Chevron
Job Location: El Segundo Refinery
Date Drilled: 04/01/86
Geologist: R. Graff
Safety Officer: R. Graff
Driller: Beylik Drilling

Job Number: 8210-ROW
Well #: 152
Surface Elevation:
Total Depth: 225'
Depth To Fluid:
Drilling Method: Mud Rotary

% LEL	PPM Draeger	Blow Count	Sample Depth	Sample Type	Feet	Visual Classification
					170	
					172	[CL] Dark grey, silty clay grading grading to lesser
					174	amounts of silt, with shell fragments, wood fragments
					176	and lignite.
				ES	178	
					180	
					182	
					184	
					186	
					188	[GM] Grey, angular to subangular, gravelly, medium to
					190	coarse sand with a trace fine, trace silt.
				SW	192	
					194	
					196	
					198	[CL] Greenish-blueish grey clay stringer.
					200	[GM] Grey, angular to subangular, gravelly, medium to
					202	coarse sand wit a trace fine, trace silt.
					204	
					206	
					208	
					210	
					212	
					214	
					216	
					218	Interbedded clay stringers.
					220	
					222	
					224	
					226	Total depth - 225'

APPENDIX B

Input from HDD Experts on Feasibility of Shallow HDD Wells Beneath the Seafloor at El Segundo

Geosyntec consultants

Appendix B
Input from HDD Experts on Feasibility of Shallow HDD Wells Beneath the Seafloor at El Segundo

Supplemental Evaluation of Feasibility of Horizontal Directionally
Drilled Subsurface Intakes
Proposed Desalination Facility
El Segundo, California

Geosyntec contacted several HDD experts and requested their input on the feasibility of shallow HDD well installations beneath the seafloor at El Segundo. This Appendix lists the experts contacted and documents the information provided to the experts and their input.

LIST OF HDD EXPERTS CONTACTED

1. Maureen Carlin, PhD (thesis on large scale HDD projects)
   Laney Directional Drilling Co. www.LaneyDrilling.com
   Strategic Marketing Manager
   281-540-6615
   MCarlin@laneydrilling.com

2. Mark Havekost, PE
   Principal Engineer
   McMillen Jacobs Associates https://mcmjac.com/
   1500 SW First Avenue, Suite 750 | Portland, OR 97201
   503.384.2909
   havekost@mcmjac.com

3. Brian Ittig (manager of an oceanography research program with instrumentation on sea floor. Used HDD for 5000 ft conduits for fiber optic cable at Pacific City, OR).
   https://interactiveoceans.washington.edu/story/Horizontal_Directional_Drilling_Begins
   bittig@u.washington.eu
   Sent email to Brian Ittig—no response.

4. Jeremy King
   The HDD Company http://www.crossinggroup.com/the-hdd-company/
   Suite 210, 4525 Serrano Parkway
   El Dorado Hills, CA 95762
   530 676 5705
   JKing@crossinggroup.com

Geosyntec consultants

5. Anthony Jones
   President Intake Works www.intakeworks.com
   (licensed provider of Neodren® from Catalana de Peforacions in Spain
   Sacramento CA
   916 990 3699

6. Michael D. Lubrecht L.G.
   Senior Geologist
   Directed Technologies Drilling, Inc. www.horizontaldrill.com
   3476-B W. Belfair Valley Rd.
   Bremerton, WA 98312
   800-239-5950
   mike@horizontaldrill.com

7. Tan Qiang, PhD
   (publication: Leak-Off Mechanism and Pressure Prediction for Shallow Sediments in Deepwater Drilling)
   State Key Laboratory of Petroleum Resources and Prospecting
   China University of Petroleum-Beijing
   Beijing 102249, China
   tanqiang_cup@126.com
   Sent email. No reply.

8. Ali Rostami (did PhD thesis and several publications on HDD technology with emphasis on estimating the maximum allowable pressure of the drilling fluid during HDD operation in non-cohesive soil.).
   Horizon Engineering http://www.horizoneng.ca/wordpress/
   604-990-0546
   Vancouver BC, Canada
   contactoffice@horizoneng.ca
   Sent email to Ali Rotami c/o Horizon Engineering contact office. No reply.

9. Jeff Scholl, P.E. engineering manager for J.D. Hair & Associates Inc.
   J. D. Hair & Associates, Inc. http://jdhair.com/
   2424 East 21st Street, Ste 510
   Tulsa, OK 74114-1723
   918-747-9945
   info@jdhair.com

Geosyntec consultants

INFORMATION PROVIDED TO THE HDD EXPERTS

The following description of conditions, hypothetical approach and request for input was sent to the experts:

> *We're working on evaluating feasibility of subsurface seawater intakes using HDD at a depth of less than 20 ft below the seafloor. The subsurface is dominantly loose sand, but generally with increasing amounts of gravel and cobbles to a depth of ~20 ft below the seafloor down to a clay layer. The intakes pipes would need to be above the clay layer.*
>
> *A conceptual design calls for several 500 mm (~20 in) outer diameter micro-porous filter pipes installed to a distance of 1500 to 2000 ft offshore. The maximum depth of the ocean would be 30 or 40 feet. The possibility has been suggested that the HDD installations could be done with no exit from the sea floor-- as opposed to pulling them back into a boring that would exit the seafloor.*
>
> *Based on my review of literature on HDD, I'm concerned that the locally abundant gravel and cobbles at the target depth could be a problem.*
>
> *Also, we are concerned that at the shallow depth, adequate drilling fluid pressure may not be possible to maintain circulation and facilitate insertion of the pipe without breakouts of the drilling fluid on the seafloor.*
>
> *And please let me know if you are aware of any seafloor HDD installations without an exit point on the seafloor.*
>
> *We'd welcome input from you and your colleagues.*

INPUT FROM THE HDD EXPERTS

Input from HDD experts follows:

1. Maureen Carlin, PhD (thesis on large scale HDD projects)
   Laney Directional Drilling Co. www.LaneyDrilling.com
   Strategic Marketing Manager
   Office: 281-540-6615
   MCarlin@laneydrilling.com

   Corresponded by email 1/3 and 1/4/2019. She advocates the Direct Pipe® method as more appropriate than standard HDD in the setting.

email input from Maureen Carlin 1/4/2019:

This project sounds very similar to some of the desalination projects that Laney is currently looking at. At a very high level, we believe this would be feasible in the near future as a Direct Pipe® application in lieu of an HDD application. I am not sure if you are familiar with Direct Pipe® but it is basically a modified micro-tunneling technique developed by Herrenknecht AG (HK) out of Germany. Unlike HDD, it is a single pass process that uses a steerable tunnel boring machine-cutting head in combination with a thrusting unit. The technology tunnels and pushes the pipe into place at the same time, filling the void as it progresses. There have been approximately 110 installations to date and we have completed 11 in the US.

For the existing Direct Pipe® application, some minor modifications would be required that we are currently in discussion with HK. In a nutshell, the Direct Pipe® system could install 2,000'+ of ~ 42"-48" steel casing via a MTBM (Micro- Tunneling Boring Machine) with a retractable head that would remain below the sea floor and would have zero to minimal risk of IR's. Once the initial Direct Pipe® installation of the steel casing is completed, all of the Direct Pipe® umbilicals, pumps and the tunneling head are retracted back through the interior of the installed casing. Once they are fully retracted, we would then push/thrust a ~36" diameter micro-porous filter pipe through the installed casing out ~ 2000+LF. Once the micro-porous filter pipe is inserted, we would then retract the external 42" casing via the same thrusting mechanism but in reverse. The final outcome is ~ 2000 LF of 36" diameter micro-porous filter pipe that would significantly increases the overall productivity and throughput of the desalination system.

With regards to your specific concerns please see the following:

(1) Based on my review of literature on HDD, I'm concerned that the locally abundant gravel and cobbles at the target depth could be a problem.

We would need to see the actual geotechnical information available, however, one of the most significant advantages of Direct Pipe® over HDD is the ability to navigate through gravel and cobbles up to approximately 1/3 the diameter of the installation. Thus, this would not present a significant challenge as long as the soil conditions were within that range.

(2) Also, I'm concerned that at the shallow depth, adequate drilling fluid pressure may not be possible to maintain circulation and facilitate insertion of the pipe without breakouts of the drilling fluid on the seafloor.

Geosyntec consultants

Direct Pipe® has the unique and significant benefit of drastically reducing the risk of inadvertent returns due to the fact that Direct Pipe® produces significantly lower annular pressure acting on the surrounding subsurface formation as compared to HDD. With that said, the geometry of a Direct Pipe® installation can be much shallower than HDD (<20') with lower potentials for inadvertent returns.

G. Thrupp reply by email 1/4/2019:

Are there any examples where the Direct Pipe® application has been used in shallow sediments under the seafloor?
Based on your statement that this would be feasible in the near future, I'm assuming the single entry (blind completion) technology is still being developed.

Although at this stage, I am more interested evaluation of feasibility (constructability), it would also be helpful to have rough range of cost—maybe for other examples. The project would likely require several—say 5 to 10, subsurface intakes to achieve the design inflow of 40 mgd.

M. Carlin reply by email 1/8/2019:

Specific to Direct Pipe® no, however, it is really just gaining strength for shore approaches. Large diameter Microtunneling has been used for this application in at least 2 projects I am aware of. A very rough range of cost would be approximately $2,500-$3,000 per foot for a 2,000' shore approach in soft soil conditions.

Notes from GT phone conversation w MC 1/8/2019:

HDD and Direct Pipe® methods have been used beneath the seafloor—but with exit from the seafloor. MC is not aware of Direct Pipe® installations is within upper 20 feet of the seafloor.

The Direct Pipe® technology is still being developed for potential SSIs for desal—likely will be possible in future.

2. Mark Havekost, PE
   Principal Engineer
   McMillen Jacobs Associates https://mcmjac.com/
   1500 SW First Avenue, Suite 750 | Portland, OR 97201
   503.384.2909
   havekost@mcmjac.com

G. Thrupp notes from phone call with M. Havekost 1/4/2019:

If casing is advanced then could work, but lots of friction so requires large thruster.
A key risk is being able to pull the casing and keep the intake pipe in place.
Direct Pipe® method better for retracting because it uses an over-cutting reamer, but still big risk. HDD pack-pull is a bigger risk.
Need pipe thruster or hammer to pull back—can be a problem.
Need smooth coating system—flush joints… flat as possible.
Imperative to do pull-back load calcs. Million-pound rig likely needed.
Need to assume some failed bores.
How do you keep the inside pipe in place?

4. Jeremy King
   The HDD Company http://www.crossinggroup.com/the-hdd-company/
   Suite 210, 4525 Serrano Parkway
   El Dorado Hills, CA 95762
   530 676 5705
   JKing@crossinggroup.com

1/3/2019 email reply by Jeremy King:

We received your inquiry regarding installing sub surface intakes via HDD and we would be happy to discuss your project with you. Below is my contact information and I have also included a link to an animation that shows our installation process for the Micro-porous HDPE pipe. Look forward to hearing from you.

https://thvc-my.sharepoint.com/:v:/g/personal/jking_crossinggroup_com/EeHWoYd0DhhLv1vNf5vH7QsBYVLrkJI1VzHNnVAAC7zawg?e=Ticedv

GT: The link to the video is also available on the crossing group website. The video is a schematic rendering of an SSI installation using HDD without exiting the seafloor: 10-in pilot boring. Reaming and installation of casing. Installation of micro porous pipe inside the casing. Removal of the casing.

Notes from G. Thrupp phone call with J. King 1/8/19

They have not installed any Neodren® intakes. A test Neodren® HDD well was planned in Camp Pendleton, San Diego area, but never done.

Geosyntec consultants

Normally when exiting, they plug the borehole to maintain drilling mud circulation from the entry pit.

An outfall was installed using HDD in Delaware: 3800 ft, 30 casing was pushed in 2000 ft. Then 24-inch HDPE outfall pipe was pulled back.

For single entry a vibratory system would be used to aid in casing extraction. Water would be injected at pressure to clean drilling mud from porous pipe.

Prefer to be install HDD deeper than 20 ft to lessen fluid loss. Smaller pipe then 20 in might be more suitable for gravel and cobbles.

The Crossinggroup also does Direct Pipe® installation—almost double the cost of HDD. Smallest size is quite a bit larger than 20 in. Requires steel casing. Jeremy knows of no method to remove drill head assembly to facilitate single entry completion with Direct Pipe®.

5. Anthony Jones
   President Intake Works www.intakeworks.com
   (licensed provider of Neodren® from Catalana de Peforacions in Spain
   Sacramento CA
   916 990 3699

   G.Thrupp notes from phone call with Tony Jones Friday 1/11/2019.

   Tony indicated that there is no precedence for HDD SSIs in a similar setting, but that with technology advancements it should be possible. Exiting the seafloor would typically be required during the drilling and installation, and technology exists to minimize discharge of drilling mud at the exit point. Also, in sensitive settings, special drilling muds are used that are relatively environmentally benign. He is aware of offshore utilities installed in shallow HDD borings. Not sure if HDD SSIs are feasible offshore in unconsolidated sand at depths less than 20 feet but recommends a pilot test. Tony also indicated that technology is being developed for on-site manufacture micro-porous pipe for SSIs, which can be a major benefit for remote settings and sites with access limitations.

6. Michael D. Lubrecht L.G.
   Senior Geologist
   Directed Technologies Drilling, Inc. www.horizontaldrill.com
   3476-B W. Belfair Valley Rd.
   Bremerton, WA 98312

800-239-5950
mike@horizontaldrill.com

Mike Lubrecht called and emailed 1/3/2019. Believes HDD not feasible at the required shallow depth.

email input from Mike Lubrecht 1/3/2019:

I enjoyed our conversation this morning about directional drilling under the seafloor to install desal plant intakes. As we discussed, the primary concern for the proposed approach is likely to be the relatively high risk of release of drilling mud to the ocean, through the relatively thin cover over the bore. As a general rule of thumb, we like about a foot of cover for each inch of bore diameter. To install a 20" pipe will require a 30" bore, so at a minimum, 30' of cover would be much better than 20 – although that rule of thumb is based on land-based operations, and the confining pressure/hydrostatic head of the overlying ocean at about 2.5 ATA would also help contain the mud.

We discussed single (blind) vs. double-ended completions. I think a blind completion of pipe with that diameter, in a bore that is likely to have gravelly/cobbly zones, might be problematic. If too much caving occurs, it is not inconceivable that the pipe could deflect, leave the bore, and break through the seafloor, if very careful monitoring is not done. Exiting on the seafloor has its own set of challenges, but has been done successfully for years. As we discussed, the use of biodegradable, environmental friendly drilling fluid may be a factor in improving the feasibility of such an operation from the standpoint of environmental protection.

9. Jeff Scholl, P.E. engineering manager for J.D. Hair & Associates Inc.
   J. D. Hair & Associates, Inc.
   2424 East 21st Street, Ste 510
   Tulsa, OK 74114-1723
   918-747-9945
   http://jdhair.com/
   info@jdhair.com

G.Thrupp notes from phone call with Jeff Scholl Monday 1/7/2019.

He says < 20 ft depth is too shallow—"would certainly frac-out". He is unaware of any single-entry HDD projects. He says exits from the sea floor are done but will result in discharge of drilling fluid to the water. He says the "Direct Pipe® method" would be more appropriate, but very expensive.

Appendix 13C
HDD Constructability

ESA

Memorandum

June 11, 2019

To:	Zita Yu, PhD, PE – West Basin Municipal Water District	Ref. No.:	11187218
From:	Craig Camp; Mark Donovan, PE	Tel:	949-585-5251
CC:			

Subject: Challenges and Risks Associated with Subsurface Intake Construction via HDD

1. Introduction

GHD has reviewed the "DRAFT ADDITIONAL EVALUATION OF FEASIBILITY OF HORIZONTAL DIRECTIONALLY DRILLED SUBSURFACE INTAKES" for the proposed West Basin Desalination Project, prepared by Geosyntec including appendices A and B dated 16 April 2019, and has prepared additional technical information on this subject.

This memo also includes a Risk Matrix on some of the major risks associated with the Horizontal Directionally Drilled (HDD) method for this project.

2. Technical Investigation

The above mentioned Report by Geosyntec accurately characterizes the challenges associated with the HDD wells (sometimes called drains) for this project located in El Segundo, CA.

This memo provides more detailed information on the specific challenges, and subsequent risks, of HDD construction methodology for water intake wells. Where suitable, potential mitigation measures or alternatives are put forth.

Water intake wells differ from outfalls, surface intakes, and undercrossings of rivers or other surface obstructions, in that they withdraw fluids using the native soils as filter medium and typically, as in this case, require the use of blind drilling (i.e. no exit of the HDD). Specific challenges associated with HDD blind drilling construction in cobble-laden formations include:

1. The use of viscous bentonite mud
2. Deflection of the drill string,
3. Drilling of a blind hole, and

2.1 Use of Viscous Bentonite Mud

Description

Viscous bentonite mud (drilling mud with a measured viscosity ranging from 80 seconds to over 120 seconds as measured using a marsh funnel; for reference water has a viscosity of 26 seconds) is required as a drilling fluid for drilling course-grained soils as encountered on this Project. The NSF/EPA approved drilling mud is necessary to stabilize the borehole (by filling void space in the soil), facilitate the removal of excavated material (or soil cuttings), and generally extend the drill tool life cycle. Drilling mud is mixed on the surface, pumped through the drill rod, and injected at the cutting tool. The required injection pressure increases with depth and as the length of the hole increases.

Risks

There are several risks associated with the use of drilling mud for this Project, the most serious one being an inadvertent return, or **"frac-out" of the drilling mud into the ocean**. This would occur if the required injection pressure increases to a point where the surrounding formation is not able to contain the drilling mud, and following the path of least resistance, flows through the formation and into the seawater. The technical analysis in section 3.3.1 in the previously referenced Geosyntec report confirms the assertion that under the project conditions, the surrounding formation is not able to contain the drilling mud, and a frac-out would occur.

Another significant risk associated with the drilling mud are related to **well clogging and long term, stable capacity**. Drilling mud properties can cause issues in well production due to its ability to fill the formational voids, thus inhibiting soil permeability and water infiltration.

Potential Mitigation

A potential mitigation measure to lessen the likelihood of an inadvertent release of drilling mud into the ocean, and to reduce clogging, may be to use a commercially available, NSF/EPA approved biological based specialty fluid that breaks down the drilling mud with the use of enzymes to restore the voids and prevent drill fluid migration to the ocean. This method requires sufficient time for the enzyme to break down the drilling fluid, followed by limited flushing to restore native ground permeability.

However, even with the use of such a product, the limited 20 feet of cover may still not be enough to prevent a frac-out. While the enzyme solution itself is not toxic, if released into the ocean, it would likely create a high turbidity plume, flocculate, and settle onto the ocean floor, potentially impacting benthic organisms.

2.2 Deflection of the Drill String

Description

Deflection of the drill string will occur in cobble-laden ground. Cobble and boulders deflect the pilot bore from its intended path, even with the careful application and monitoring of a guidance system by the operator Once the guidance system detects deflection, the HDD operator must retract the drill string approximately 20 feet, re-orient the drill head to counter the deflection, and re-drill the hole. The retraction of the drill string may require the removal of several drill rods before commencing with the re-drilling of the hole. Re-drilling a hole is more time consuming than drilling a new hole because the operator may need to move the drill rod in and out several times to correct the deflection.

Risk

Risks associated with the deflection of the drill string include:

- Correcting deflections can be time consuming, adding construction time and financial risk to the project
- A significant deflection can result in the drill string exiting the formation into the ocean, and a subsequent release of drilling fluid into the offshore marine environment.

Potential Mitigation

The main mitigation measure for the deflection of the drill string in a cobble laden formation such as this project is ensure the drill rig is equipped with a robust guidance system, and that a skilled operator is at the controls. Even with this in place, the risk of drill string deflection for this project is very high, and the contractor should plan for project delays.

2.3 Bind Drilling

Description

Blind drilling with HDD can and has been used to install horizontal wells. Depending on the diameter of the screen there are two methods. The first method is for installing a well with a screen pipe that can fit inside the drill rod. Blind drilling using HDD typically requires that the drill bit be broken off at the end of the excavation, while retracting the drill string and leaving the screening pipe in place. The second method is for a screen pipe with a diameter larger than the inside of the drill rod. The application of an over-wash casing installed over the drill pipe allows the extraction of the drill pipe and drill bit. The contractor inserts the screening pipe inside the over-wash casing. Once the screening pipe is in place, the contractor extracts the over-wash casing. The current state of the art requires a 12-inch hole to install a 6-inch screen pipe. These installations are currently limited to about 1,500 feet in the most favorable conditions, due to limitations in screening pipe manufacturing and HDD equipment capabilities.

Risk

With Blind Drilling, pipe extraction work becomes much more critical. Risks associated with pipe extraction include:

- Tensile failure, resulting in a collapsed hole
- Inability to retract drill string
- Personnel safety concerns associated with the required use of cutting torches

Potential Mitigation

As the use of cutting torches will be required for this project, mitigation measures to reduce personnel injury would include proper worker safety training and appropriate personal protection equipment (PPE).

3. Risk Matrix

As described above, there are several major risks associated with the use of HDD for this project. To further characterize these risks, a Risk Register has been developed and each risk has been analyzed with respect to both likelihood of occurrence and consequence of the event, and subsequent “Risk Level” assigned. This evaluation is presented in the following tables. The first table depicts how a risk is categorized based on a combination of likelihood of occurrence and consequence. The second table further defines the consequence of each level across a number of categories. The third and final table is the Risk Rating.

Table 1 Risk Categorization

Risk Level						
	Consequence					
		Insignificant	Minor	Moderate	Major	Severe
Likelihood	Almost Certain	Medium	Medium	**High**	**High**	**Extreme**
	Likely	Medium	Medium	Medium	**High**	**Extreme**
	Possible	Low	Medium	Medium	**High**	**High**
	Unlikely	Low	Low	Medium	Medium	**High**
	Rare	Low	Low	Low	Medium	Medium

Table 2 Risk Level Description

Category	Risk Level Description				
	Insignificant	Minor	Moderate	Major	Severe
Health & Safety	First Aid Only	Single medical treatment of a serious nature	Multiple medical treatment of a serious nature	Multiple injuries resulting in loss of work time	Single fatality and/or severe irreversible disability
Environment	Negligible on-site impact	On-site localized impact, immediately contained	On-site short-term impact immediately recoverable	On-site medium-term impact with potential for fines	Significant on-site long-term harm and/or significant fines
Legal / Compliance	Insignificant non-compliance with internal operational standards	Minor non-compliance with external standards with low potential for impact	Non-compliance with moderate potential for impact, i.e. breach of regulations	Breach of regulation or repeated non-compliance with high potential for prosecution	Breach of regulation resulting in substantial fines and prosecution at company and individual levels
Business / Operation / Financial	Minor operational/ reputational/ customer impact	Short term impact to operations. One off public exposure in local media or word of mouth	Medium term impact to operations resulting in increased costs and significant exposure in local media	Long term impact to operations resulting in significantly increased costs and significant exposure in regional media	Closure of facility and significant exposure in national media

Table 3 Risk Rating

Risk Identification			Risk Rating		
Risk Issue	**Risk Category**	**Impact / Consequence**	**Consequence**	**Likelihood**	**Rating**
Frac-out of drilling mud into the ocean	Environmental	A release of drilling mud into the offshore marine environment, harming marine life	Sever	Almost Certain	Extreme
Frac-out of drilling mud into the ocean	Legal/Compliance	A release of mud into the offshore environment would likely result in fines, impacts to reputation, etc.	Severe	Almost Certain	Extreme
Well Clogging and loss of capacity	Business/Operation/ Financial	Loss of capacity from wells would directly impact production from the desalination facility, or require significant capital investment to restore capacity, increasing costs to West Basin	Major	Possible	High
Deflection of the Drill String	Environmental	A significant deflection of the drill string resulting in the drill string exiting the formation into the ocean would cause a release of drilling fluid into the offshore marine environment. This would adversely impact marine life	Major	Possible	High
Deflection of the Drill String	Legal/Compliance	A release of drilling fluid into the offshore environment would likely	Major	Possible	High

Risk Identification			Risk Rating		
		result in fines, impacts to reputation, etc.			
Deflection of the Drill String	Business/Operation/ Financial	Minor deflections of the drill string result in additional time and expense to complete the drilling, causing financial impact to the West Basin	Moderate	Almost Certain	High
Blind Drilling	Business/Operation/ Financial	The additional technical challenges associated with Blind Drilling will result in additional project costs	Moderate	Likely	Medium
Blind Drilling	Health and Safety	The required use of cutting torches increases the risk of personnel injury	Minor	Possible	Medium

4. Conclusions

Based on the above identified Extreme Risks in both Environmental and Legal areas, plus several other High-Risk issues the use of HDD methodology for installing a subsurface intake for this Project is **NOT RECOMMENDED**.

5. References and Additional Information

Craig Camp, contributing author to this Memo, is GHD's Tunneling & Trenchless Manager located in San Diego, CA. Craig holds a BS in Mining Engineering from the University of Idaho. Mr. Camp has over 38 years of experience in underground construction. His expertise encompasses all phases of microtunneling and other trenchless construction methods including conceptual design reviews, preliminary design reports based on anticipated ground conditions, production estimates, specification reviews, drawing reviews, geotechnical baseline reports (GBR) reviews, project cost estimating, and resolution of project issues. He has been involved in over 100 trenchless construction projects installing over 250,000 feet of pipelines throughout North America, including Miami International Airport in Florida; JFK International Airport in New York; Nimitz Reconstructed Sewer in Honolulu, Hawaii; and Novelty Hill Sewer in Seattle, Washington.

Craig conducted telephone interviews with two contractors from firms experienced in the construction of horizontal intake wells by HDD, for water intake or similar applications. The contractors contacted were:

- Jim Doesburg of Directed Technologies Drilling Inc. http://horizontaldrill.com/
- Greg Horn of ECI Drilling International, LLC http://www.ecidrilling.com/

Appendix 13D

Final Subsurface Seabed Well Construction Cost Estimate

ESA

Prepared for

West Basin Municipal Water District
17140 South Avalon Blvd, Suite 210
Carson, California 90746

SUBSURFACE SEABED WELL CONSTRUCTION COSTS

PROPOSED DESALINATION FACILITY EL SEGUNDO, CALIFORNIA

Prepared by

Geosyntec consultants

engineers | scientists | innovators

3415 S Sepulveda Blvd Suite 500
Los Angeles, California 90034

Project Number: LA0324

May 2017

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LIST OF ACRONYMS AND ABBREVIATIONS

CEQA	California Environmental Quality Act
Desal PMP	Ocean Water Desalination Program Master Plan
EIR	Environmental Impact Report
HDPE	high-density polyethylene
ISTAP	Independent Scientific Technical Advisory Panel
MGD	million gallons per day
N/A	Not Applicable
NRG Facility	NRG Generating Station site in El Segundo
desal	ocean water desalination
SSI	Subsurface Seawater Intake
UWMP	Urban Water Management Plan
West Basin	West Basin Municipal Water District

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 (Malcolm Pirnie - Arcadis, 2013). 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) followed by a demonstration facility in Redondo Beach that was operated from 2010 to 2014. The goal of the demonstration facility was to research and test numerous methods and processes for all stages of operation of a desalination facility (intake, treatment, discharge) that could be used for full scale designs.

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. As part of this EIR, West Basin conducted an evaluation of the feasibility of subsurface seawater intakes (SSIs) in compliance with the California State Water Board's updated Ocean Plan (2015). Because screened ocean intakes can impact marine life, the use of SSIs is required for seawater extraction from the ocean when "feasible". The definition of feasibility is based in part on the analyses required under the California Environmental Quality Act (CEQA). SSIs extract ocean water from the coastal margin that must pass through the seafloor.

The SSI feasibility study evaluated the NRG Facility location in El Segundo (see Figure 1.1) with a production capacity of 20 million gallons per day (MGD)[1], which would

---

[1] 20 MGD is considered the minimum capacity for the project per analysis of the need for desalinated water based on West Basin's 2010 Urban Water Management Plan (UWMP) (RMC, 2011) and the Desal PMP.

require an ocean water intake (feed water) capacity of approximately 40 MGD.[2] The study considered site-specific geotechnical data, hydrogeology of the coastal margin, 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, consistent with the factors outlined in the 2015 Ocean Plan (Geosyntec, 2016).

The following seven known SSI technologies (see Geosyntec, 2016 – Appendix B for detailed descriptions), were evaluated;

1. Vertical wells
2. Slant wells
3. Radial (Ranney) collector wells
4. Horizontal directional-drilled wells (sometimes called drains)
5. Seabed infiltration gallery
6. Beach (surf zone) infiltration gallery
7. Deep infiltration gallery (water tunnel)

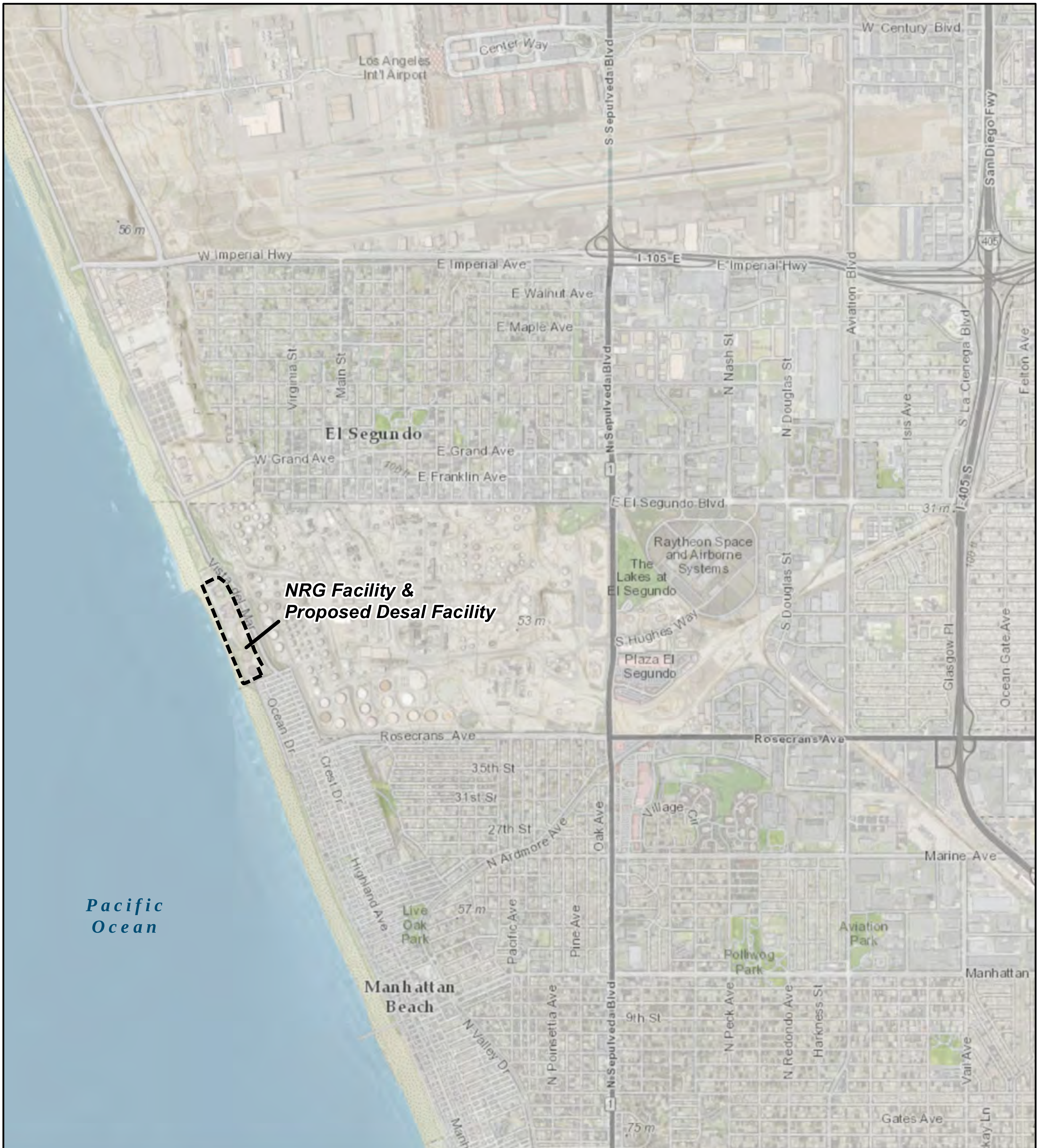
These seven SSI technologies have been used at least once in desalination projects in California or elsewhere. The analysis determined that none of the seven SSI technologies are feasible for the design intake rate of 40 MGD (Geosyntec, 2016); the seabed infiltration gallery was determined to be potentially technically feasible but economically not feasible, and additional analysis performed in 2017 supported this conclusion (Geosyntec, 2017).

One of the factors in determining that the horizontal directional-drilled wells were not feasible was the presence of a low permeability layer approximately 20 feet below the seabed, limiting the hydraulic connection between transmissive zones where extraction of ocean water would occur and the overlying ocean waters, and the challenges associated with horizontally drilling above the low-permeability layer in the presence of cobbles and gravel within the shallow seafloor. An alternative construction method has

[2] Use of the Sea Water Reverse Osmosis process produces a yield of 50% of the water extracted from the ocean.

been identified for installing horizontal wells in the seabed above the low-permeability layer: trenching and laying down micro-porous pipes without the need to install the pipes via horizontal directional-drilling. This “seabed wells” alternative is likely technically feasible, however it would require offshore construction, and the economic viability of this alternative required additional analyses.

The purpose of the current study is to conduct site-specific and scale-specific cost analyses for installation via trenching of micro-porous pipe seabed wells at the NRG Facility location in El Segundo for a 20 MGD production capacity (40 MGD intake capacity). Analyses include consideration of construction costs only; operation and maintenance costs and life-cycle analyses are not part of this study.



Legend

0 3,000 Feet

N

Site Location Map

Subsurface Seawater Intake Study
West Basin Municipal Water District

Geosyntec consultants

LA0324 | March 2017

Figure 1.1

P:\GIS\WestBasinMWD\Project\2015Oct\Fig1_1_SiteLocation.mxd 10/13/2015 2:44:19 PM

1.1 Report Organization

This remainder of the report is organized as follows:

- Section 2, *Approach*, describes the overall technical approach taken.
- Section 3, *Seabed Well Construction, Size and Configuration,* describes the conceptual seabed well intake technology considered in this report, including construction approach, micro-porous pipe sizes and configuration.
- Section 4, *Cost Estimates,* presents the construction cost estimates of the seabed wells.

2. APPROACH

The study considers the construction of a micro-porous pipe seabed well intake system with installation via trenching to meet the desired 40 MGD intake capacity (corresponding to 20 MGD production capacity).

The study develops estimates for capital construction costs associated with the seabed wells. Capital costs associated with the desalination plant, annual operations and maintenance costs, and life cycle costs of the project are not part of this evaluation. The study does not account for environmental impacts and mitigations.

The capital construction costs for the seabed well intakes are developed at the Class 4 AACE[3] level based on conceptual design and site-specific setting, as discussed in Section 3.

---

[3] Association for the Advancement of Cost Engineering.

3. SEABED WELL CONSTRUCTION, SIZE AND CONFIGURATION

3.1 Overview of Seabed Well

The proposed seabed wells are essentially the same as horizontally directionally drilled wells (e.g., Neodren), except they are installed through trenching rather than using drilling technologies. Horizontal micro-porous high-density polyethylene (HDPE) pipes that act as both a well screen and filter pack are installed in the shallow seabed. With this technology, no additional external packing media is required for long-term operation. The installation in the shallow seabed allows for good hydraulic connection to the ocean and high unit yields. Seawater percolates through the sand into the micro-porous pipes, and is then pumped onshore to the desal plant. Construction would rely on typical undersea construction techniques (Section 3.3) and involve trenching of the seafloor down to about 15 feet[4] below the seabed, laying of the micro-porous pipes, and backfilling with excavated material.

Large numbers of seabed wells may be required to obtain the desired intake capacity, and coupled with complex construction occurring in potentially challenging off-shore conditions, this makes construction expensive (ISTAP, 2015). The additional filtering through the sand layers of the seafloor may decrease the pre-treatment requirements and lower future operation and maintenance costs of the desal plant (Missimer et al., 2013). Analysis at Huntington Beach concluded that reduction in operation and maintenance costs of SSI were limited, with an estimated reduction of 7 to 15% of operating costs for a seabed infiltration gallery compared to an open intake (ISTAP, 2015). Furthermore, additional analysis, performed for a seabed infiltration gallery, indicated that these modest reductions may be offset by additional maintenance requirements of the gallery (Geosyntec, 2017).

Additional details of horizontal wells in the seabed (and other SSI technologies) were presented in the SSI feasibility study, including general discussions (Geosyntec, 2016 – Appendix B) and discussions and analyses specific to the NRG Facility site at El

[4]Analysis of beach profiles indicates up to approximately 10 feet depth of sand displacement during erosion and deposition cycles (Geosyntec, 2016 – Appendix K). However, the analysis was based upon measurements in 1991, 1992, 1993, 1995, 1996, and 1997, which did not include large El Nino storm years (e.g., 1983 or 1998). As such 10 feet may not represent the full range of variation. A depth of 15 feet was assumed for this costing estimate, but this should be further assessed in future analysis.

Segundo (Geosyntec, 2016). Specific challenges and constraints for subsurface micro-porous pipes at the NRG Facility that were identified include:

- The uncertainty of the capacity of the micro-porous pipes at El Segundo (see Section 3.2).
- Potential deposition of silts and clays on the Santa Monica Bay seafloor can occur with El Nino storms and result in a gradual reduction of the hydraulic conductivity of seafloor overlying the pipe, which could decrease well yield and affect long term performance.
- Potential clogging within the pores of the pipe may be irreversible and could result in significant decreases in yields over time.
- The uncertainty of performance of the micro-porous pipes given that construction and operation has never been done in the challenging ocean conditions at El Segundo.
- High technical and economic risk.

3.2 Seabed Well Size and Configuration

For this analysis, an intake rate of 40 MGD via the seabed wells is specified, required to achieve full scale intake for a production capacity of 20 MGD, which is considered the minimum capacity for the project (Section 1). The seabed well configuration for 40 MGD intake rate is based on the assumption of no redundancy for the micro-porous pipe intake, i.e., the number of seabed wells considered would provide the capacity for the 40 MGD intake rate without additional capacity from additional wells. The Huntington Beach SSI project assumed a design redundancy of 20%, i.e., the SSI is designed with a capacity corresponding to 120% of the planned intake (ISTAP, 2015). In this study, it is assumed that a screened open intake will provide the necessary redundancy for operation of the desalination plant at El Segundo (Geosyntec, 2017). If the seabed well capacity decreased, for example due to clogging, the screened open intake would be utilized to augment the flow to the planned 40 MGD intake rate. This assumption results in a lower capital cost for construction of the seabed well SSI compared to the case with redundancy.

The seabed well capacity is assumed to be 3 MGD per well, corresponding to the default capacity for horizontal wells identified in the SSI feasibility study (Geosyntec, 2016). It is then assumed that 14[5] wells will be required to meet the desired 40 MGD intake capacity. The individual horizontal well collectors usually yield between 1.1 and 3.4 MGD (Voutchkov, 2013), and capacity for existing horizontal wells in Alicante, Spain has been documented between 2.3 and 3.1 MGD (Voutchkov, 2013) for pipes between 1,600 and 2,000 foot long. Therefore the assumption of 3 MGD per well for El Segundo is a high-end and potentially optimistic estimate. Additional wells may be required to reach the 40 MGD intake rate following installation and testing of the initial 14 wells.

The proposed seabed well layout, comprising 14 primary wells and two contingency wells, is illustrated in Figure 3.1. The costing and descriptions in the remainder of this report are for construction of 14 wells. Each well consists of 350 feet of non-permeable HDPE pipe section crossing the beach from the NRG Facility, and of 1,500 feet of micro-porous pipe section extending under the ocean. Wells are constructed in pairs (see Section 3.3), and each pair of wells are connected to separate[6] collector lines (i.e., seven collector lines in total) running parallel to the shore to a pump station. The proposed nominal pipe diameters are 20” for the micro-porous and non-permeable sections running out to the ocean and 28” for the collector lines.

3.3 Seabed Well Construction Approach for El Segundo

Because of the challenges associated with horizontal directional-drilling within the upper 20 feet of the seafloor, the construction approach relies on trenching and installation of the micro-porous pipes using typical undersea construction techniques. In order to enable installation of the wells through the surf-zone, trestles would need to be constructed for at least the first 1,000 feet through the surf zone. To reduce the uncertainty of using two different construction techniques (e.g., trestles for the first 1,000 feet and float-in structures for the last 850 feet of the seabed wells), it is assumed

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[5]While 13 wells may be able to meet the 40 MGD capacity (if each well can yield 3.1 MGD), the construction method assumes two wells are constructed from a single trestle (see Section 3.3). As such there are cost benefits to constructing an even number of wells.
[6]The lines from the pairs of wells are separate in order to allow operational flexibility (e.g., enable closure of one pair of wells during maintenance).

that the seabed wells would be constructed using 1,850 foot long trestles. It is also assumed that the trestles will be constructed such that two wells (one on each side) can be installed from each trestle. This assumption results in cost efficiency for installation of the wells and associated construction of the trestles. The layout and construction assumptions are summarized in Table 3.1.

All of the construction equipment and methods proposed for the trestle construction portion have been fully developed and proven on previous marine projects on the Pacific coast of North America and around the world for the construction of ocean intakes and outfalls.

Legend

Non-Permeable Pipe Section
Micro-Porous Pipe Section
Collector Lines from each pair of Seabed Wells
Contingent Seabed Wells

N

0 600 Feet

Seabed Wells Layout

Subsurface Seawater Intake Study
West Basin Municipal Water District

Geosyntec consultants

LA0324	March 2017	Figure 3.1

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Table 3.1: List of Construction Assumptions

Assumptions	Values	Reference
Sitting		
Maximum Water Depth (ft)	30	Figure 3.1
Maximum Distance to shore (ft)	1,850	Figure 3.1
Micro-porous Pipes		
Design Redundancy	0%	Open intake provides redundancy
Micro-porous Pipe Section Length (ft)	1,500	
Capacity per Pipe (MGD)	3	Geosyntec, 2016
Pipe Diameters	20”	
Micro-porous Pipe Spacing (ft)	100	Geosyntec, 2016
Numbers of Pipes	14	
Installation of Seabed Wells		
Trestle Length to Install Two Seabed Wells (ft)	1,850	
Trestle Width to Install Two Seabed Wells (ft)	40	Two seabed wells can be installed per trestle (one on each side)
Installation of Collector Lines		
Collector Lines	28” HDPE	
Total Length of Collector Lines (ft)	2,400	

ft = feet

HDPE = High-density polyethylene

MGD = million gallon per day

" = inches

N/A = Not applicable

4. CAPITAL COST ESTIMATES

The capital costs for the project are summarized in Table 4.1. The capital costs for the installation of the seabed wells were based on the construction costs developed by Black & Veatch for construction of a seabed infiltration gallery at El Segundo, which included construction of a trestle and trenching of a conveyance tunnel from onshore pump station to the gallery location 6,500 ft offshore (Geosyntec, 2017). The main assumptions for the seafloor well costs are as follows:

- Seabed well installation via trenching;
- Seabed well size and configuration based on Table 3.1;
- Micro-porous material cost of approximately $200 per linear foot[7];
- Installation of seabed wells 15 feet below the seafloor;
- Construction of 1,850 foot long trestles for trenching and installation of the seabed well pipes through the surf zone and beyond, assuming two seabed wells can be installed from each trestle (Section 3.3);
- Disposal of all excavated/dredged material at an offshore site, 10 miles from the construction site;
- Installation of collector lines onshore at a depth of 10 feet; and
- Unit prices are based on historical data and 2016 RS Means cost data[8] adjusted for marine construction and for geographical area as per Geosyntec, 2017.

The construction cost for the subsurface seabed wells is $372M. This is expected to be a low estimate, as additional wells might be required to meet the 40 MGD intake rate, which would increase the construction cost approximately proportionally.

[7] Based upon personal communication with Dr. Anthony Jones of Intake Works LLC (March 16, 2017).
[8] https://www.rsmeans.com/

Table 4.1: Capital Cost Estimates for Seabed Wells

Description	QTY	UOM	Unit Cost	Subtotal
Installation of Seabed Wells	1	LS		$ 200,060,000
Trestle Contruction for 7 @ 1,850 LF @ 40' wide	518,000	SF	$ 250	$ 129,500,000
Excavation for Wells	168,000	CY	$ 50	$ 8,400,000
Installation of 20" micro-porous pipe wells (14 @ 1,500 LF)	21,000	LF	$ 1,100	$ 23,100,000
Installation of 20" impervious HDPE pipe (14 @ 350 LF)	4,900	LF	$ 900	$ 4,410,000
Installation of 20" impervious HDPE pipe links (14 @ 50 LF)	700	LF	$ 900	$ 630,000
Backfill	166,000	CY	$ 80	$ 13,280,000
Trestle Removal for 7 @ 1,850 LF @ 40' Wide	518,000	SF	$ 40	$ 20,720,000
Dispose of Dredging Spoils	2,000	CY	$ 10	$ 20,000
Installation of Collector Lines	1	LS		$ 5,020,000
Beach Staging Area Prep/Restore	10	AC	$ 150,000	$ 1,500,000
Excavation (onshore)	13,000	CY	$ 30	$ 390,000
Installation of 28" HDPE Collector Lines	2,400	LF	$ 300	$ 720,000
Backfill	9,000	CY	$ 30	$ 270,000
Dispose of Dredging Spoils	4,000	CY	$ 10	$ 40,000
Connect Collector Lines to Pump Station	7	EA	$ 300,000	$ 2,100,000
Onshore Pump	366	HP	$ 10,000	$ 3,660,000
Direct Construction Subtotal	1	LS		$ 208,740,000
Mobilization/Demobilization - 2%	1	LS		$ 4,175,000
Bonds & Insurance - 1.5%	1	LS		$ 3,132,000
Overhead & Profit - 15%	1	LS		$ 31,311,000
Un-priced Allowance (Contingency) - 30%	1	LS		$ 62,622,000
Subtotal Construction Costs	1	LS		$ 309,980,000
Professional Services - 20%	1	LS		$ 61,996,000
Total Capital Cost	1	LS		$ 371,976,000

	Unit	Quantity
Well Pipe Properties		
Number	EA	14
Solid Length	LF	400
Micro-porous Length	LF	1,500
Combined Length	LF	1,900
Size	in	20
Well Pipe Earthworks		
Total Length	LF	26,600
Width	LF	10
Height	LF	17
Dredging Volume	CY	168,000
Backfill Volume	CY	166,000
Spoils Volume	CY	2,000
Trestle		
Number	EA	7
Length	LF	1,850
Width	LF	40
Total Surface	SF	518,000
Collector Lines		
Total Length	LF	2,400
Size	in	28
Collector Lines Earthworks		
Length	LF	2,400
Width	LF	11
Height	LF	13
Dredging Volume	CY	13,000
Backfill Volume	CY	9,000
Spoils Volume	CY	4,000

5. REFERENCES

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