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scwd² Seawater Desalination Intake Technical Feasibility Study

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scwd² Desalination Program

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Glossary of Terms and Abbreviations

APF	Area of Production Foregone (sometimes called Habitat Production Foregone) is the result of an analysis that provides an estimate of the amount of habitat (production foregone) it would take to produce the organisms lost to entrainment. This method can address all losses across all habitat types. This analysis relies on the calculation of proportional mortality and an estimate of the area of the body of water (source water body) from which entrained larvae could have come from. Both proportional mortality and source water body are derived from Empirical Transport Model. Source: Raimondi, P.
CeNCOOS	Central and Northern California Ocean Observing System uses various physical, biological, and chemical sensing technologies to add to our knowledge of changing ocean conditions.
CEQA	(California Environmental Quality Act) – CEQA is a State law that requires state, local, and other agencies to evaluate the environmental implications of their actions.
DEIR	Draft Environmental Impact Report – A report required by the California Environmental Quality Act to describe the environmental impact of a proposed project.
EIR Certification	EIR certification is an action required by CEQA in which the lead agency or agencies certify the document is complete, complies with CEQA, and reflects agency's independent judgment.
ETM	Empirical Transport Model – ETM estimates the proportional loss to larval abundance in the source water due to entrainment. This is done by calculating the daily rate of mortality due to entrainment and compounding it (like compound interest) over the period (in days) that the larva is vulnerable to entrainment.
Hydraulic conductivity	Hydraulic conductivity (K) is a coefficient of proportionality describing the rate at which water can move through a permeable medium.
Paleochannel	An ancient, currently inactive, river or stream channel
P_m	Proportional mortality is calculated based on the ETM. It is the percentage of the larvae at risk that are entrained and killed from a source water population.
Scoping	Early consultation with interested agencies and the public to determine which issues should be addressed in an EIR. A scoping meeting is required for all projects of statewide, area-wide, or regional significance.
SCWD	Santa Cruz Water Department

scwd²	Seawater Desalination Program Task Force with members from local governing bodies: the Santa Cruz City Council and the Soquel Creek Water District Board
Shot point	The location at which the seismic source is initiated
Sub-bottom profiler	A geophysical instrument that provides the data on sub-seafloor strata by sending sound signals into the seafloor and recording the return signals
SqCWD	Soquel Creek Water District
SWP	Source Water Population (SWP) is that spatial area that contains the larvae at risk of entrainment.
SWRO	Seawater reverse osmosis is a method of desalinating seawater into freshwater using energy to force the water through membranes
Transmissivity	Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit of hydraulic gradient. It is the product of the hydraulic conductivity and the saturated thickness of the aquifer.
Twtt	Two-way travel time, time that it takes for the seismic wave energy to reach the reflecting interface from the acoustic energy source and return to the recording array
USACE	U.S. Army Corps of Engineers
USGS	United States Geological Survey
vibracore	A system to extract seafloor sediment cores that utilizes vibration to achieve penetration into the seafloor. a soil sampling technique drawing sediment from less than 15 ft deep, through a tube that is 4 inches in diameter

Executive Summary

Introduction

As part of their overall Integrated Water Plans, the City of Santa Cruz Water Department (City) and Soquel Creek Water District (District) have implemented water conservation measures, evaluated recycled water use, and have partnered to implement the **scwd**² Desalination Program. The objectives of the **scwd**² Desalination Program are to provide up to 2.5 million gallons per day (mgd) of local, reliable, drought-proof water that cost effectively meets or exceeds water quality goals. This new water supply would help the City meet its water needs during drought and help the District address over-pumping of the underlying aquifers during non-drought years.

This **scwd**² Seawater Desalination Intake Technical Feasibility Study provides an overview of the work that the City and District have conducted over the past 10 years in evaluating a seawater intake for a proposed desalination facility in accordance with their respective Integrated Water Plans. The study accomplishes the following goals:

1. Provides a primer and overview of intake technologies and approaches and a summary of regulatory requirements for a seawater intake located in Santa Cruz, CA
2. Accomplishes a preliminary screening of candidate intake technologies and approaches using data from recent in-depth **scwd**² investigations and pilot studies to narrow down the intake alternatives to those which promise to supply the required amount of feedwater for the desalination facility
3. Provides conceptual level design concepts and costs for five intake alternatives for the **scwd**² Desalination Program based on the application of these intakes in the locations under consideration (an offshore alluvial basin of the San Lorenzo River, Mitchell's Cove, and the Santa Cruz Municipal Wharf area), and
4. Provides an evaluation of the technical feasibility of the alternative intake approaches and a recommendation on the apparent best intake alternative approach.

The purpose of the seawater intake system is to provide a specified quantity of source water to the desalination plant. A primary objective of this study is to evaluate the technical feasibility of sub-seafloor and screened, open ocean intake approaches for the **scwd**² Desalination Program.

The Intake Technical Feasibility Study evaluation herein is focused on technical and engineering aspects of the intake alternatives. The following evaluation criteria reflect the **scwd**² Desalination Program objectives and are similar to the evaluation criteria recommended in the American Water Works Association Research Foundation's (AwwaRF) Seawater Desalination Intake Selection Decision Tool.

- **Production Capacity and Reliability:** This performance criterion considers the ability of the intake system to provide up to 6.3 mgd of seawater for the operation of the 2.5 mgd desalination facility at all times and especially during periods of drought. Because the primary function of the intake system is to provide a specified quantity of source water to

the desalination plant, this criterion is considered as a “pass-fail” screening level criterion. If an alternative cannot provide the required production capacity, the alternative “fails” this screening criterion and is not considered further. All intake alternatives that “pass” this criterion are further evaluated against the other criteria below.

- **Proven Technology and Track Record:** This performance criterion considers whether or not the intake technology has been successfully installed and operated at other desalination facilities and the operational track record for the intake technology.
- **Energy Use:** This performance criterion considers the relative amount of energy required for the operation of the different intake alternatives. The energy use of the intake is related to the friction of the water moving into the intake through the seafloor or screens, and the distance the water is pumped to the desalination plant. The energy use of the desalination facility pretreatment system that would be associated the proposed intake is also included.
- **Permitting:** This performance criterion is intended to reflect the complexity and effort involved in permitting the different intake systems. Based on existing information and understanding of regulations enforced by the California Coastal Commission, Regional Water Quality Control Board and Monterey Bay National Marine Sanctuary, every effort must be made to minimize impacts to the marine environment by selecting a location of relatively low biological activity; selecting construction practices that limit impacts to the marine and benthic environments; and selecting an operating technology (sub-seafloor or screened open-ocean intake) that limits impacts to marine species. All alternatives would require permits for construction and operation; operation monitoring would likely be part of the permit(s).
- **Operational Flexibility and Maintainability:** This performance criterion considers the relative complexity and flexibility in operating and maintaining the intake system. The ability to clean and maintain the system on a regular basis is considered for regular maintenance. While system shutdowns of one or two days are anticipated, longer shutdown periods could reduce overall production from the desalination facility and create additional operational complexity and costs. Another factor is the expected longer-term functionality of the system and the ability to potentially modify the intake system to maintain production.
- **Constructability:** This performance criterion considers the relative complexity of constructing the intake system.
- **Project Lifecycle Costs:** Project lifecycle cost is an important criterion for the **scwd²** Desalination Program to meet the project objectives with a cost-effective, economically feasible approach. The cost comparison of the intake alternatives includes capital, operations and lifecycle costs of the intake system and related infrastructure.

The project Environmental Impact Report (EIR) will consider those intake system alternatives that are determined to be technically feasible or potentially feasible, based on the results of this report. The Intake Technical Feasibility Study will not cover environmental impacts or mitigation measures regarding the seawater desalination intake alternatives presented herein; the **scwd²** Desalination Program is carefully considering these issues elsewhere.

Types of Intake Systems

The primary purpose of a seawater intake system is to withdraw a desired amount of seawater from the ocean while minimizing impacts to the marine organisms in the ocean environment. Marine organisms range from microscopic organisms that float with the currents (phytoplankton and zooplankton) to larger organisms such as fish, marine mammals and birds. Section 2 describes how intakes are designed to minimize environmental impacts to marine organisms and the regulatory requirements for seawater intake systems.

Two overall intake approaches exist and are being evaluated for the **scwd**² Desalination Program: a sub-seafloor intake approach and a screened, open-ocean intake approach.

The four major types of sub-seafloor intakes recommended for consideration for the **scwd**² Desalination Program are consistent with the types of sub-seafloor intakes that have been used or are being considered for desalination facilities in California and in other parts of the world (Kennedy/Jenks, 2008). These include:

- Vertical Beach Wells
- Slant Wells
- Radial Collector Wells
- Engineered Infiltration Galleries

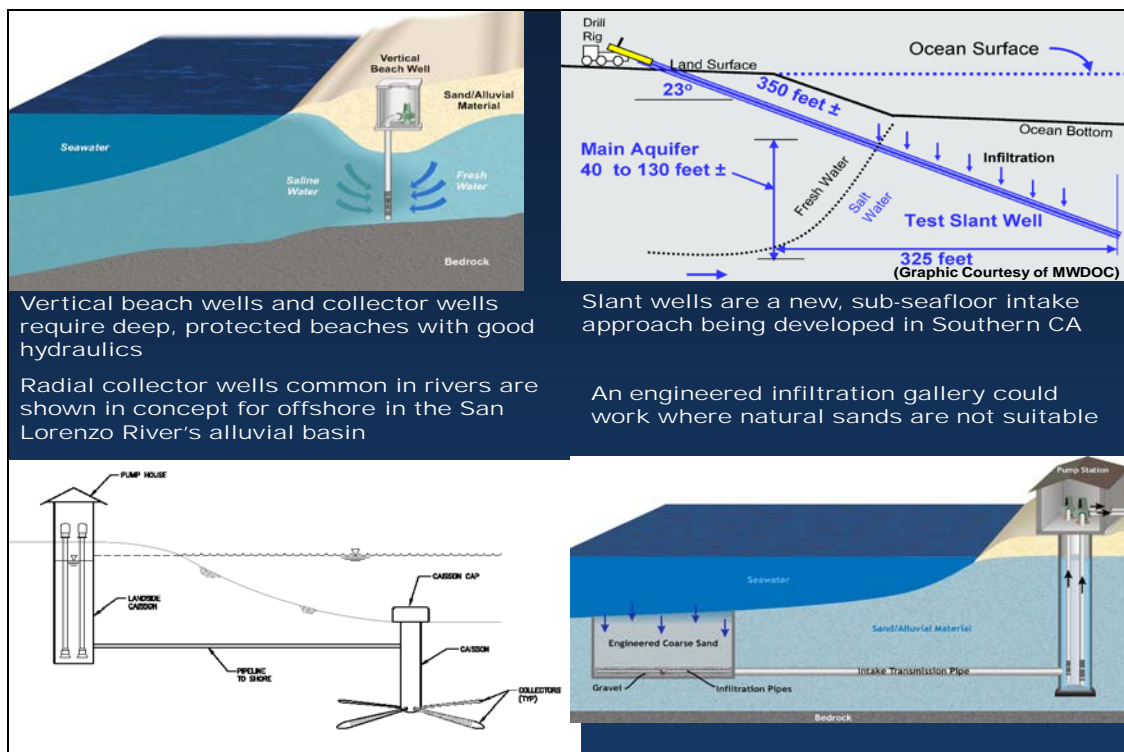
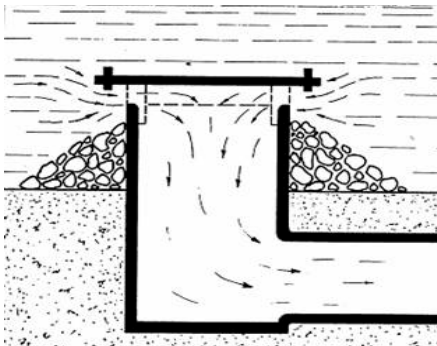


Figure ES-1: Graphic of Subsurface Intake Technologies

Most sub-seafloor intakes draw in feedwater (seawater and/or brackish groundwater) through sediments from a horizontal direction, as well as down through the seafloor. Sub-seafloor intakes can provide some natural filtration of the seawater before it is treated at the desalination facility. Section 3 provides more detailed discussions of the different types of sub-seafloor intake technologies.

Another alternative for an intake system is a screened, open-ocean intake that draws seawater through a protective screen. Different types of protective screens have been developed and used for open water intakes in rivers and ocean environments. These types of open intake screens were assessed in a memorandum prepared for the **scwd**² Desalination Program in 2008 by experts in fish protection technologies. The location of the intake influences the choice of the type of screen. The technical and biological functionality of the screen is important to its efficient operation, which affects engineering performance, cost, and operation and maintenance requirements (Kennedy/Jenks, 2008). Those technologies that offer proven protection to fish and other aquatic life include:

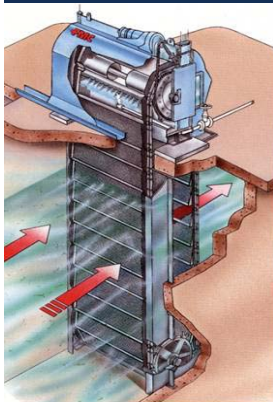
- Velocity cap and fine-mesh traveling water screens
- Passive, narrow-slot cylindrical wedgewire screens
- Aquatic filter barriers



Velocity caps reduce the velocity at the intake to prevent impingement.



Aquatic Filter Barriers have worked well in lakes with minimal current forces on the fabric barrier.



Traveling water screens are used with a velocity cap to minimize entrapment. Organisms that are entrapped and impinged are actively returned to the ocean.



Passive screened intakes have very low intake velocities and small screen slot size which helps to minimize impacts.

Figure ES-2: Graphic of Screened Open-Ocean Intake Technologies

Protective screens, such as the passive screened intakes shown in Figure ES-2, differ in the type of protection they provide. Of these three screen technologies, narrow-slot cylindrical wedgewire screens were recommended in 2008 for the **scwd**² Desalination Program (shown in Figure ES-2 in the bottom right) due to the protection offered marine organisms in early life stages in the intended location(s) (an energetic open ocean environment). The passive screened intake is designed to reduce impingement and entrainment by preventing passage of organisms into the intake by the use of narrow slots and a low through-slot intake velocity. The concept is to mount the screens on the terminus of one or two pipelines. To move forward with a test of this concept, a pilot scale study of the effectiveness of the narrow-slot cylindrical wedgewire screen was conducted. Section 8 contains a more detailed discussion of these open water screen technologies.

Offshore Geophysical Study

In 2001, a conceptual level hydro-geological study was conducted to evaluate the potential for vertical beach well intakes for a seawater desalination facility in the Santa Cruz area (Hopkins, 2001). The report concluded that the Santa Cruz coastline from the beachfront adjacent to the Santa Cruz Boardwalk to Rio Del Mar does not have suitable geology and hydro-geological conditions for vertical beach wells to produce sufficient source water for a 2.5 mgd desalination facility. In 2008, **scwd**² commissioned a review of new technologies and approaches to sub-seafloor intakes being developed in California and in other areas of the world because of the advantages of sub-seafloor intake technologies with respect to passive protection of marine organisms. Additional investigation and evaluation of sub-seafloor intake systems was recommended.

Between 2008 and 2010, **scwd**² conducted a detailed Offshore Geophysical Study (ECO-M, 2010) to identify the location, dimensions and depth of the probable offshore portion of an alluvial basin associated with the San Lorenzo River, and to provide an initial characterization of the type of sediment filling the basin. The geophysical and hydro-geological data and information obtained from the offshore study permit evaluation of the feasibility of the sub-seafloor intake approaches for the **scwd**² Desalination Program.

scwd² convened an independent group of scientists and regulators to serve on an Offshore Geophysical Study Technical Working Group (OGS-TWG). The OGS-TWG scientists and members of the regulatory community reviewed the work plan, technical work and provided substantive comments on the study. This review and supplemental information provided by OGS-TWG members such as the United States Geological Survey (USGS) was important for **scwd**² because scientists with expert knowledge in geology and the seafloor environment offered opinions about the interpretation of the geologic data and the feasibility of sub-seafloor intake systems in the proposed locations.

The following two figures explain what is known, what can be inferred from what is known, and what is not known about the site specific qualities of the San Lorenzo River alluvial basin that would affect the decision to locate one of the subsurface intake alternatives within it.

From the OGS, previous onshore borings, USGS studies, and our understanding of coastal geology:

- There is information and data that we know based on acoustic surveys, borings, and field studies.
- There is information and data that we can infer or estimate based on what we know.
- There is information and data that we do not know without further data collection activities.

The OGS confirmed that the alluvial channel off the San Lorenzo River exists and is up to 150 feet deep, narrow with steep sides, holes and towers. The blue lines mark the channel boundaries. (ECO-M, 2010)

The information that we know includes:

- Physical characteristics of onshore SLR alluvial channel
- Variability and characteristics of onshore sediments
- Physical characteristics of offshore SLR alluvial channel
- Variability and hydraulic conductivity of offshore sediments 8 to 15 feet below seafloor from vibracores
- Mobile fine sediment layer at the seafloor

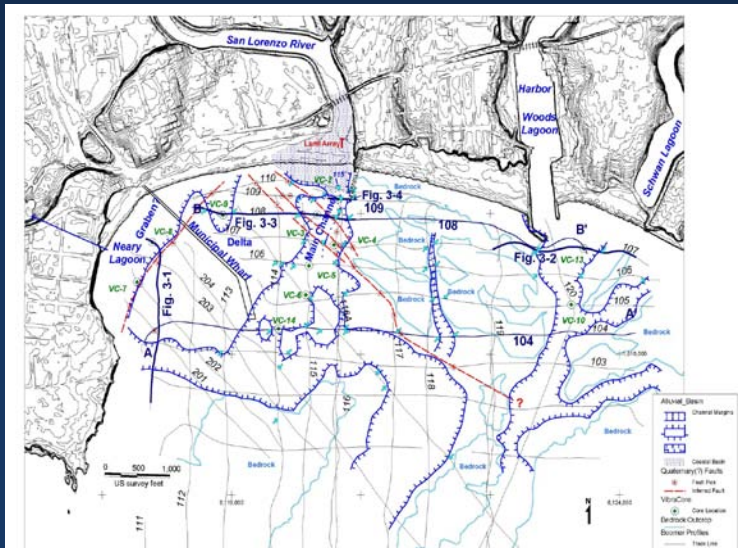


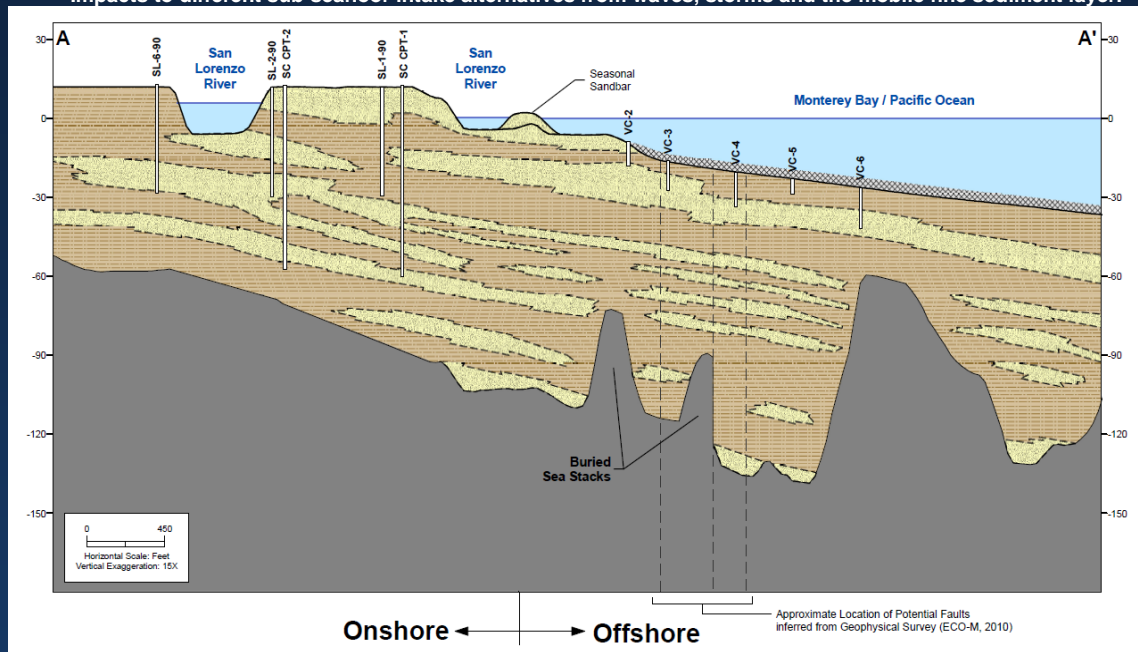
Figure ES-3: Historical and New Data Allows for Physical Characterization of the San Lorenzo River Alluvial Basin

The sub-seafloor physical geology and characteristics of the offshore San Lorenzo River alluvial channel appear to be consistent with the physical geology and characteristics of the onshore San Lorenzo River channel. The San Lorenzo River drops from the coastal mountains to the shore over a relatively short distance, and enters the ocean along a relatively high energy wave and coastal erosion environment. This, along with the nature of the bedrock and other underlying sediments in the Santa Cruz area, creates narrow, steep-sided, meandering channels both onshore and in the offshore alluvial channel (ECO-M, 2010).

These geological conditions cause the San Lorenzo River alluvial channel to have a significant amount of variability, over relatively short distances, in the physical characteristics of the channel and alluvial materials that have filled the channel over long periods of time. This high degree of variability over short distances has been found onshore through geological surveys, borings and investigations of the San Lorenzo River channel (USACE borings, SCWD well investigations, and USGS investigations). A similar high degree of variability is seen in the shallow soil samples extracted from the offshore San Lorenzo River alluvial channel (ECO-M, 2010).

The information that we can infer is:

- Offshore deeper sediment variability and hydraulic conductivity.
- Approximate production capacity from different sub-seafloor intake alternatives.
- Impacts to different sub-seafloor intake alternatives from waves, storms and the mobile fine sediment layer.



The offshore deeper sediments can be inferred from onshore data and local geologic conditions (Kennedy/Jenks, 2010)

Information we do not have includes:

- Offshore, deep geological borings that would be required as the next step for detailed design.
- Actual production values from sub-seafloor intakes – requires installation of actual intake well, collector or gallery.

Figure ES-4: Information we can Infer from Existing and New Data, Regarding the Sediment in the Offshore Alluvial Channel.

The highly variable, heterogeneous characteristics of the sediment filling the San Lorenzo River alluvial channel, is typical of rivers entering the ocean along a high-energy, rocky coastline. The San Lorenzo River is unlike other California rivers that have relatively uniform and homogeneous geological and alluvial characteristics. For example, the Ventura River in Ventura County and the San Juan Creek in Orange County, travel across wide plains from the mountains to the ocean and have a lower energy ocean environment at the coastline. The conditions and the local geology in Ventura and Orange County have created relatively wide, deep and more homogeneous alluvial conditions beneath these rivers and likely in the offshore alluvial channels associated with these rivers.

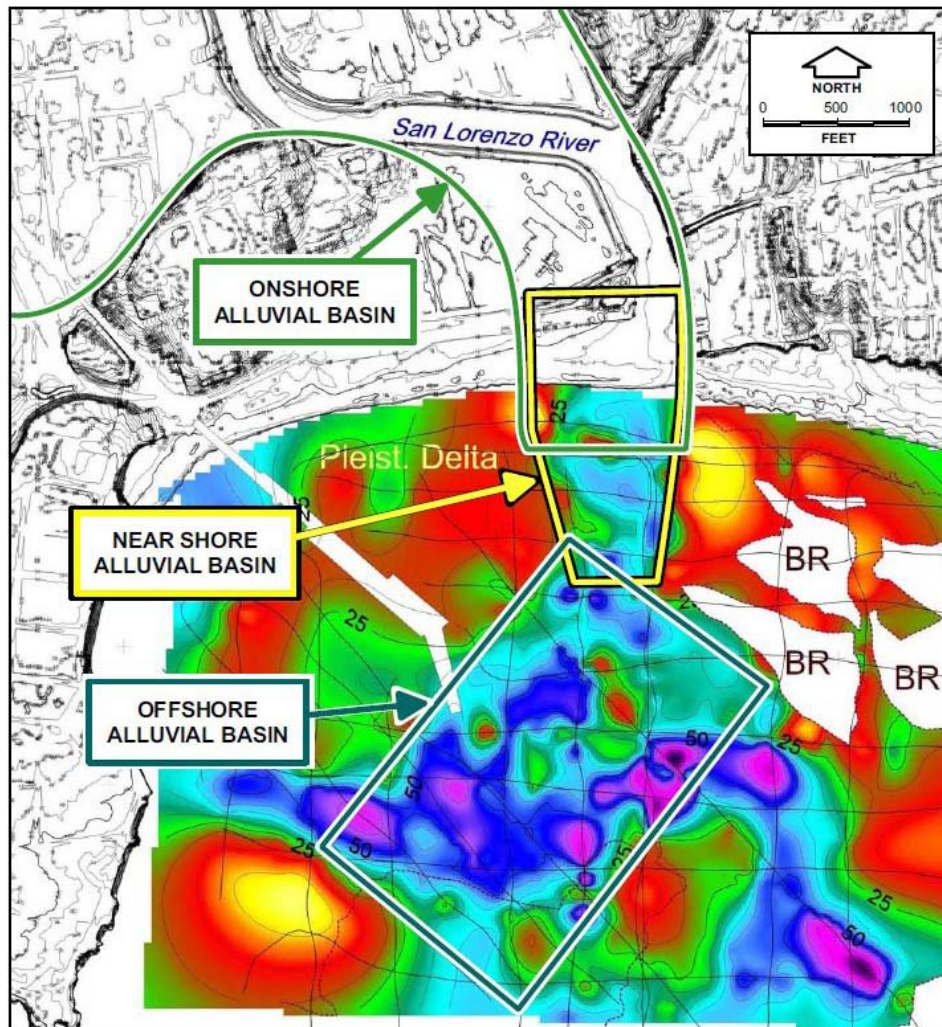


Figure ES-5: Sub-Basins in the San Lorenzo River Alluvial Channel (ECO-M, 2010)

Based on the Offshore Geophysical Study of the San Lorenzo River alluvial channel, three sub-basins were identified for the potential location of different sub-seafloor intake systems. Figure ES-5, above, shows in blue (from light to dark, including pink) the sub-seafloor offshore alluvial basin, which is described in greater detail in Section 4 of the Intake Technical Feasibility Study.

The sediments in the San Lorenzo River alluvial channel were sampled and compared to sediment data from existing onshore geological borings to estimate the potential production of water from sub-seafloor intake systems. Analysis of the sediments in the San Lorenzo River alluvial channel, comparison with existing onshore geophysical data, and discussions with USGS scientists resulted in the following conclusions:

- There is a mobile, active layer of fine sand and silt on the seabed from sediment discharge from the San Lorenzo River. This fine sediment layer could act as a confining layer to the movement of seawater down through the alluvial materials in the offshore alluvial basin (ECO-M, 2010).

- Some layers of alluvial materials had medium and coarse-grained sand that would permit water to move toward a sub-seafloor intake. However, there are also fine sands, silt and clay layers in the alluvial materials that could be thick enough to inhibit water movement (ECO-M, 2010).
- In the sediment samples farther from shore, silt and clay layers were found below the seafloor. The offshore basin is anticipated to contain a greater amount of the fine-grained fraction of sediment than the other two sub-basins (ECO-M, 2010). These silt and clay sediment layers could act as a barrier to the movement of seawater down through the alluvial materials.
- The sub-seafloor physical geology and characteristics of the offshore San Lorenzo River alluvial channel are highly variable and are consistent with the physical geology and characteristics of the onshore San Lorenzo River channel (ECO-M, 2010).

Technical Feasibility of Sub-Seafloor Intake Systems

Sections 4 through 7 of the Intake Technical Feasibility Study provide preliminary layouts, design concepts, advantages and disadvantages, and conceptual costs for the sub-seafloor intake alternatives located in the San Lorenzo River alluvial channel. The sub-seafloor intake alternatives include:

- Vertical Beach Wells in the Onshore Alluvial Sub-basin
- Slant Wells in the Nearshore Alluvial Sub-basin
- Offshore Radial Collector Wells near the Santa Cruz Wharf
- Offshore Engineered Infiltration Gallery near the Santa Cruz Wharf

Preliminary Screening of the Intake Alternatives

The intake alternatives must pass the screening process to ensure that they will provide feedwater to the seawater reverse osmosis (SWRO) facility. Based on existing onshore geological data, the results of the Offshore Geophysical Study acoustic survey and sediment sampling, and on geological and sediment data from the USGS, the vertical well, slant well and engineered infiltration gallery sub-seafloor intake systems were found to be not technically feasible. The “fatal flaws” (i.e., reasons why each alternative is not expected to provide reliable feedwater to the SWRO facility) with these sub-seafloor intakes include:

- Due to the constraints from the local geology and highly variable alluvial sediments, vertical wells, slant wells and onshore radial collector wells would not provide sufficient volumes of water for the 2.5 mgd SWRO facility.
- The San Lorenzo River was designated by Water Rights Order 98-08 as fully appropriated from 6/1 to 10/31 each year. Fresh water levels in the river could be impacted by sub-surface brackish groundwater drawn into the onshore and near-shore intake systems. Due to Order 98-08, the reliability of these intake systems would be

insufficient when the seasonal sandbar is in place, which limits tidal inflow in the dry season. In addition, the withdrawal of groundwater in the onshore basin could lead to seawater intrusion to the City's nearby freshwater wells (Hopkins, 2001).

- Intake systems on Santa Cruz Main Beach would be impacted by storm waves and from high winter-time flows discharging from the San Lorenzo River which could wash out significant amounts of sand from the well field and damage the wells. Building a seawall or other well protection system would not be permitted because of protections for the endangered steelhead salmon in the San Lorenzo River.
- An engineered infiltration gallery is not technically feasible because the gallery would be covered over and plugged with silts and sediments from the San Lorenzo River (for more information, see Appendix A). The gallery would require frequent, significant maintenance. This maintenance would entail dredging and replacement of engineered media at high cost and disruption to the operations of the intake system. Storm wave energy could also damage or "dig-up" an engineered gallery in the near-shore area.

Based on the Offshore Geophysical Study and the conceptual design criteria presented in the Intake Technical Feasibility Study, the offshore radial collector well sub-seafloor intake was found to be potentially feasible technically. However, members of the OGS-TWG from USGS and UCSC cautioned **scwd**² regarding the collection of further data with deep offshore sediment samples. They drew conclusions by inference from available data, that it is unlikely that there would be enough porous sediment, without low permeability layers, throughout the alluvial aquifer laterally and vertically to allow for recharge to the intake wells. To be sure of the ability of the offshore radial collector wells to provide a sufficient volume of water, the entire system would need to be constructed, to conduct a pump test. Thus, this intake approach would have significant challenges due to potential capacity limitations, significantly higher project capital and lifecycle costs, and significant risk involved with this offshore intake approach.

Open Ocean Intake Effects Study

In 2009 and 2010, **scwd**² conducted a thorough Open Ocean Intake Effects Study, or Intake Effects Study (IES), to evaluate the entrainment impacts expected from the operation of the 2.5 mgd SWRO desalination plant with a passive, narrow-slot cylindrical wedgewire screen intake. The Intake Effects Study (Tenera, 2010) included sampling for marine organisms in the area near the potential location for an open-water intake, and a comparative study of a pilot-scale narrow-slot cylindrical wedgewire screen intake and an "unscreened intake". The entrainment study and intake pilot testing provided data on the species and life stages of organisms that are susceptible to entrainment. The study also evaluated impingement of marine organisms on the pilot intake screen, as well as corrosion and bio-fouling of potential screen materials, and a qualitative investigation of current dynamics around the intake screen.

scwd² convened a group of scientists and regulators to serve on an Intake Effects Study Technical Working Group (IES-TWG). The IES-TWG members reviewed the work plan, technical work and provided substantive comments on the study. This independent review and supplemental information provided by the IES-TWG members was important for **scwd**² because scientists with expert knowledge in marine biology and entrainment impact assessment offered

input with the study methodology, data collection and analysis, and report drafts of the Intake Effects Study.

The pilot study of a narrow-slot cylindrical wedgewire screen examined the following operational characteristics of the proposed narrow-slot cylindrical wedgewire screen *in situ*: 1) larval entrainment, 2) impingement, 3) screen corrosion/biofouling, and 4) hydrodynamics around the screen during operation. The pilot scale intake screen had a 2.0-mm (0.08-inch) slot opening and was sized to ensure a maximum through-screen velocity of 0.1 m/sec (0.33 ft/sec), which is consistent with Department of Fish and Game intake requirements. Based on the results of pilot tests of wedgewire screens in Galveston Bay and in the San Francisco Bay, Z-alloy (a material with copper-nickel) was chosen to meet the challenge of controlling corrosion and biological growth on manufactured materials in seawater. Z-alloy proved to be resistant to biofouling over the 13-month continuous deployment of the intake screen during the entrainment and impingement performance testing. Figure ES-6 shows a pilot scale intake screen with 2 millimeters (mm) slot spacing between the wedgewire screen bars.



Figure ES-6: Pilot Scale Narrow-Slot Cylindrical Wedgewire Screen, (Tenera, 2010)

As part of the Intake Effects Study, over 53 hours of video with the intake in operation was obtained for the impingement investigation. *In situ* video of the surface of the screen module during operation showed 262 interactions with fishes, with fishes contacting the screen in 71 (27%) of the events, with no observed impingement. Figure ES-7 is a series of still photos from the impingement video that shows the types of interactions of marine organisms with the operating intake screen. Operating the intake with through-screen velocities lower than the ambient currents and wave-induced water motion prevents impingement (Tenera, 2010).

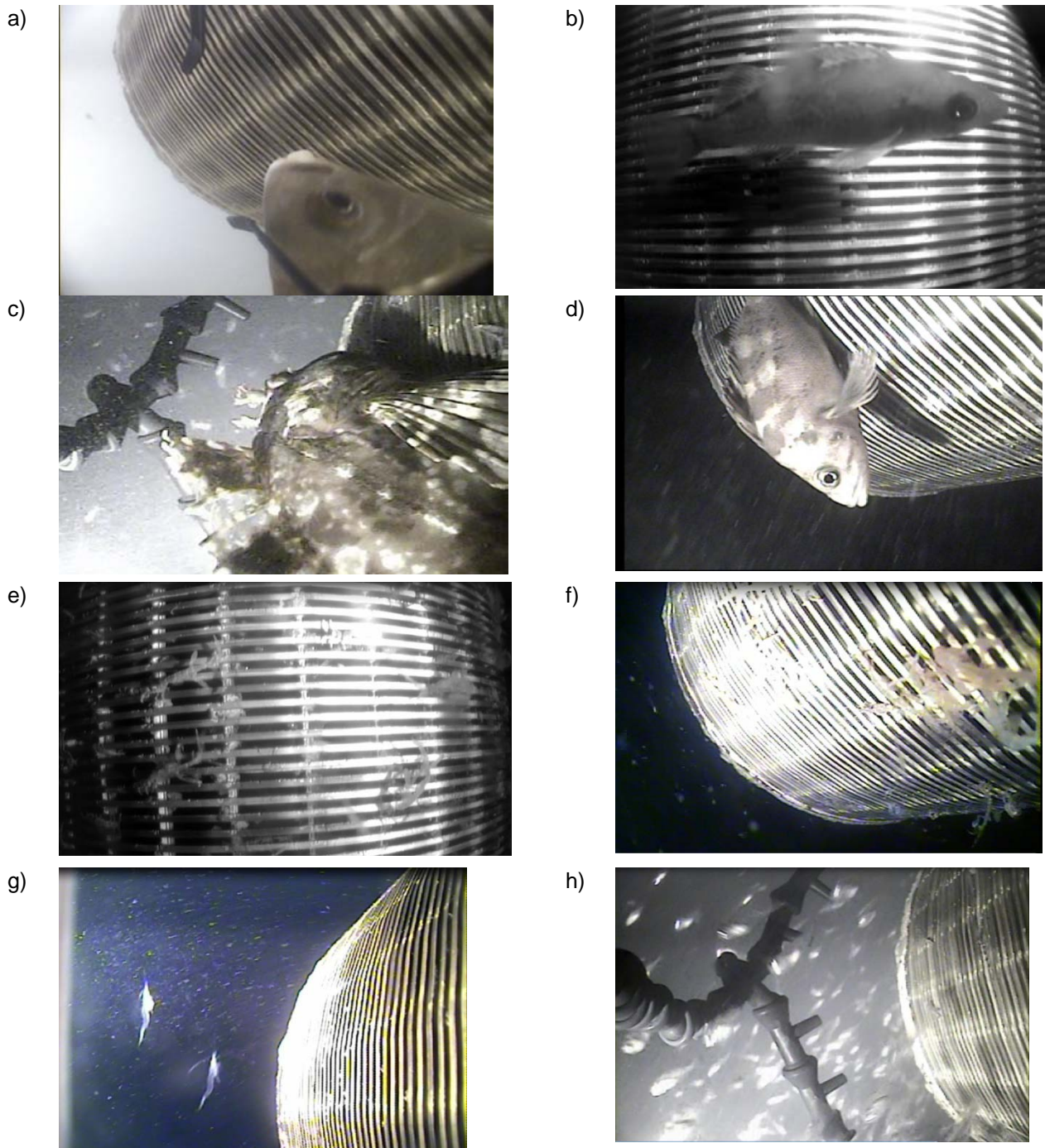


Figure ES-7: Photographs Taken during Wedgewire Screen Pilot Study with Pump Operating (Tenera, 2010)

Notes: a) perch feeding on invertebrates on screen; b) rockfish swimming close to screen; c) cabezon sitting on screen; d) rockfish sitting on screen; e and f) caprellids crawling on screen; g) shrimps swimming near screen; and h) school of juvenile rockfish swimming near screen.

The Intake Effects Study demonstrated that a passive, narrow-slot cylindrical wedgewire screen intake can withdraw the desired amount of seawater from the ocean while preventing impingement of juvenile and adult fish and other marine organisms that are larger than the screen slot size. The qualitative evaluation of dye in water moving around the intake screen showed currents and wave motion helping to clean the screen and prevent impingement of small organisms. The results and conclusions regarding the technical feasibility of a screened open ocean intake from the **scwd**² Intake Effects Study include the following:

- No threatened or endangered fish or marine organisms on the endangered species list were found in the source water area samples or the pilot intake screen samples.
- No local species on the state watch list were found in the source water area samples or the pilot intake screen samples.
- The passive screened intake, with an intake velocity less than the local ambient currents and wave generated water motion, was successful in eliminating impingement.
- For fish and marine organisms that were larger than the 2 mm screen slot size, the passive screened intake prevented entrainment. For fish and marine organisms that were smaller than the 2 mm screen slot size, there was no statistically significant difference between the entrainment of the screened and unscreened intake.

The passive narrow slot wedgewire screen technology has a number of advantages over the other types of screened intakes and is the recommended technology for evaluation of a screened, open-ocean intake approach for the **scwd**² Desalination Program. Section 8 provides more detailed discussions of the different types of screened, open ocean intake technologies.

Technical Feasibility of Screened, Open-Ocean Intake Systems

Sections 10 and 11 of the Intake Technical Feasibility Study provide preliminary layouts, design concepts, advantages and disadvantages, and conceptual costs for two screened, open ocean intake alternatives for the **scwd**² Desalination Program. The intake alternatives include:

- Screened, open-ocean intake at Mitchell's Cove
- Screened, open-ocean intake near the Santa Cruz Wharf

Based on the results of the Intake Effects Study, and the evaluation of the two screened, open ocean intake alternatives, both alternatives are technically feasible.

Evaluation of Intake Alternatives

Section 12 of the Intake Technical Feasibility Study describes the evaluation and comparison of the sub-seafloor and screened open-ocean intake alternatives. The evaluation criteria (summarized above) reflect the **scwd**² Desalination Program objectives and are focused on the engineering aspects of the intake system.

A summary of the intake alternatives that are technically or potentially technically feasible and the analysis for each evaluation criterion is shown in Table ES-1 below.

Table ES-1: Summary of Intake Alternatives Evaluation

Criterion	Offshore Radial Collector Wells	Screened, Open-Ocean Intake near Mitchell's Cove	Screened, Open-Ocean Intake near Santa Cruz Wharf
Proven Capacity and Reliability	May or may not meet required capacity	Can meet required capacity	Can meet required capacity
Proven Technology and Track Record (Risk)	Not proven ¹ in offshore marine environment	Proven in offshore marine environment	Proven in offshore marine environment
Energy Use²	1.5 kWh/kgal ³	2.3 kWh/kgal	2.4 kWh/kgal
Permitting	Moderate effort	Moderate effort	Moderate effort
Operational Flexibility and Maintainability	Low degree of flexibility, potential low or high maintenance complexity	High degree of flexibility, moderate maintenance complexity	High degree of flexibility, moderate maintenance complexity
Constructability	High degree of complexity for construction	Moderate degree of complexity for construction	Lower degree of complexity for construction

A summary of the conceptual cost assumptions for the intake alternatives are provided in Section 12. The intake system conceptual level construction costs range from \$15 to \$20 million for the screened, open-ocean intake alternatives to \$35 million or more for the offshore radial collector well alternative. The annualized lifecycle cost is approximately \$1.3 to \$1.7 million per year for the screened, open-ocean intake alternatives, and approximately \$2.5 million or more per year for the offshore radial collector well alternative.

The advantages of the offshore radial collector well alternative include:

- Proven passive protection of marine organisms from entrapment, impingement, and entrainment.
- Sub-seafloor intake reduces the bio-fouling on the seawater transmission piping and facilities.

¹ For more information about the limited applications of radial collector wells installed in beaches along the Pacific Ocean, see Section 6.1.1.1.

² Energy use includes pumping water from the intake to the desalination facility and the energy of assumed associated pretreatment ahead of the SWRO process. The overall energy of the desalination facility is estimated to be 14.5 kWh/kgal.

- Sub-seafloor intake may reduce the suspended solids that need to be filtered out at the desalination facility, potentially lessening the requirements of the pretreatment system, especially during red tide conditions.
- Onshore Pump Station may be below ground.

While the offshore radial collector well alternative could be potentially feasible technically, based on the results of the Offshore Geophysical Study, input from the TWGs, and the engineering evaluation in this Intake Technical Feasibility Study, it is not recommended for the **scwd²** Desalination Program for the following reasons:

- Lowest production reliability when compared with screened, open-ocean intakes.
- Unproven approach. In order to understand the actual production capabilities from such a system, a full-size system would need to be constructed, operated and monitored. This carries the risk that after committing significant resources to construct the system, the intake may not provide the required capacity.
- Lowest operational flexibility when compared to the screened, open-ocean intakes.
- Most complex to construct when compared with screened, open-ocean intakes.
- Highest capital and life-cycle cost when compared with screened, open-ocean intakes. Cost estimates could be higher, given that it is unclear how many radial collector wells would be needed to obtain the production capacity.

The advantages of the passive screened open-ocean intake approach include:

- Reliable, proven intake technology that can provide sufficient volumes of water for the initial 2.5 mgd facility and potential future expansion.
- Proven passive protection of marine organisms from entrapment and impingement (Tenera, 2010).
- For fish and marine organisms that are larger than the 2 mm screen slot size, the passive screened intake prevents entrainment. [Note: For fish and marine organisms that are smaller than the 2 mm screen slot size there would likely be no statistically significant difference between the entrainment of a screened and unscreened intake (Tenera, 2010).]
- Could utilize existing infrastructure or micro-tunneling to reduce offshore construction impacts to the seafloor.
- Onshore pump station facilities could be incorporated with an existing structure or constructed below ground to reduce aesthetic impacts.
- Multiple screens could be used to provide redundancy and maintain operations during system maintenance.

- Technology is proven with a long successful track record of operation in freshwater and ocean environments.
- Intake alternative with the lowest capital and life-cycle costs when compared with off-shore radial collector well intakes.

The disadvantages of the passive screened open-ocean intake approach include:

- Bio-growth and accumulation of sediment on the inside of the intake pipelines requires periodic maintenance and cleaning operations.
- The ocean water drawn into a screened, open-ocean intake systems will contain suspended solids that will require filtration pretreatment ahead of SWRO process.
- During red tide events, algae will be drawn into the intake system and will require dissolved air floatation pretreatment ahead of the SWRO process.
- Screens could be susceptible to damage during storm events if heavy debris is mobilized by high wave velocities.

Based on the evaluation of the different intake alternatives and locations, the screened open-ocean intake alternative, near Mitchell's Cove or near the end of the Santa Cruz Wharf, is technically feasible and the recommended apparent best intake approach.

Conclusion

The **scwd**² Desalination Program has conducted a thorough and in-depth evaluation of the technical feasibility of sub-seafloor intakes and screened, open ocean intakes to provide seawater to the 2.5 mgd SWRO desalination facility. This Intake Technical Feasibility Study describes and summarizes the detailed investigation into the technical feasibility of sub-seafloor and screened open ocean intake alternatives.

Because sub-seafloor intake technologies are the preferred intake approach with respect to passive protection of marine organisms from entrapment, impingement and entrainment, **scwd**² commissioned an Offshore Geophysical Study to evaluate the local geology off Santa Cruz. Based on the results of the Offshore Geophysical Study, input from the OGS-TWG, and the engineering evaluation in the Intake Technical Feasibility Study, the vertical well, slant well and infiltration gallery sub-seafloor intake systems are not technically feasible for the **scwd**² Desalination Program. The offshore radial collector well sub-seafloor intake was found to be potentially technically feasible, but would have significant challenges due to potential capacity limitations, significantly higher project capital and lifecycle costs, and significant risk involved with this intake approach which is unproven in the ocean environment.

scwd² also conducted an Open Ocean Intake Effects Study (IES) to evaluate the entrainment impacts expected from the operation of a passive, narrow-slot cylindrical wedgewire screen intake system. The IES found that a screened intake with a very low intake velocity prevented impingement and minimized entrainment. See the Intake Effects Study for a discussion of impingement and entrainment associated with a screened, open ocean intake for a 2.5 mgd seawater desalination facility.

Based on the results of the Offshore Geophysical Study and the Intake Effects Study, input from the TWGs, and the evaluation of the engineering criteria, the screened, open-ocean intake systems are technically feasible, and are the recommended apparent best intake alternative for the **scwd**² Desalination Program.

As a next step, Kennedy/Jenks recommends conducting an additional evaluation of the screened, open-ocean intake approach to build on the work of this planning level Intake Technical Feasibility Study. The additional evaluation would more specifically identify the project locations and design components to support the work of the **scwd**² project Environmental Impact Report.

This would include a study of potential onshore locations near Mitchell's Cove where a below-ground pump station could be constructed, and connected to an offshore sandy bottom seafloor area through either micro-tunneling or another approach to minimize environmental impacts. Additional evaluation of the locations near the Santa Cruz Wharf could also be developed. Other sites along the coast between Natural Bridges and the Wharf could also be considered.

