PROPOSITION 50 INTEGRATED REGIONAL WATER MANAGEMENT FINAL REPORT
Evaluation of a Screened Open Ocean Intake and Subsurface Intake Options for a Seawater Desalination Facility in Santa Cruz, California

November 2011

Prepared for:
State Water Resources Control Board
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City of Santa Cruz and Soquel Creek Water District
Collaborating to conserve, protect and create reliable water resources

Grant Agreement No.: 07-507-550-2
Grant Agency: California State Water Resources Control Board
Grant Program: Integrated Regional Water Management Program
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Component Project No.:8
Component Title: Evaluation of Open Ocean Intake and Subsurface Intake for Desalination Facility
Subgrantee/Component Lead: City of Santa Cruz
Component Grant Award: $611,000
Matching Funds Total: $5,451,830
Watershed: San Lorenzo River
Project Type: Desalination

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GRANT SUMMARY

Completed Grant Summaries are made available to the public on the State Water Resources Control Board's (SWRCB) website at http://www.waterboards.ca.gov/funding/grantinfo.html

Date filled out: 5/16/11

Grant Information:
1. **Grant Agreement Number:** 07-507-550-2
2. **Project Title:** NORTHERN SANTA CRUZ COUNTY INTEGRATED REGIONAL WATER MANAGEMENT PLAN - Evaluation of Open Ocean Intake and Subsurface Intake for Desalination Facility (Component 8)
3. **Project Purpose – Problem Being Addressed:** This project provides critical design parameters for the source water intake structure to be used in a regional desalination project being pursued by the City of Santa Cruz Water Department (SCWD) and the Soquel Creek Water District (SqCWD). The desalination facility would provide a supplemental source of drinking water for approximately one hundred thirty five thousand (135,000) Santa Cruz County residents who currently depend on limited local surface water and groundwater sources affected by drought and overdraft. The SCWD and SqCWD are committed to beginning construction of a full scale desalination plant following the evaluations and final approval of a project. Construction of the full scale desalination plant is planned to begin following the certification of an Environmental Impact Report and approval of applicable permits. The intake study addressed system performance as well as environmental concerns associated with various intake configurations. The project also included a physical study of the optimal intake structure in terms of physical configuration, materials, screens, and coatings.

4. **Project Goals**

a. **Short-term Goals:** The project's short-term goals were to complete the studies necessary to evaluate the suitability of the open ocean intakes and subsurface intakes. Kennedy/Jenks together with **scwd²** staff laid out the framework for the intake studies in 2008 based on the recommendations section of the Review of Open Intake Approach: Technical and Regulatory Issues (Alden Research Laboratory, 2008) and the Review of Subsurface Intake Studies (Kennedy/Jenks, 2008). The frameworks presented a series of tasks to follow, however the tasks were changed due to several factors: the advice of members of the Technical Working Groups for the open ocean intake study and the subsurface intake study, and acknowledgement of more appropriate methods of obtaining the necessary data and conducting the analysis for the site location for the intended end use of supporting the design of the intake for the proposed seawater desalination facility.

The objectives of the open ocean intake approach were to:

1) Summarize ways to minimize impingement and entrainment impacts of an open intake;
2) Discuss technical and potential regulatory issues; and
3) Recommend further studies as appropriate.

The initial effort to obtain these objectives was in the Open Ocean Intake Effects Study (Tenera Environmental, 2010). The objectives of this study were to:

1) Establish a baseline characterization of larval fish, fish eggs, caridean shrimps, and cancrid crab species by sampling the species composition, abundance, and variability in the open ocean near the proposed intake; and
2) Model the potential impacts on local fish, caridean shrimp, and cancrid crab populations caused by loss of entrained organisms.

Other objectives of the study completed by Tenera Environmental were to:

3) Assess the operational effectiveness of the proposed narrow-slot cylindrical wedgewire screen in preventing entrainment by sampling with a pilot-scale screened intake and an "unscreened intake";
4) Conduct an underwater videographic study to assess larval impingement on the wedgewire intake screen;
5) Do a dye test to examine the hydrodynamics near the wedgewire screen during pumping; and
6) Study corrosion and bio-fouling of potential screen materials.

The objectives of the subsurface intake approach were to:

1) Review previous information on the potential subsurface intakes
2) Summarize the technical and potential regulatory issues associated with the use of a subsurface intake for this project, and
3) Recommend studies to further investigate a subsurface intake approach.

The initial effort to attain these objectives was the Offshore Geophysical Study (EcoSystems Management Associates, 2010). The objectives of this study were to:

1) Map the extent of the offshore paleochannels in three dimensions
2) Characterize the sediment within the paleochannels
3) Provide preliminary seawater production information for the San Lorenzo River alluvial basin and conceptualize well configurations including vertical, horizontal, slant, radial collector wells, and infiltration gallery collection systems.

Based on the findings of both of these studies, an Intake Technical Feasibility Study (Kennedy/Jenks, 2011) was prepared to:

1) Review previous intake assessments
2) Provide a summary of regulatory requirements
3) Provide a general description of intake technologies and approaches
4) Summarize recent in-depth investigations and pilot studies specific to the proposed intake technologies and approaches
5) Provide feasibility level design concepts and costs for five intake alternatives for the **scwd²** Desalination Program
6) Provide an evaluation of the feasibility of the alternative intake approaches.

b. **Long-term Goals**: Long-term goals include applying the design parameters identified in this project, in conjunction with the results of the 1-year desalination Pilot Plant study (initiated in 2008), toward the evaluation, design, and construction of a full scale desalination water treatment facility. A full-scale facility would provide much needed additional water supply to Santa Cruz County residents during a drought, as well as provide an additional source of water for groundwater recharge during non-drought periods. Long-term benefits include protecting water supply reliability and groundwater quality.

5. **Project Location**: (lat/longs, watershed, etc.) General vicinity Lat. = 36.95, Long. = -122.04; San Lorenzo watersheds

a. **Physical Size of Project**: (miles, acres, sq. ft., etc.) Study to include region of approx. 5-7 miles of coastline

b. **Counties Included in the Project**: Santa Cruz

c. **Legislative Districts**: (Assembly and Senate) Assembly 27 and Senate 11, 15

6. **Which SWRCB program is funding this grant?** Please "X" box that applies.

☐ Prop 13 ☐ Prop 40 ☒ Prop 50 ☐ EPA 319(h) ☐ Other

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Grant Time Frame: Refers to the implementation period of the grant.

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Project Partner Information: Name all agencies/groups involved with project. City of Santa Cruz, Soquel Creek Water District, Regional Water Management Foundation

Nutrient and Sediment Load Reduction Projection: (If applicable) N/A

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Abstract

From 2008 to 2011, the City of Santa Cruz and Soquel Creek Water District conducted technical investigations to understand the intake systems that could be used to supply seawater to the proposed desalination facility. The following reports were prepared to explain how a screened open ocean intake or whether a subsurface intake system would function *in situ* at full capacity to provide 6.3 mgd of seawater to the proposed 2.5 mgd desalination facility. The ***scwd²*** *Open Ocean Intake Effects Study* established a baseline of marine organisms in the vicinity of the proposed intake, and tested a pilot scale wedgewire screen underneath the Santa Cruz Municipal Wharf. The pilot test showed that impingement could be eliminated using a low velocity intake flow, and organisms larger than the screen slot size would not be entrained. The pilot test also demonstrated a negligible bio-fouling rate on the copper-nickel alloy wedgewire screen in seawater. The ***scwd²*** *Offshore Geophysical Study* (OGS) consisted of a survey of the sub-seafloor alluvial basin offshore of the San Lorenzo River. The results of the survey were used to define sub-seafloor intake concepts with information about the basin's shape, size, and sediment. Analysis of the hydraulic qualities of the shallow sediment samples taken offshore was correlated with historical sediment records from cores drilled along the levee to infer the characteristics of deeper alluvial sediment offshore. This was used to prepare an estimate for the potential yield of the sub-seafloor alluvial basin aquifer. The ***scwd²*** *Intake Technical Feasibility Study* (ITFS) took the scientific and field data from the two aforementioned studies to develop planning level engineering design concepts and costs. The evaluation of each intake concept against a set of criteria revealed several technically feasible options for the screened open intake system and one potentially technically feasible option for an offshore radial collector well intake. The studies were guided by two interdisciplinary technical working groups with local knowledge and expertise. The results of the intake studies are being used for the preparation of the Environmental Impact Report due in the spring of 2012. The information produced in these studies is being used in the decision-making and permitting process for the proposed **scwd²** desalination facility. Water agency managers in areas considering desalination in California may also benefit from reviewing these studies when forming their own study plans and technical working groups for intake studies.

Acknowledgements

The Santa Cruz Water Department wishes to thank the taxpayers of the State of California for funding the Proposition 50 Water Quality, Supply and Safe Drinking Water Projects Act. Funds from Proposition 50 in the amount of $611,000 were awarded to the Santa Cruz Water Department and the Soquel Creek Water District for the intake studies. SCWD is grateful to Laura McClean and Kelley List, State Water Resources Control Board and Tim Carson, Regional Water Management Foundation for their supportive management of the grant while administering the award.

The Santa Cruz Water Department also wishes to acknowledge the valuable contributions of the Soquel Creek Water District, and the **scwd²** Task Force. Specifically, SCWD would like to acknowledge the efforts of:

Soquel Creek Water District
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Appendices

Appendix A: IRWM Grant Fund Expenditures, Subcontractors, and Deliverables

Appendix B: Final Annual Project Assessment Status of the PAEP

Appendix C: Intake Studies and Options Fact Sheet, November 2010

Appendix D: Participants in Technical Working Groups

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Appendix F: **scwd²** Seawater Desalination Program Review of Open Intake Approach: Technical and Regulatory Issues

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Appendix H: City of Santa Cruz Water Department & Soquel Creek Water District **scwd²** Desalination Program Open Ocean Intake Effects Study

Appendix I: **scwd²** Seawater Desalination Program Offshore Geophysical Study.

Appendix J: **scwd²** Seawater Desalination Intake Technical Feasibility Study.

Tables & Figures

Glossary of Terms & Abbreviations

Alluvial	Deposited by a stream or moving water
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.
CDPH	California Department of Public Health
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.
City	City of Santa Cruz
DAF	Dissolved air flotation is a pretreatment method
DEIR	Draft Environmental Impact Report – A report required by the California Environmental Quality Act to describe the environmental impact of a proposed project.
DWR	California Department of Water Resources
ECO-M	EcoSystems Management Associates – geophysical survey firm
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.
GHWTP	Graham Hill Water Treatment Plant
gpm	gallons per minute
gpm/sf	gallons per minute per square foot (unit of filtration rate)
GMF	granular media filters
Hydraulic conductivity	Hydraulic conductivity (K) is a coefficient of proportionality describing the rate at which water can move through a permeable medium.
HAB	harmful algal blooms
HR	high rejection
IES	**scwd^2** Open Ocean Intake Effects Study
IRP	Integrated Resources Plan
ITFS	**scwd^2** Intake Technical Feasibility Study

IWP	Integrated Water Plan
kWh	kilowatt hour; a unit of electrical energy
LE	low energy
LML	Long Marine Laboratory
LPRO	low pressure reverse osmosis
MCL	maximum contaminant level
MDL	minimum detection limit
Mitigation Measure	The California Environmental Quality Act requires that when a significant environmental impact will occur, feasible mitigation measures must be proposed that will substantially lessen or avoid that effect. Mitigation measures may involve compensating for the impact, avoiding the impact, restoring the impact, or the like.
MF	microfiltration
mg/L	milligrams per liter
mgd	million gallons per day
MLLW	Mean lower low water
OGS	**scwd²** Offshore Geophysical Study
O&M	operation and maintenance
PAEP	Project Assessment and Evaluation Plan Outline – a document prepared for grant administration and reporting on progress of the work.
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.
Paleochannel	An ancient, currently inactive, river or stream channel
Permeability	The capacity of porous rock or sediment to transmit fluids
pEIR (Program EIR)	A program EIR addresses a series of actions that can be characterized as one large project. Once a program EIR is completed, future actions may or may not require subsequent environmental review under CEQA.
Project EIR	This most common type of EIR applies to one particular project.
RO	reverse osmosis
RWQCB	Regional Water Quality Control Board
Salt rejection	The measure of salts removed by the RO desalination process based on the reduction of total dissolved solids, which is a parameter used to measure salinity
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
SSF	slow sand filters
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.
SWRCB	State of California Water Resources Control Board

SWRO	Seawater reverse osmosis is a method of desalinating seawater into freshwater using energy to force the water through membranes
SWTR	Surface Water Treatment Rule
TM	technical memorandum
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
UF	ultrafiltration
UV	ultraviolet disinfection
µg/L	micrograms per liter
vibracore	A system to extract seafloor sediment cores that utilizes vibration to achieve penetration into the seafloor
WSS	**scwd**^{2} Watershed Sanitary Survey
WWTF	City of Santa Cruz Wastewater Treatment Facility

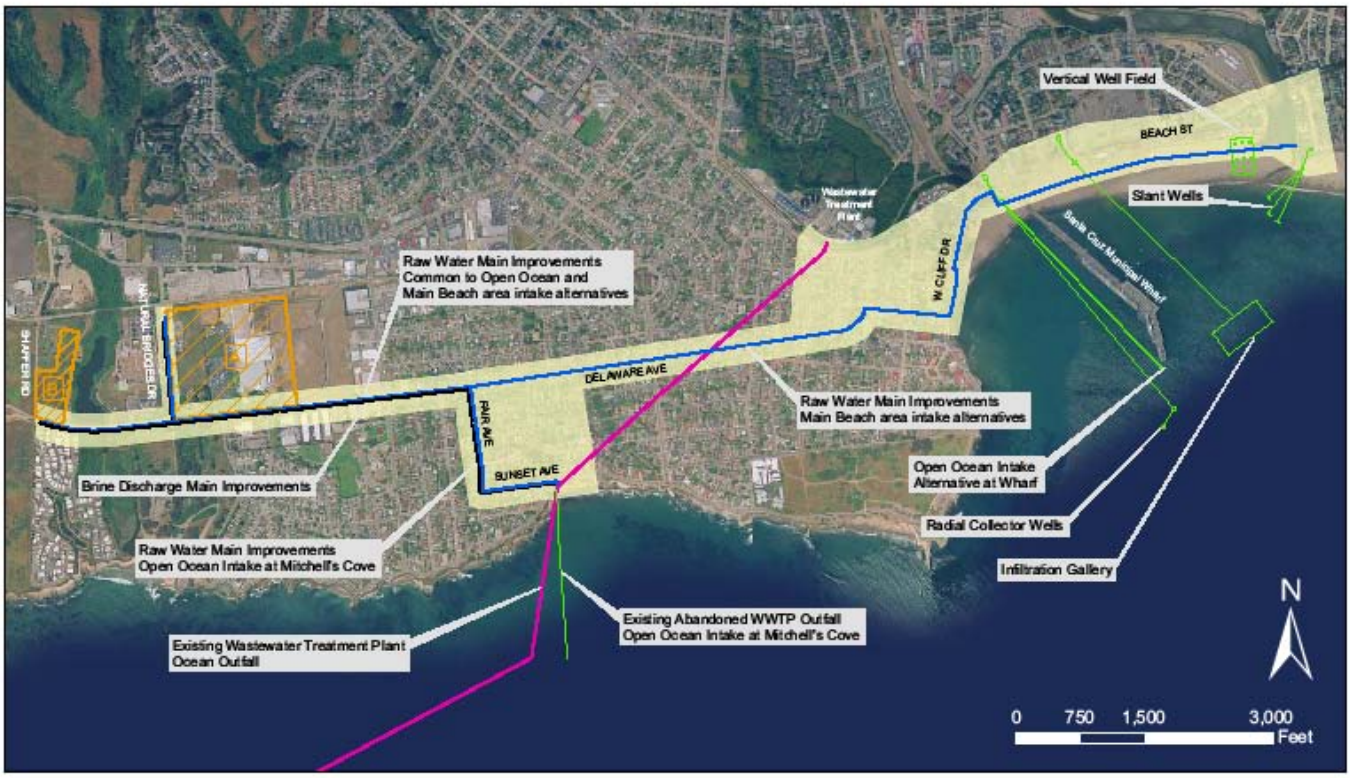
1. Introduction

This report offers an evaluation of the technical studies conducted to develop the design parameters of the source water intake structure for a 2.5 million gallon per day regional seawater desalination facility. The City of Santa Cruz Water Department prepared this report for the State Water Resources Control Board using a format provided to all Proposition 50 grantee recipients. To maximize the value of this report, this introduction states the purpose of each section listed in the Table of Contents to aid a reader interested in locating a specific kind of information.

- The Executive Summary (Section 2) contains brief descriptions of the information obtained in the screened open ocean intake studies and the sub-seafloor intake studies. The Executive Summary explains 1) what was necessary to understand in greater depth for the consideration of the seawater intake systems, 2) what data was produced, and lastly 3) the utility of this data for the determination of technical and operational feasibility of the intake options.
- The Problem Statement section (Section 3) explains why the City of Santa Cruz and Soquel Creek Water District are working cooperatively to develop this supplemental water supply source, and the rationale behind the decision to pursue each intake study.
- The Project Goals section (Section 4) contains the objectives of the Open Ocean Intake Effects Study, the Offshore Geophysical Study, and the Intake Technical Feasibility Study, as well as the goal of developing a supplemental water supply.
- The Project Description section (Section 5) is multi-faceted; it contains information about the work performed with the $611,000 grant award and work performed with $5,451,830 in matching funds. The first part of this section covers the process of pursuing the open ocean intake studies and the sub-seafloor intake studies in a chronological fashion. An explanation is provided for the way each study developed and changed in its methodology over time. The information contained in the second part of the Project Description section summarizes work performed with matching funds used for the regional seawater desalination facility project (for example, this includes the Watershed Sanitary Survey, the Pilot Program, and CEQA/NEPA environmental compliance services).
- The Data from the Intake Studies section (Section 6) contains full descriptions of the open ocean intake studies and the sub-seafloor intake studies. The significance of the data is discussed with respect to the intake selection process for the proposed seawater desalination facility.
- The Data Evaluation section (Section 7) is where the evidence produced in these studies is analyzed. Each intake alternative is described and evaluated in terms of the engineering characteristics that would affect the technical and operational feasibility of the intake option.
- The Public Outreach section (Section 8) describes the transparency of public information and the communication methods associated with the seawater desalination program since the pilot plant work began.
- The Conclusion section (Section 9) evaluates whether the targets were met during the project and provides information about next steps for the **scwd²** Seawater Desalination Program.

To orient the reader to the location where the intake studies were performed, the figure on the following page shows the proposed desalination plant sites, pipeline routes, and locations of each of the intake alternatives described in this report. It was prepared for use in the Notice of Preparation of an Environmental Impact Report (EIR) in November 2010.

Figure 1-1. Various Desalination Facility Plant Sites, Pipeline Routes, and Intake Locations (scwd², 2010)



Legend

- Proposed Brine Discharge Main
- Proposed Raw Water Main
- Existing Sewer Main
- Proposed Intake Alternatives
- Proposed Desalination Facility Plant Sites Still Under Consideration
- Proposed Pipeline Corridor

2. Executive Summary

This report presents an evaluation of technical investigations of open ocean intake and sub-seafloor intake alternatives being considered for the City of Santa Cruz and Soquel Creek Water District **scwd²** Seawater Desalination Program. The intake would provide a source of supply to a 2.5 mgd seawater reverse osmosis facility to be shared by both agencies. Both methods have their advantages and disadvantages in terms of operations and maintenance, reliability and cost.

Figure 2-1. Offshore of Mitchell's Cove Beach is the location where a 0.6 km (2,000 ft) abandoned outfall pipe may be used for a screened, open ocean intake in sandy marine habitat.

This summary begins with an overview of the intake options considered for a screened, open ocean intake and a sub-seafloor intake. It then covers information about the objectives and findings of the investigations, and concludes with a brief evaluation of the feasibility of the intake options.

2.1 Preliminary Intake Options Considered

Screened, Open Ocean Intake Options:
An abandoned reinforced-concrete outfall pipeline offshore of Mitchell's Cove could be modified into a screened open ocean intake system with multiple intake screens, dual intake pipelines, an onshore pump station, and a transmission pipeline. An additional location is evaluated on the sandy bottom near the existing infrastructure of the Santa Cruz Municipal Wharf.

Sub-Seafloor Intake Options:
The proposed location for all sub-seafloor intake options is in the San Lorenzo River alluvial basin. Vertical wells could potentially draw water from below Santa Cruz Main Beach next to the mouth of the San Lorenzo River. Three slant wells could potentially be drilled horizontally from Seabright Beach into the sub-seafloor channel where submersible well pumps would pump the water out of the wells to the desalination facility site. The water would travel through a below grade structure (allowing slant well access) through pipe in a conduit caisson to a transmission pipeline. Two offshore radial collector wells could be located in alluvial material near the end of the Santa Cruz Municipal Wharf. The offshore radial collector well intake system would include an onshore pump house over a landside caisson connected via a pipeline to an offshore caisson with well screens drilled into alluvial sediment. Two engineered galleries could potentially be excavated offshore and filled with engineered media that will infiltrate seawater. Seawater would travel through a subsurface pipe drilled horizontally to the site of the gallery.

These preliminary engineering concepts for screened, open ocean and sub-seafloor intake options were developed using data from site specific field studies. The information presented below for the open ocean intake studies and the sub-seafloor intake studies was evaluated in the engineering assessment of the technical feasibility of the intake alternatives.

2.2 Open Ocean Intake Studies

The investigations described in the Open Ocean Intake Effects Study performed by Tenera Environmental were recommended for the **scwd²** Seawater Desalination Program in a *Review of the Open Ocean Intake Approach: Technical and Regulatory Issues* (Kennedy/Jenks, 2008). Regulatory requirements regarding open ocean intakes were used to inform the data collection plan with respect to the estimation of marine effects of a screened intake. Operations and maintenance issues of open ocean intakes in other locations were used to develop a recommendation for a site specific study of a different type of alloy material for a narrow-slot cylindrical wedgewire screen. This type of screen was selected for pilot testing because of its potential to minimize entrainment and impingement of marine life. The studies were designed to supply information that will be required prior to the design, permitting and construction of a full-scale open intake. Scientific experts in the field and technical experts from the agencies with the responsibility to issue permits for an open ocean intake influenced the design of the investigative research and offered valuable advice and feedback in several Technical Working Group meetings.

2.2.1 Open Ocean Intake Effects Study

The Open Ocean Intake Effects Study, or Intake Effects Study (IES), (Tenera, 2010), assessed potential impacts to marine life from water withdrawals of 7 million gallon per day (mgd) (2.5 mgd drinking water capacity) seawater reverse osmosis (SWRO) desalination facility.

Offshore Intake and Source Water Study

Data was collected (Fig 2-2) over 13-months on the concentrations of fish eggs, and larvae of fishes, caridean shrimps, and cancrid crabs in the source water at the proposed intake to understand the source water entrainment potential of these species.

Figure 2-2. Paired plankton nets used for sampling (Tenera, 2010)

Intake Screen Pilot Studies

A pilot study and evaluation of a narrow-slot cylindrical wedgewire screen was conducted. This pilot study examined the following operational characteristics of the screen *in situ*: 1) larval entrainment, 2) impingement, 3) screen corrosion/biofouling, and 4) hydrodynamics around the screen during pumping. The pilot scale intake screen (shown in Fig. 2-3, 2-4) 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 stream flows. Results of the pilot studies testing showed that Z-alloy proved to be resistant to biofouling over 13-months, and the qualitative evaluation of dye in water moving around the intake screen showed currents and wave motion helping to clean the screen and together with a low intake velocity prevented impingement of small organisms.

Intake Effects Assessment Study

The intake effects assessment study compared the screened intake with an unscreened intake to study the operational effectiveness of the screen on larval entrainment. No threatened, endangered, or listed species were entrained. The data from the pump samples were analyzed to determine if any differences could be detected between concentrations of fish, caridean shrimp, and cancrid crab larvae from the screened and unscreened intakes. An analysis combining all of the larval fishes collected was done using taxa counts for each sample. This analysis showed: 1) the standard 2mm narrow-slot wedgewire intake screen excluded 100% of adult and juvenile fish species in the area, 2) the unscreened intake entrained juvenile and adult fishes, and 3) while no statistically significant reduction in entrainment was found, annualized screen-test results demonstrated that the screen resulted in 20% reduction in total annual larval fish entrainment (Tenera, p. ES-7).

Results of the Assessment of the Potential Impacts of the Proposed Open Ocean Intake Flow

Data regarding both the types and the numbers of organisms entrained from the pilot scale study is included in the IES. Entrainment effects at power plant and desalination pilot facility intakes in California have been assessed using several models, the Empirical Transport Model (ETM) and the Area of Production Foregone (APF) model. The Technical Working Group (IES-TWG) advised Tenera to calculate and present the results of the ETM in the IES, to provide a basis for later calculation of APF values for each species. The Empirical Transport Model estimates the proportional loss to the standing stock of larvae in the source water due to entrainment using an estimate of mortality calculated as the ration of the number of larvae entrained to the number estimated in the source water. Using the ETM, estimated entrainment impacts for the most abundant fishes, caridean shrimps, and cancrid crabs based on 7 mgd flows and 2009-2010 intake location survey data were calculated. The greatest projected proportional mortality (Pᴍ) for the top 80% of the fish larvae in the source water area for the 7 mgd intake flow was 0.06%; and for the caridean shrimp and cancrid crab larvae in the same estimated conditions it was 0.02% (Tenera, 2010). The estimated entrainment impacts of the **scwd²** screened open ocean intake will be evaluated for environmental significance in the project EIR.

Figure 2-3. Juvenile rockfish swimming by the intake screen (Tenera, 2010)

Figure 2-4. Shrimp swimming by the pilot scale intake screen (Tenera, 2010)

2.3 Sub-Seafloor Intake Studies

A series of studies were done to ascertain the suitability of sub-seafloor intake systems that have been conducted for the **scwd²** Seawater Desalination Program.

Hopkins Groundwater Consultants (2001) performed a conceptual reconnaissance-level hydrogeology study in the onshore/nearshore. After review of the data, Hopkins found generally unfavorable overall hydrogeological conditions for vertical beach wells and collector wells (Figure 2-5).

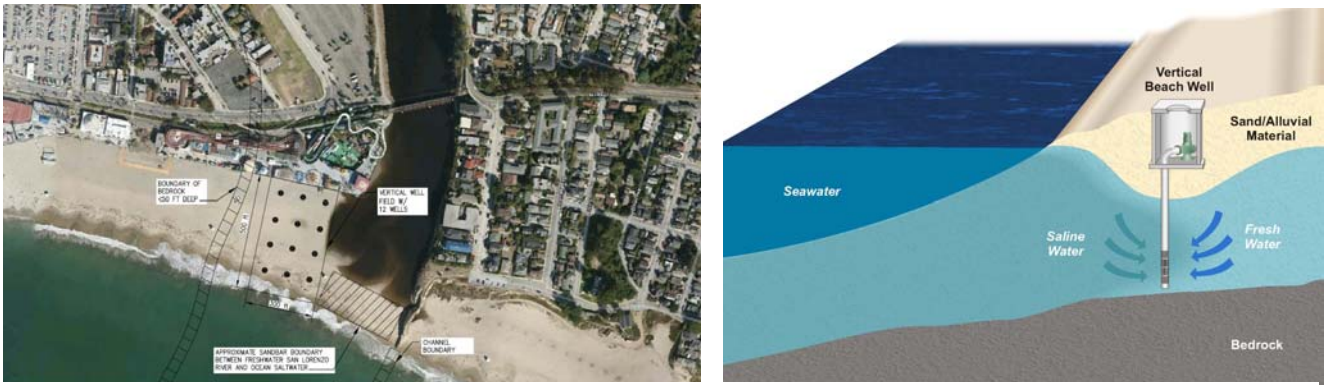


Figure 2-5. Sub-seafloor vertical well intakes in the onshore alluvial basin conceptual location is next to the mouth of the San Lorenzo River. On the left the black dots represent vertical wells; on the right is a graphic showing the function of vertical beach wells. (Kennedy/Jenks, 2011)

The *Review of Subsurface Intake Studies and Recommendations for Additional Investigations* (Kennedy/Jenks, 2008) recommended further study of the area offshore of the San Lorenzo River for the potential location of slant wells or an engineered infiltration gallery. Figure 2-6 shows these two concepts.

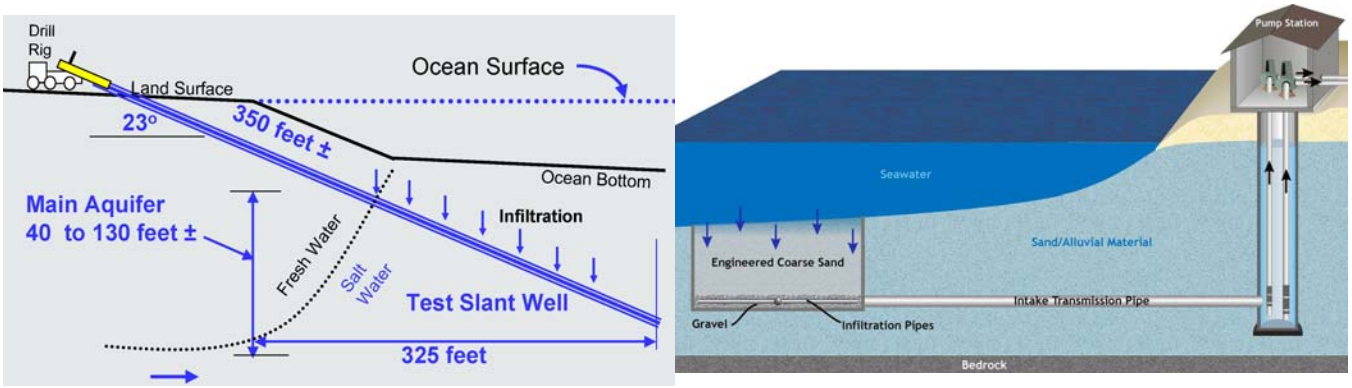


Figure 2-6. Graphic of a slant well design (courtesy of MWDOC) and a graphic of an engineered infiltration gallery. (Kennedy/Jenks, 2008)

The Offshore Geophysical Study (OGS) prepared by Ecosystems Management Associates (ECO-M, 2010) provided the critical information (channel depth, thickness of materials, overall shape, and characterization of the sediment) needed to develop an understanding of the physical dimensions of the subsurface alluvial basin for conceptual designs of the proposed types of subsurface seawater intakes. Figure 2-7 is a structural contour map of the buried alluvial channel under the seafloor. The 1,000 foot wide part of the channel near the river mouth ranges from 40 to 128 feet deep (12.2 to 39 m). The channel narrows and then widens moving offshore, where it deepens to approximately 150 ft (46 m) near the end of the Municipal Wharf.

In addition to the physical dimensions of the channel, the condition for seawater recharge of the intake system wells varies among the three sub-basins (Fig 2-7). Aquifer conditions in the tidal area of the San Lorenzo River (onshore alluvial basin) would vary due to the seasonal sand bar. Conditions in the nearshore alluvial basin have limited production potential because of the limited length of the shoreline, the shallow aquifer, and the narrow channel. ECO-M concluded that the production potential of the offshore alluvial basin would be affected by the bottom and sides of the aquifer, which confine flow, and by the aquifer transmissivity and seepage rate of seawater through the seafloor sediment.

Based on the OGS sediment sample data, comparison with existing onshore geophysical data, the preliminary hydrogeologic estimates of aquifer potential, and discussions with USGS scientists, Kennedy/Jenks concluded in the Intake Technical Feasibility Study that there was sufficient information about the geological characteristics of the alluvial basin to evaluate

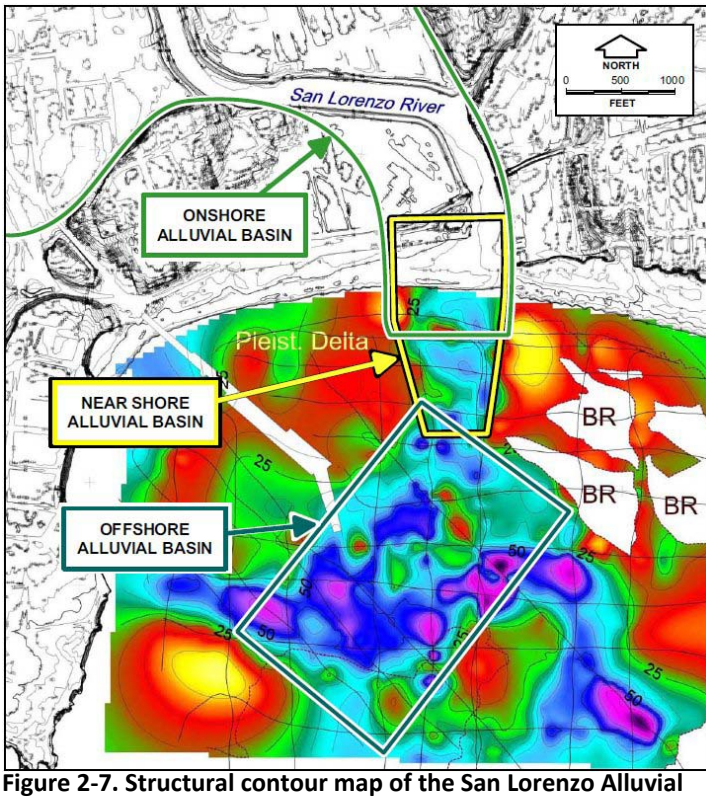


Figure 2-7. Structural contour map of the San Lorenzo Alluvial Basin. The alluvial basin channel colors are green (shallowest), light blue, dark blue and pink (deepest). Red and yellow portions of the survey area represent very shallow sands over bedrock. (ECO-M, 2010)

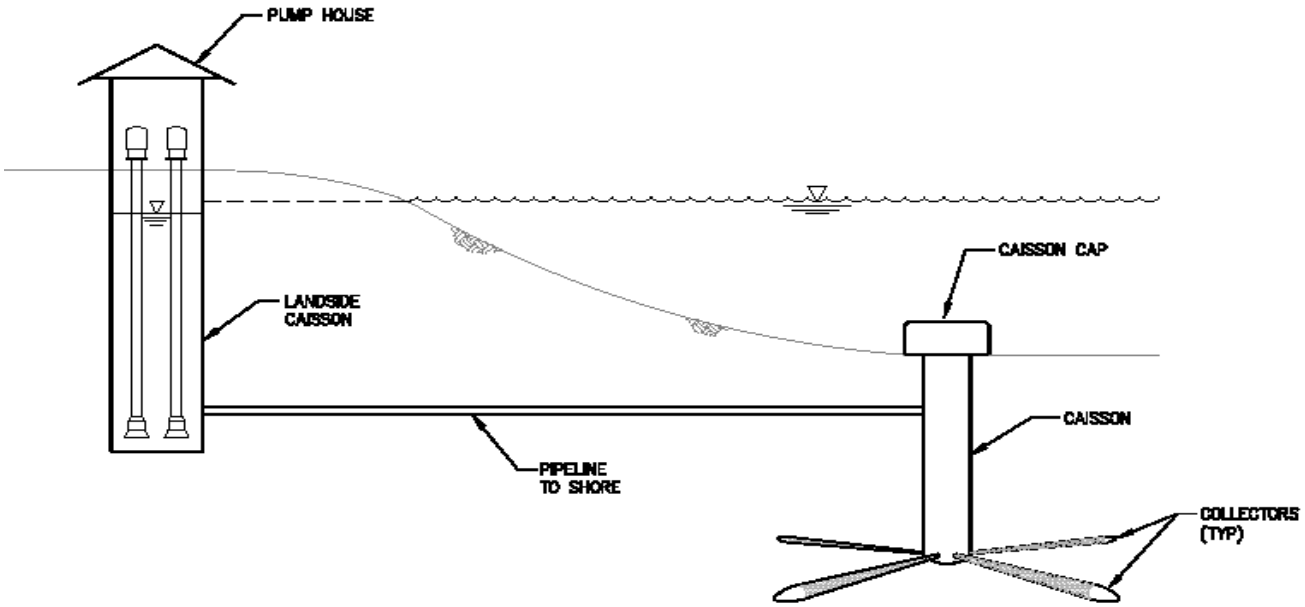


Figure 2-8. This graphic shows the conceptual offshore approach for a radial collector well which could potentially be built in suitable offshore alluvial material. (Kennedy/Jenks, 2011).

the technical feasibility of the location for the potential use of subsurface intakes.

2.4 Evaluation of the Technical Feasibility of the Intake Options

In preparation of the Intake Technical Feasibility Study, (ITFS) Kennedy/Jenks reviewed the preceding reports, developed conceptual engineering designs, and evaluated the following intake options:

- Screened, Open Ocean Intakes in two locations, offshore of Mitchell's Cove and off the Santa Cruz Municipal Wharf (Figure 1-1.)
- Vertical Wells in the onshore San Lorenzo Alluvial Sub-basin (Figure 2-5)
- Slant Wells extending from underneath Seabright Beach into the nearshore San Lorenzo Alluvial Sub-basin (Figure 2-6, Figure 6-17, 6-18)
- Offshore Radial Collectors in the offshore San Lorenzo Alluvial Sub-basin (Figure 2-7, Figure 2-8)
- Offshore Engineered Infiltration Gallery in the offshore San Lorenzo Alluvial Sub-basin (Figure 2-6, Figure 2-7)

The operational and technical feasibility of the intake approaches was evaluated first for the ability to reliably produce sufficient water. The slant well intake system is not expected to achieve necessary flow rates to provide 6.3 mgd of seawater for operation of the desalination facility at all times (amount required to produce 2.5 mgd) due to the following limitations: 1) there is only space for approximately three slant wells, and 2) the narrow alluvial channel's geometry combined with the heterogeneous qualities of the sediment may limit the recharge potential to the wells. The offshore engineered infiltration gallery is not expected to be able to reliably provide the required production capacity due to frequent plugging of the engineered media by fine sediment and the potential for the erosion of the engineered media during large storm events. The offshore radial collector wells were found to be potentially feasible technically. However, because they may not be able to produce the required production capacity (as with the infiltration gallery) and the design concept is unproven in the offshore marine environment, they were not recommended for further evaluation. The two screened, open ocean intakes can meet the required capacity. Next, the remaining alternatives were evaluated as shown in Table 2-1.

Table 2-1. Summary of Intake Alternative Evaluation (Kennedy/Jenks, 2011)

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 in offshore marine environment[1]	Proven in offshore marine environment	Proven in offshore marine environment
Energy Use[2]	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

[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 of the ITFS.

[2 & 3] 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.

Based on the OGS and the conceptual design criteria presented in the ITFS, 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.

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. (Kennedy/Jenks, 2011)

In conclusion, the screened, open ocean intake and sub-seafloor intake reports and field work investigations formed a solid basis upon which to evaluate the suitability of the intake alternatives to provide source water to the potential 2.5 mgd desalination facility. The ITFS recommended for further evaluation screened, open ocean intakes offshore of Mitchell's Cove and near the Santa Cruz Municipal Wharf as technically feasible options, and radial collector well subsurface intakes for the San Lorenzo River offshore alluvial basin as a potentially technically feasible option.

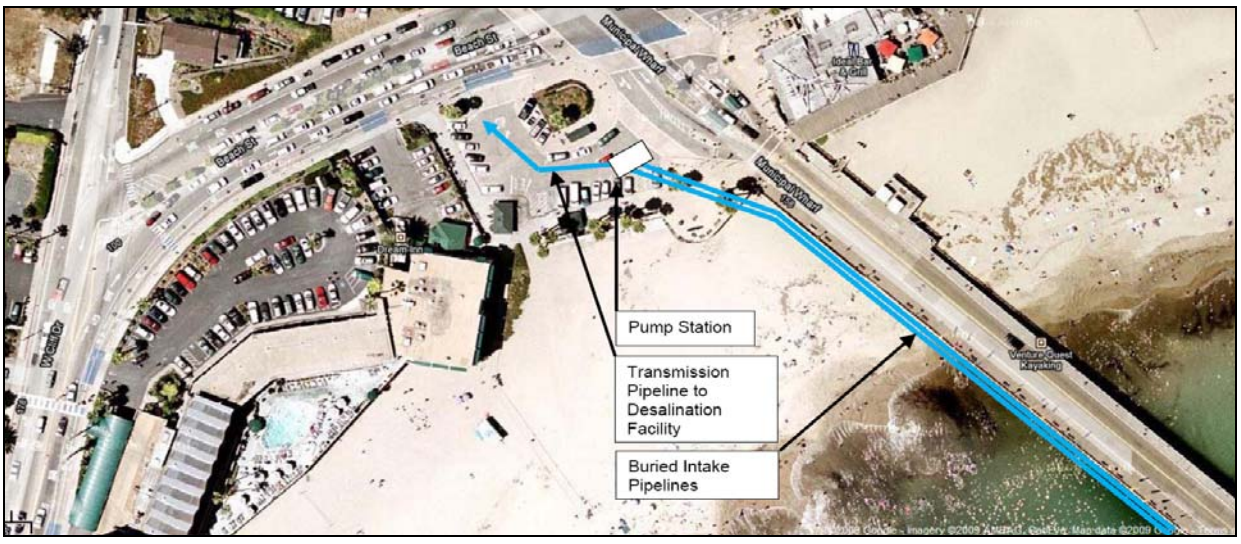


Figure 2-9. Conceptual Municipal Wharf-located intake pipelines and pump station aerial view.