EQUINOX CENTER

HEALTHY ENVIRONMENT STRONG ECONOMY VIBRANT COMMUNITIES

H2OVERVIEW PROJECT

The Potential of Seawater Desalination As a Water Supply in San Diego County

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About H2Overview

San Diego County is at a crossroads in its water policy. A clean, adequate water supply is the lifeblood of our region's quality of life and economy. Extended droughts, a growing population, crumbling infrastructure, legal disputes and concerns about threatened species have put San Diego County's water supplies at risk, and resulted in escalating water prices. We can't wait any longer to develop a comprehensive vision and action plan to deal with our water challenges.

Equinox Center's **H2Overview** project provides balanced, easily accessible research and potential solutions to policy makers and community leaders about how we can use water more efficiently and develop more reliable, local, sources of water. Through a series of reports under the **H2Overview** umbrella, Equinox Center analyzes the complex issues surrounding potentially significant local water sources.

Seawater Desalination in San Diego County is the fourth report in the series and takes an objective look at desalinated seawater as a potential local source for San Diego.

About Equinox Center

To ensure a healthy environment, strong economy and vibrant communities for the San Diego Region, Equinox Center researches and advances innovative solutions to balance regional growth with finite natural resources. The Center is an independent, non-partisan, not-for-profit organization dedicated to helping San Diego County craft an intelligent and sustainable future while enhancing economic opportunities in the region. Equinox Center works at the heart of four major issue areas: water, land use, energy and transportation. For more information, please see our website or contact us. www.equinoxcenter.org ; (760) 230-2960

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Executive Summary

Being located in a semi-arid climate and adjacent to the great Pacific Ocean, it is not surprising that water managers in the San Diego region are considering adding seawater desalination to the region's water portfolio. As our population grows, and total demand for water increases, seawater desalination is considered to be one of many potential sources that can help address our water challenges.

Although there is evidence that seawater desalination enjoys significant public support in San Diego County, desalination has also been the source of controversy and legal battles over the last ten years. Debates about the costs, energy intensity and environmental impacts of seawater desalination have left some in the region uncertain about the potential of this source to help meet future water needs. At times, the discussion has become severely polarized, hampering a more productive dialogue about enhanced water reliability in the region.

In this report Equinox Centers explains seawater desalination for the general public, community leaders and policy makers who are not specialized in water management. Equinox Center has collaborated with experts to provide an independent, science-based review of the opportunities and challenges posed by this water source. The report summarizes the latest research from desalination facilities world-wide and recommends strategies on how the region should proceed when considering seawater desalination. Below are the report's key points, conclusions and recommendations.

- Efforts to include seawater desalination in San Diego County's water portfolio are based on a projected population increase, a shrinking and more expensive supply of imported water, and limited local supply alternatives outside of water use efficiency and recycling.

- Four seawater desalination facilities are in different stages of development in the region. Each proposed project has its own unique characteristics and should be considered on a case by case basis. Together these projects could represent 10-15% of San Diego's water supply by 2020.

    - Poseidon Resources LLC's Carlsbad desalination plant, with a production capacity of 50 million gallons per day (MGD) (56,000 acre-feet per year), has completed the permitting process and is in the process of securing financing with the hope of beginning operation in 2013. The San Diego County Water Authority is currently discussing a water purchase agreement with Poseidon for the Carlsbad plant's product water, but formal negotiations have not yet begun.

    - San Diego County Water Authority is conducting preliminary studies to design a proposed facility on Camp Pendleton, near the mouth of the Santa Margarita River (50-150 MGD or 56,000-150,000 acre- feet).

    - A plant near Rosarito, Baja California, Mexico is being investigated by a number of regional water agencies (providing between 25-50 MGD or 28,000-56,000 acre-feet of water per year to the San Diego region).

    - The Otay Water District is separately studying the possibility of working with a private developer to build another plant in Rosarito. The project would provide 25 MGD to Otay and would be expandable to 50 MGD (28,000-56,000 acre-feet per year).

- Like any water source, seawater desalination presents opportunities and challenges.

Findings

- The quality of water from seawater desalination is relatively high--better than our current treated imported water supply.
- Seawater desalination would provide a drought-proof water source and reduce the region's dependence on imported water and other sources (groundwater, surface water) that will likely be affected by climate change.
- Seawater desalination projects could have economic benefits to the region as the process employs technology that is locally manufactured in San Diego County.
- Seawater desalination generally enjoys public support in the region, although there are some concerns about some seawater desalination projects resulting in the privatization of our drinking water supply.
- Desalinated seawater currently has a higher marginal cost compared to other sources, and this could potentially have a negative economic impact on the region if water prices increase significantly as a result of adding this source in large quantities to the region's supply.
- The energy intensity of seawater desalination is higher than other water sources. If extensive development of seawater desalination in San Diego County is pursued, it may jeopardize the region's climate and air quality goals. The use of renewable energy sources to supply power to desalination plants could help mitigate this issue.
- The environmental impacts of seawater desalination are dependent on the siting of the facility, the design of the plant and technology used, and the characteristics of the surrounding habitat and ecosystem. With good design that utilizes the most advanced technologies, many of these impacts can be mitigated.
- Many of the known marine impacts can be reduced or mitigated, but there is still uncertainty about longer term impacts of brine disposal and entrainment on sensitive marine ecosystems. More studies will need to be done over time to assess this issue.

Recommendations on Design and Implementation

- ***Siting Plants.*** Project proposals should comply with or exceed the California Coastal Commission's requirements to protect coastal land and ensure that facilities will not cause significant visual impact, or loss of access to beach or coastal areas and habitat.
- ***Energy Efficiency and Renewable Energy***. To reduce impacts on air quality and to help the region reach its climate goals, desalination facilities should install the most energy efficient technology available, incorporate renewable energy sources and mitigate against any remaining climate impact.
- ***Minimize and Monitor Marine Impacts***. Seawater desalination projects should use the most advanced technology available for seawater intakes and brine disposal. Baseline studies for each proposed seawater desalination plant site and rigorous monitoring programs should be implemented at the onset of a project. If necessary, processes or equipment should be adjusted to protect fragile marine environments based on monitoring data.

Recommendations on Planning

Desalination plants are large infrastructure projects that demand more energy and capital outlays than other local water sources. Due diligence is needed to ensure our region is factoring into its investment decisions the full potential of other less expensive local options with significant potential yield, such as conservation and recycling.

Similar to the Australian National Water Initiative, the San Diego region should consider creating a blueprint for a water supply strategy that optimizes economic, environmental and social outcomes. Some of the components of the plan would include the following:

- ***Better Understand How Much the Region Can Reduce its Demand for Water Through More Aggressive Conservation and Water Efficiency Efforts***. Using less water is the least expensive and the most environmentally friendly way to address water supply challenges, but the analysis of how much more we could conserve, and how to get there, is currently missing from the dialogue. A better understanding of this issue for the business, residential and agricultural sectors would help drive more accurate investment decisions.

- ***Determine the Value of Reliability and Availability in the Region's Water Supply***. What is the real risk of water supply disruptions or shortfalls, and what are customers in the region willing and able to pay to increase water reliability?

- ***Weigh Environmental Impacts and Benefits of All Water Supplies***. Human use of any water supply will have some environmental impacts. Ultimately, consideration of the potential impacts and benefits of desalination will need to be weighed against the impacts and benefits of other water supply alternatives (for example, it could be argued that localized environmental impacts from desalination would be less than impacts from water supplies pumped from the Sacramento-San Joaquin Bay Delta, but this analysis has not been done).

- ***Engage in Transparent, Regional Dialogue About Our Water Future***. Water managers, key stakeholders, regional planners, local decision makers and community members should *together* determine the region's water values and priorities. What does the region want its water supply to look like from the view of reliability, cost, quantity and quality? How do we want to weigh the factors in this report when making decisions about our future water supply? One opportunity to engage in dialogue is through the San Diego County Water Authority's new Urban Water Management Plan, a draft of which will be released in early 2011 for public comment.

In conclusion, while it is not a panacea for our region's water challenges, desalination can be a viable water source to include in San Diego County's water portfolio.

The region has an opportunity to optimize its water portfolio, like a financial portfolio. An optimized water portfolio would effectively provide the greatest yield at the lowest cost, while factoring in the variables of reliability, water quality, risk, environmental impact and energy. Desalinated seawater could be a reliable, drought-proof part of our portfolio, as long as any environmental impacts are minimized and mitigated and the region is willing to pay more for the reliability it provides.

Introduction

San Diego County water agencies are poised to add seawater desalination to the region's water supply portfolio. One plant already has permits to proceed and others are being proposed with the goal of diversifying the region's local water supply and increasing its reliability over the next 20 years. Debates about the costs, energy intensity and environmental impacts of seawater desalination have left some in the region uncertain about the potential of this source to help us meet our future water needs. Unfortunately, at times the discussion has become severely polarized, hampering a more productive dialogue about the future of desalinated seawater in our region's water portfolio. Meanwhile, the region's residents, businesses and farmers want decision makers and water managers to make informed decisions based on the best available data to move the region forward toward enhanced water security.

The region's residents, businesses and farmers want decision makers and water managers to make informed, rational decisions based on the best available data to move the region forward toward enhanced water security.

In this report, Equinox Center explains seawater desalination for the general public and for community leaders and policy makers who do not specialize in water management. Equinox Center has collaborated with experts to provide an independent, science-based review of the opportunities and challenges posed by this water source. We summarize the latest research about desalination facilities world-wide and recommend strategies on how the region should proceed when considering this seawater desalination. Our aim is to inform and help reframe the regional dialogue about what kind of role desalination could play in San Diego County.

Desalination in San Diego County

The Need to Diversify Water Supplies in San Diego County

The pursuit of water desalination in San Diego County must be considered in the context of the region's current local water supply challenges. Though its Mediterranean, semi-arid climate is the envy of much of the world, San Diego is not hydrologically blessed. The region's rainfall tends to be light, averaging only 10 inches annually along the coast, where the majority of the population lives. Therefore, precipitation can make up only a very small percentage of our total water supply.

The San Diego region imports over 80% of its water...but our historic reliance is coming under increased pressure that authorities do not expect will abate.

A study by the U.S. Geological Services (USGS) that systematically assesses the County's groundwater resources is due out by the end of 2011 and should give us a better picture of the available water underground. Historically, it has been believed that most of the County's groundwater aquifers are small, difficult to extract from, and have salt concentrations too high to be used for drinking water without treatment. And, as has been the case in recent years, San Diego County endures regular cycles of drought that affect groundwater and rainwater availability.

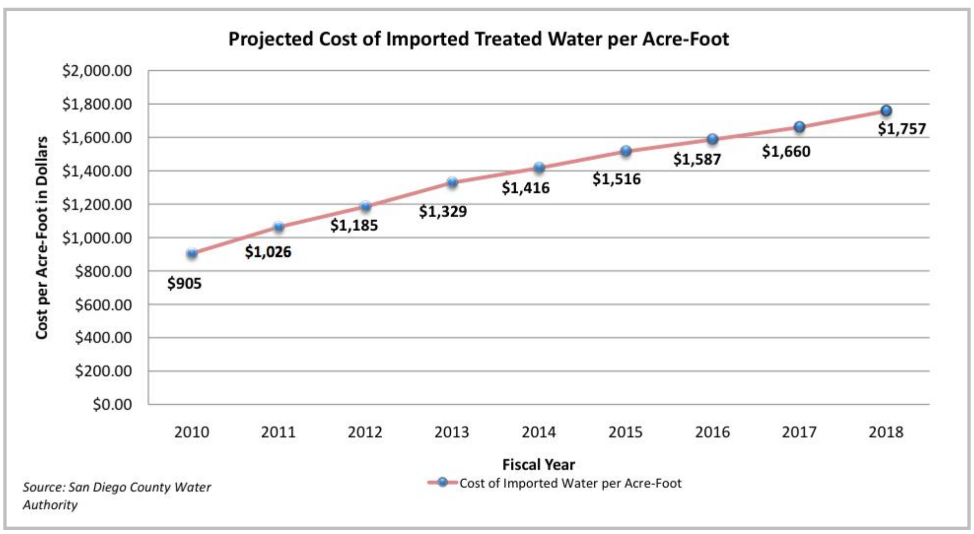
Consequently, we import over 80% of our water through the San Diego County Water Authority (SDCWA), mostly from the Colorado River and the State Water Project, located in Northern California's Sacramento-San Joaquin Delta. But our historic reliance on imported water is coming under increased pressure that authorities do not expect will abate.

A federal court ruling requires California to reduce water consumption from the Colorado River to comply with previously agreed upon water allocations. Lake Mead, one of the Colorado River's primary reservoirs, is at dangerously low levels. Studies from the Scripps Institute of Oceanography and the USGS have projected that the Colorado River may face delivery shortfalls in the future if climate models are accurate (Barnett and Pierce 2009).

Meanwhile, the State Water Project supply is at risk due to reductions ordered by courts and federal agency decisions aimed at protecting the Delta's endangered fish species. There are also major infrastructure issues that could result in saltwater intrusion into areas where water is pumped from the Delta to San Diego. In addition, the California State Department of Water Resources puts the probability of a major earthquake causing multiple levee failures in the Delta at 62% in the next 20 years (California Department of Water Resources 2009). An earthquake could also impact the integrity of the aqueducts that deliver water from both the Colorado River and Northern California.

The probability of a major earthquake causing multiple levee failures in the Sacramento-San Joaquin Delta (a primary source of San Diego's water supply) is 62% during the next 20 years...desalinated seawater is less vulnerable to such interruptions.

Price is another factor that leaves San Diego searching for alternatives. As water from Northern California and the Colorado River becomes scarcer, it also becomes more expensive. The SDCWA forecasts that imported water will cost approximately $1,757-per-acre-foot by 2018. This is nearly double its $900-per-acre-foot price tag in 2010.



To compound a limited and more expensive imported water supply, San Diego County faces upward pressure on demand from an increasing population. The San Diego Association of Governments (SANDAG) projects the population of San Diego County will increase by 650,000 by 2030, for a total county population of approximately 3.6 million. Current conservation efforts, cooler weather, the economic recession and increased water prices have reduced our region's demand for water by 18% in the past two years. However, conservation that occurs as a result of mandatory restrictions during drought periods generally does not reflect permanent behavior change and usage tends to increase after restrictions are lifted. Still, water managers believe at least some of the reduced consumption within the County will continue after the recession and the drought, as residents and businesses install more water efficient technologies and switch to low-water landscaping. In addition, state legislation passed in November 2009 has mandated that water authorities deliver a 20 percent per capita reduction in water use by 2020, but it is still unclear how much conservation could play a larger role in helping us deal with our water supply challenges. Although revised water savings projections could increase in the SDCWA's new Urban Water Management Plan due out in spring 2011, water authority staff believe that conservation will not suffice to meet the demand of a growing population, and that it must diversify its water supply portfolio with local "wet" water supplies.

Equinox Center has found that effective methods to incentivize conservation and water efficiency in the long term exist, including proper water pricing, such as steeply tiered price structures, which is addressed in Equinox Center's *Primer on Water Pricing*, available on our website. The Center plans to do more research in 2011 to gauge the true potential of water conservation and efficiency.

What is Seawater Desalination?

Clean and safe water is one of the most valuable commodities in the world and 97% of the water available on Earth resides in the oceans. Worldwide, there are more than 10,000 seawater desalination facilities producing over 13 million acre-feet of potable water per year (Desal Data 2010).

A variety of technologies exist that will desalinate seawater, producing one stream of potable water and another stream with a high concentration of remaining salts, typically referred to as *brine*.

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There are several categories of desalination technologies but over half of the seawater desalination plants in the world today use membranes. All the plants proposed for the San Diego region would use Reverse Osmosis (RO), which is a membrane technology. The process of RO uses high pressure to force seawater through membranes which separate water molecules from salt molecules. Although RO is the fastest growing seawater desalination technology in the world, thermal distillation processes have been used successfully in areas of the world with abundant sunshine and could be an option for this region. A more detailed description of RO and thermal distillation technologies appears in Appendix 1.

Desalination has an important history in San Diego County—in a sense the modern desalination business was born here. In 1969, the first plant to successfully demonstrate one component of the RO process was located at what is now Riverwalk Golf Course in Mission Valley (Burge 2009). The membranes used in the Reverse Osmosis process to filter brackish water or seawater are made by several local manufacturers and a number of other desalination-related companies that supply chemicals for the process and make pressure vessels for membranes are located in the region as well.

Current Status of Desalination Projects in San Diego County

Carlsbad Proposal

Poseidon Resources is proposing to build a 50 MGD (56,000 acre feet/year) desalination plant at the Encina Power Station in the City of Carlsbad. The desalination plant would be located on a site adjacent to the power plant and would use its intake and outfall infrastructure. The final Environmental Impact Report (EIR) was released in late 2005, and a small demonstration facility is in operation at the site. The Carlsbad City Council unanimously approved the project in May

2006. Nine local water districts, including Carlsbad Municipal Water District, Rincon del Diablo Municipal Water District, Olivenhain Municipal Water District, Vallecitos Water District, Sweetwater Authority, Valley Centre Municipal Water District, Santa Fe Irrigation District, Rainbow Municipal Water District and the City of Oceanside Municipal Water District, had signed water purchase agreements with Poseidon.

Although the project enjoys support from many public officials and water managers, several lawsuits and permit appeals were filed by environmental groups. Ultimately, the proposed plant received its final permits in May, 2009. However, in mid-2010, the project structure with the nine local districts that had signed purchase agreements with Poseidon was found to be financially infeasible. In addition, as a result of Water Authority litigation challenging the MWD rate structure, MWD has decided to defer execution of the Seawater Desalination Program agreement that would have provided incentive funding for the project.

The Water Authority has now stepped in to pursue a water purchase agreement with Poseidon, whereby the Water Authority would purchase the entire output from the project. Currently, Poseidon, the local agencies and the Water Authority are working to clear certain pre-conditions including the local agencies relinquishing their previous water purchase agreements. These pre-conditions must be satisfied before water purchase agreement negotiations can commence. The SDCWA board recently approved adding $500,000 to its 2011 budget to prepare and negotiate a water purchase agreement with Poseidon. Without a water purchase agreement, the Poseidon project is in jeopardy.

Camp Pendleton Proposal

The second potential desalination plant, proposed by the SDCWA, would also provide 50 MGD (56,000 acre feet/year) in its first phase. The modular design of the plant would allow for a phased expansion in size, with the possibility of the plant producing up to 150 MGD (168,000 acre feet/year) in the future. The plant as envisioned would be located at the southern end of Camp Pendleton, near the mouth of the Santa Margarita River.

A pre-feasibility/fatal flaw assessment was conducted in 2005, and the SDCWA will soon begin more detailed studies focused on how to bring desalinated water into SDCWA's water conveyance system, the energy supply for the proposed facility, intake and discharge options and marine biology studies. If approved, Phase 1 of the project is estimated to cost $1.2 billion (Yamada 2010). If both the Carlsbad and Pendleton plants are built, by 2020 together they could provide at least 90,000 acre feet/year. Depending on revised demand forecasts and conservation scenarios, this could represent between 10-15% of the County's total water supply.

Baja California, Mexico

Currently there are two bi-national seawater desalination projects under consideration in northern Baja California. Several water agencies have been exploring the idea of building a seawater desalination facility in Rosarito Beach, about 15 miles south of the U.S.-Mexico border, and importing at least some of the water from that facility to San Diego County for use. The Rosarito proposal has been studied by the SDCWA, the Metropolitan Water District, Southern Nevada Water Authority, and the Central Arizona Water Conservation District. At one point, the agencies were working under the umbrella of the International Boundary and Water Commission, which addresses border issues. One goal of the project would be to take pressure off the Colorado River, which supplies water to seven states and Mexico (Burge 2009).

A second plant at Rosarito Beach is also being considered and a private developer, NSC Agua, has a contract to build a desalination plant next to the power plant on Rosarito Beach. The capacity of the plant would be about 50 MGD, similar to Poseidon's proposed Carlsbad plant. The treatment facility would be designed, constructed, and operated in Mexico by a third party. Otay Water District would purchase excess desalinated water from the plant, potentially about 25

MGD, at the border and would convey it through a new pipeline to its customers. The Otay Water District is proceeding with negotiations and expects that the plant could be completed in about 5 years if all goes well (Posada 2010).

Assessing the Opportunities and Challenges of Seawater Desalination

Opportunities

Abundant, "Drought-proof", Water Source

Desalination projects produce water that is not affected by severe droughts, an attribute that is particularly valuable in our semi-arid, Mediterranean climate. If climate change models are accurate, we may be facing more severe and prolonged droughts in the future, further constraining other water supplies such as imported water, local surface water or groundwater. Relying on the Pacific Ocean for a portion of San Diego's drinking water would provide a stable resource that would not be contingent upon how much rain and snow has fallen in any one year.

A reliable supply is especially important for our business sector and economic development. Without reliability, water-dependent businesses (such as research facilities and biotech companies) may choose to relocate to areas with more available or less expensive supplies.

Over-dependence on imported water is not an optimal or sustainable solution for San Diego County. The Delta ecosystem is severely impaired due, in part, to the amount of water pumped out of it for use in Southern California. These impairments and other water rights issues could jeopardize the reliability of San Diego's water supply. In addition to drought and environmental or legal challenges, there is the danger that supply from Northern California or the Colorado River could be interrupted for months as a result of natural disasters such as earthquakes or wildfires. One of the most attractive aspects of desalinated seawater as a component of San Diego County's water supply portfolio, is that it is a local source that is less vulnerable to longer term fluctuations in reliability and emergency-based interruptions.

Without reliability, businesses that are dependent on clean, available water sources (such as research facilities and biotech companies) may choose to relocate to areas with more available or less expensive supplies.

A reliable water supply that is under local control is more valuable than one that is susceptible to interruption and that is one reason why water managers, businesses and others in the San Diego region may be willing to pay more for desalinated water or other local sources. The cost of supply interruptions could be significant to our region, though it is difficult to assign a monetary value to reliability. The Pacific Institute, a water think tank in Northern California, has created a method for valuing water reliability and it can be found here:
http://www.pacinst.org/reports/desalination/appendix_D.pdf.

Water Quality Improvements

The San Diego region is at the end of the pipelines for both the State Water Project and the Colorado River. The water San Diego obtains from these sources is affected by the release of treated wastewater from 350 public sewage treatment plants upstream. This imported water is often high in mineral content, reflected in a relatively high ratio of total dissolved solids (TDS) and often requires softening for use.

The quality of desalinated product water is typically very high, but depends on the raw water quality of the seawater, the treatment technology selected, and the level of treatment. RO treatment of seawater removes salt and other contaminants as well as minerals, and the EPA recognizes RO as a best available technology for water treatment (City of Huntington Beach 2010). The product water is close to distilled water quality.

Like all other water sources, seawater can contain regulated and unregulated chemicals as well as very low concentrations (almost undetectable) of endocrine disruptors, pharmaceuticals, personal care products (emerging contaminants) and toxins from marine algae. Studies have found that RO removes the vast majority of contaminants.

Desalinated seawater is of a higher quality than our current imported water supply, which has higher levels of TDS, sulfate, hardness, and disinfection byproducts than desalinated water.

However, some substances present in seawater, such as boron, may not be adequately removed in a first pass through the RO process. The State of California has set a Notification Level of 1 mg/l for boron and plants in California are designed to meet this guideline (Crisp 2008). Adjustments to the RO process, such as installing second pass through membranes and lowering the pH of the water, can provide effective boron removal (NAS 2008). There is evidence that levels of boron that meet the California guideline can still have a negative impact on vegetation and agriculture, so some regions are setting limits for boron at less than the 1 mg/l level, thus requiring at least a partial second pass RO process. Carlsbad set a boron limit of .75mg/l and the Poseidon plant will seasonally use a second pass RO process in the summer months (MacLaggan 2010).

Another issue related to water quality is that RO lowers both the calcium and carbonate concentrations in seawater, which produces product water that could, without proper post-treatment, be corrosive to water distribution pipes (Gleick, Wolff and Cooley 2006). This issue can be corrected by adding lime and other constituents to the water before it is distributed.

Overall, desalinated water would actually be of a higher quality than our current imported water supply, which has higher levels of TDS, sulfate, hardness, and disinfection byproducts than desalinated water (City of Huntington Beach 2010).

Public Support

Annual surveys conducted by the SDCWA from 2003-2009 to measure public knowledge and opinions of water issues indicate that a majority of the public (70-75%) support the concept of diversifying San Diego's water supply through seawater desalination. Many people in the region believe this is the single most critical thing that can be done to ensure a safe and reliable supply. The surveys show that conservation has also become increasingly important to the public as a mechanism to ensure water supply over the long term.

Economic Benefits of Desalination Projects

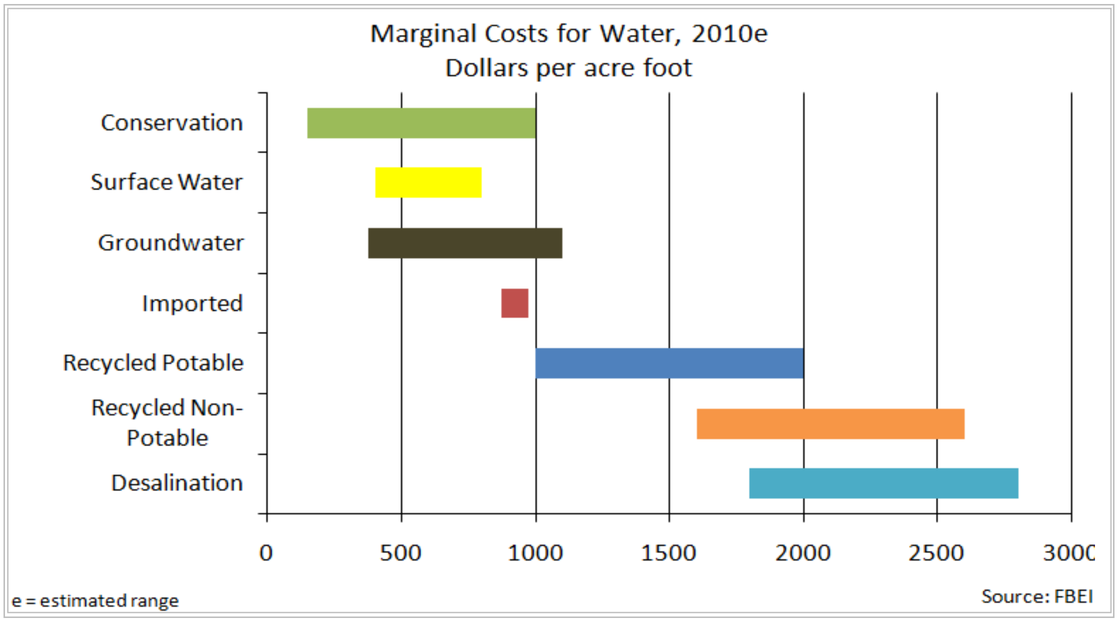
Like other large infrastructure projects, the construction and operation of desalination facilities will create jobs and bring in tax revenue. For example, Poseidon estimates the operating budget of the Carlsbad plant will be $46.6 million annually, and will create 2,100 construction jobs, 20 jobs to run the plant, and help support 400 indirect area jobs such as membrane manufacturing and chemical deliveries. Advanced treatment water plants built to recycle water use similar local technologies and chemicals.

The City of Carlsbad estimates that the Poseidon plant will bring $2 million in new property tax revenue from the redevelopment area. The city will also gain three key parcels of land near Agua Hedionda Lagoon that will increase public access to the beach and lagoon and could potentially stimulate tourism.

Challenges

Costs of Desalinated Water

According to research conducted for Equinox Center by Dr. Lynn Reaser, Chief Economist at the Fermanian Business and Economic Institute (FBEI), on the marginal costs of various San Diego Water sources, desalinated water is currently the most expensive of the region's current and potential major water sources.



It is worth noting that published data on costs are not straight forward because costs and underlying assumptions are rarely reported consistently and some cost parameters are not reported at all. After consulting with various experts and studying a wide range of reports, Dr. Reaser used her best professional judgment and economic assessment to compare consistent data and determine current and future marginal cost estimates for each source of water in the San Diego region.

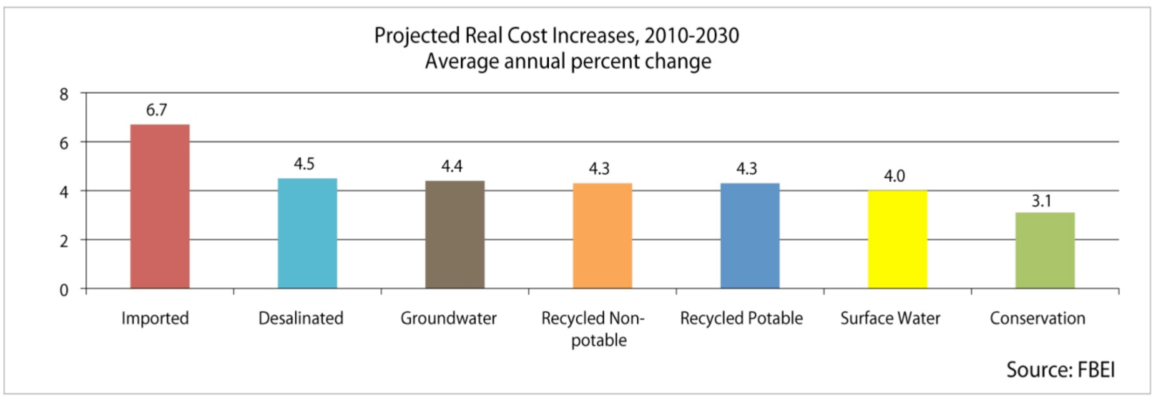
Some desalination proponents believe that the range of costs for seawater desalination may be comparable to the cost of potable recycled water in San Diego County, but it is difficult to determine exact numbers at this point because of the lack of operational projects in the County. The Indirect Potable Reuse demonstration project currently being conducted by the City of San Diego will provide more accurate field data on the cost of purified recycled water within the next 12-18 months.

The estimates in the chart above are not project specific, and actual costs will vary with each proposed project because every desalination plant has a unique design, site condition, energy need and financing package. A significant part of the variability in costs of desalination is attributed to the distances that sea water and potable water must be moved. If a desalination plant is connected to a power plant, it can use the outflow from the once-through cooling (OTC) system of the power plant to dilute the salty brine from the desalination plant before it is discharged back to the ocean. Where dilutant water for the brine needs to be brought to the plant, costs are substantially higher. Ocean water intake mechanisms also have a significant impact on costs, as do energy prices.

As a case in point, if built, the Poseidon plant will be co-located with the Encina Power Plant in Carlsbad and will use the plant's intakes and outfalls. If a purchase agreement is negotiated, the SDCWA plans to pay slightly less for the desalinated water from the plant than the range of Dr. Reaser's estimate. It is important to note however, that California regulators have ruled that OTC systems must be phased out at power plants. The Carlsbad desalination plant has a permit to use the Encina Power Station's OTC system to draw in water, even if the power station stops using the intake structure. However, regulators could apply the same ban to desalination activities in the future and Poseidon would have to reengineer its intake mechanism (Luster 2010). Poseidon has already included funds in its project budget to do so if necessary.

Because of the higher cost of desalination, many desalination projects receive subsidies that help make the water more affordable to customers. As noted earlier in this paper, MWD has decided to defer execution of the Seawater Desalination Program agreement that would have provided incentive funding for the Poseidon plant in Carlsbad. The SDCWA's board has authorized its staff to negotiate a water purchase agreement with Poseidon, with a ceiling price of $1,600/acre-foot. After 10 years, the SDCWA would have the option to buy the plant outright.

Future estimates of costs also vary widely. The cost of imported water is expected to rise faster than any other source of water, making other sources such as desalination look more feasible from an economic perspective (see chart below). FBEI's study shows desalinated seawater costs rising slightly faster than other local sources. This is due primarily to assumptions made about energy costs.



Advances in technology over the past 15 years have reduced energy requirements and helped to reduce the cost of seawater desalination. It is likely that continuing advances in technology will reduce energy needs in the future. However, FBEI researchers believe that energy costs will increase significantly in the next 10-20 years due to increased global demand on a limited resource, and that continued improvements in desalination technology will not be able to offset higher energy costs.

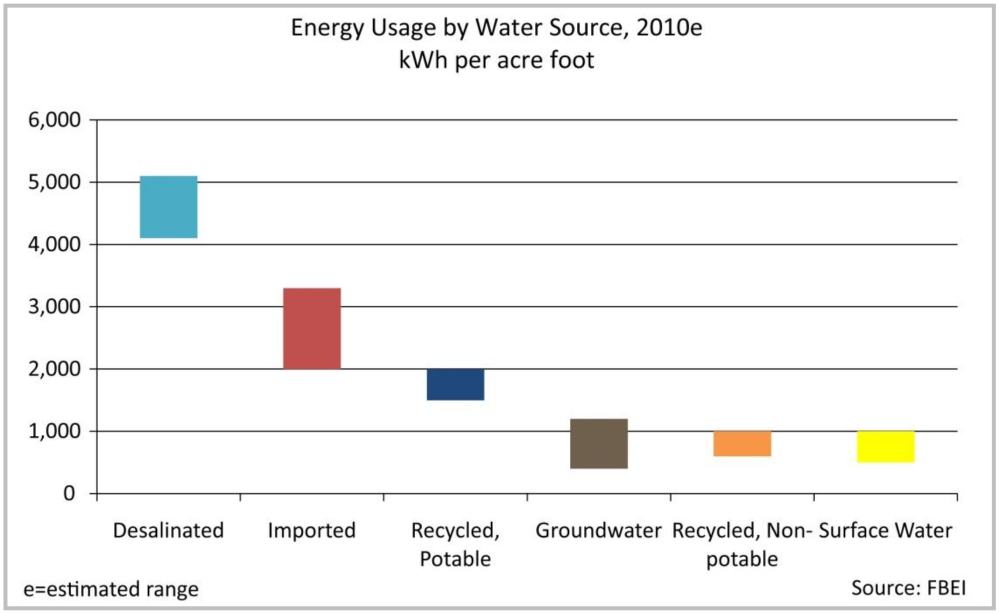
Another perspective on costs is that of "opportunity" cost. In an economic climate where financial resources are scarce, and where we may not be able to pursue all our water supply options at once, price is a critical factor. Some argue that the opportunity cost of pursuing more expensive sources of water, such as multiple seawater desalination plants, is a decrease in funding for less expensive ways to meet our water challenges, such as conservation incentives. There is no question that the region will have to pay more for almost all new supplies of water in the future due to the scarcity of water in San Diego County and in the arid West. However, the question of whether we have a "loading" priority for how we develop new supplies, and thus how we spend consumer and taxpayer dollars, should be openly and transparently discussed going forward.

Energy Requirements for Desalinated Water

All seawater desalination technologies require energy, both electricity and heat, to separate salt from water. In fact, energy is the largest single variable cost for a desalination plant, varying from one-third to more than one-half the cost of produced water (Chaudhry 2003).

Energy is the largest single variable cost for a desalination plant, varying from one-third to more than one-half the cost of produced water.

RO technology uses less energy than thermal desalination, yet still accounts for 44% of the typical operating costs of an RO plant (Semiat 2000). Compared to other water sources, the range of energy needed to produce one unit of desalinated water is high.



Numerous factors impact energy use. These include:

- Seawater temperature and salinity;
- Site elevation above sea level and site topography;
- Drinking water quality targets (in particular, salinity, boron and bromide);
- Plant design and layout;
- Type of energy recovery system employed (turbines versus work exchangers and pressure exchangers);
- Type and size of pumps and motors;
- Operational flexibility and plant operating modes (full load or part load); and
- Distance treated drinking water needs to be pumped, including to regional water distribution systems.

As desalination becomes more widely used, it is expected that improvements in technology will reduce the amount of energy required. The U.S. Navy recently announced that it has developed new desalination technology for its ships that reduces the amount of energy needed to produce freshwater for use on its vessels by 65% (Office of Naval Research 2009). It is also becoming standard practice for new desalination installations to employ the most stringent energy-recovery practices and new technologies to become more energy efficient.

In addition, a number of new plants [see Perth example in case study below, and plants in Sydney and Melbourne Australia] have installed renewable energy sources such as wind or solar, in some cases making themselves carbon neutral. Other renewable energy sources such as geothermal, ocean thermal energy conversion, and wave and tide power are being considered in various parts of the world when local conditions are appropriate. Solar-powered desalination coupled with water reuse is a centerpiece of Masdar, an initiative in the United Arab Emirates to build the world's first carbon-neutral city. Other plants, such as a new one in London, are using biodiesel-fired generators.

The use of renewable energy sources for seawater desalination has not yet been studied in San Diego County, though the SDCWA will examine the potential of using alternative sources of energy for the proposed Camp Pendleton plant. Even if desalination facilities use renewable energy however, the potential environmental impacts and costs of additional alternative energy facilities must still be taken into account.

Impact on the Environment

- ***Marine Life***. The potential impact on marine life is dependent on which type of water intake system is used, the siting of the intake system, and the make-up of the surrounding ecosystem. Historically, marine life impingement and entrainment have been considered to be the most significant adverse environmental impact of seawater desalination (Pankratz 2010). In older types of intake structures, marine organisms, such as juvenile and adult fish and invertebrates, can be killed on the intake screen (*impingement*) where the seawater is drawn into the plant.

  Entrainment can occur when organisms small enough to pass through the intake screens, such as plankton, eggs, larvae, and some fish, are killed during processing of the salt water in the desalination plant. Entrainment reduces the number of eggs that become juvenile fish, and the number of adults that are available for breeding. Scientific studies have had difficulty quantifying the exact effects of entrainment on fish populations because of lack of data, modeling limitations, and uncertainties about other factors that affect the survival of fish eggs and larvae (Rose 2000; California Energy Commission 2008).

  Recent studies indicate that newer technologies such as finer mesh screens, aquatic filter barriers and velocity caps over intakes can significantly reduce the effects of impingement and entrainment (California Energy Commission 2008). Pilot projects such as the one launched by the West Basin Municipal Water District in LA County, and video monitoring of operating desalination facilities in Australia show virtually no impingement on new intake structures.

  Estimates of the proposed Carlsbad plant's impingement impact range from 3 to 15 lbs of marine organisms/day. To offset damage, Poseidon was required to restore 55.4 acres of estuarine wetland in southern California (California Coastal Commission 2009). Poseidon has included funds in its project budget to do so and also plans to eventually upgrade the Encina intake structure to reduce impingement and entrainment.

  The SDCWA is considering new technology such as subsurface intakes to reduce or eliminate any potential impingement effects of the proposed Camp Pendleton facility. For more information on intake technology and impingement and entrainment, please see the Appendix.

- ***Brine Disposal***. Another issue related to environmental impacts of desalination is how the plant disposes of its brine. Brine typically contains twice as much salt as the feedwater and has a higher density. In addition to high salt levels, brine from seawater desalination facilities can contain very low concentrations of constituents typically found in seawater, such as manganese, lead, boron, iodine. It can also contain chemicals and impinged and entrained marine organisms from the desalination process, as noted above (Talavera and Ruiz 2001).

The effects of brine discharge into oceans, seas, and estuaries appear to vary widely. The impacts depend on the site-specific environment, the organisms examined, the amount of dilution of the concentrate, and the use of diffuser technology.

Discharging brine back into the ocean is the most common and least expensive disposal method for coastal desalination plants. Brine discharged into the ocean can be pure, mixed with wastewater effluent, or combined with cooling water from a co-located power plant. Ocean discharge assumes that dilution of brine with much larger volumes of ocean water will reduce toxicity and ecological impacts. There is evidence this is true, especially in open ocean environments where significant mixing can occur. However, there is a very limited amount of long term research about the environmental impacts of brine discharge into the oceans. To date, only a few comprehensive studies of brine discharge have been completed, and even fewer have been done on the West Coast of the U.S. (Cal AM and RBF Consulting 2005).

As new desalination plants are proposed, there is a need for more data on the cumulative impacts of brine discharge and the chemicals contained in it on the marine environment (NAS 2008). The more environmentally sensitive installations, such as the desalination plant in Perth, Australia, use multiple brine diffusers at great depths, which so far appear to reduce or possibly even eliminate harmful impacts on sea life due to brine disposal. Site specific impact evaluations and required mitigation should be performed for every proposed desalination plant, because salinity levels and organisms tolerance to different levels varies with every ecosystem.

The effects of brine discharge into oceans, seas, and estuaries appear to vary widely and there is a limited amount of long term research about the environmental impact, but research suggests that with proper dilution, short term impacts can be eliminated in certain environments.

At Carlsbad, Poseidon plans to take in approximately 300 MGD in order to substantially dilute the 50 MGD of brine that will be produced for 50 MGD of drinking water. Poseidon contracted with scientists at UCSD's Scripps Institute of Oceanography to conduct environmental impact studies of increased salinity, and those studies showed no perceptible impact on sea life (Graham 2005).

In addition to brine disposal in the ocean, up to 500 pounds per day of sludge from the Poseidon plant will be conveyed as a liquid to the local wastewater collection system for further treatment and disposal at the Encina Water Pollution Control Facility.

- ***Climate Change and Air Quality***. Desalination plants that rely on fossil fuel-driven utility grids have drawn criticism for their high energy needs, which can contribute to climate change and worsen air quality.

  Taking an average of the energy usage numbers for desalination compiled by Dr. Reaser at FBEI (4,500 kWh/acre-foot), and San Diego Gas and Electric's (SDG&E) greenhouse gas (GHG) conversion factor of 739 lbs C02e/MWh of electricity used, Equinox estimates that a plant that produces 50,000 acre-feet of water per year will generate about 179 million lbs C02e/year. This is a rough estimate but according to our calculations, about equal to 0.2%, of the total GHGs produced in the county (EPIC 2010), or the GHGs emitted in supplying about 36,000 households in San Diego County with electricity.[1]

[1] We have added 7.5% to both the electricity usage for the theoretical desalination plant and to the calculation for typical household electricity usage (from California Energy Commission for SDG&E service area) to account for transmission losses. This is standard practice, according to EPIC.

Some of these emissions can be reduced or mitigated through new energy recovery technologies, tree plantings or other mitigation techniques. However, given the San Diego region's commitment to the State of California's clean air and climate goals, the issue of GHG and other air emissions generated by seawater desalination plants is one that needs to be thoughtfully considered before new plants are constructed. For example, despite planned mitigation efforts at Poseidon's Carlsbad plant, according to the Poseidon Environmental Impact Report (EIR), the project will contribute to a significant cumulative impact on air quality related to particulate matter, ozone (for which the San Diego air basin is in non-attainment) and ozone precursors. There are no feasible mitigation measures that could be applied to the project that would reduce this cumulative impact to below a level of significance (Poseidon Resources 2005).

In addition to considering the impact of proposed desalination plant emissions on our region's climate goals, it is also necessary to consider how climate change may impact these plants. Most scientists agree that climate change will affect water resources. For example, according to the San Diego Foundation's 2050 Climate Study, sea level is projected to rise by up to 12-18 inches by 2050. A rise in sea level over several decades may over the lifetime of the project have some effect on desalination structures built adjacent to coastal areas. And, depending on the location of the seawater intake, the temperature of the feedwater may increase slightly, requiring small changes to the desalination process. Although these direct impacts to desalination structures and processes appear to be small, they should be understood and taken into account prior to the design of major desalination facilities (NAS 2008).

Coastal Land Development

The impacts of coastal desalination plants extend beyond the ocean, and into the realm of coastal development and land use. The California Coastal Commission regulates development along the California coast, stating in their Coastal Act that "public work facilities be sized based on the ability to maintain, enhance, or restore coastal resources, and that development allow all coastal resources to remain viable" (CCC 2004).

Any type of coastal development can alter views, beach access, and take up valuable shoreline that could be used for recreation, tourism, or nature conservation (Gleick *et al.* 2006; Einav *et al.* 2002). San Diego is known for its long stretches of beaches with ample coastal access. Our beaches are synonymous with our quality of life. They are also an economic engine that attracts millions of tourists here every year, pumping money into our local economy. San Diego's waterfront is a limited resource that deserves to be protected and balanced with our region's growing need for water.

One alternative to siting desalination plants on the coast would be to build them slightly farther inland, so they do not sit on the shore or in direct sight. This would increase the cost and energy requirements to move the water further distances, yet may be an acceptable expense to preserve our unique coastal areas.

In the case of the Poseidon plant in Carlsbad, the facilities sit on a commercial/industrial site and are set back from the Pacific Coast Highway. The major facility is designed to look like an office building to have minimal aesthetic impact.

Privatization of Water

Some groups such as Food and Water Watch have raised concerns about the privatization of drinking water sources. While some seawater desalination plants are constructed and owned by public entities such as a regional water authority or water district, others are designed, built and operated by private companies, but the public entity such as a water district or regional water authority actually retains ownership of the plant. However in some cases, a private corporation not only builds and operates but also owns the plant (as would be the case in the Poseidon plant in Carlsbad) and the water it produces. Critics of the privatization of water argue that this scenario reduces public accountability and can lead to higher prices because private companies are answering to the demands and expectations of company shareholders which may be at odds with managing the supply for the public good. There are clearly unresolved conflicts over private ownership and operation of seawater desalination facilities. This issue is outside the scope of this paper but should be included in any regional discussions about the region's water future.

Conclusion

San Diego County has an opportunity to use desalinated seawater as a viable component of its diversified water portfolio to meet our growing water demand. Its attractiveness as a local source of water that is not governed by weather or subject to California's complicated water rights law and history is indisputable. It scores high in the area of availability and reliability, both of which are key to San Diego's future as our businesses and population continue to grow.

Seawater desalination also has some challenges, including its high energy usage and financial costs, and the need to design it to properly mitigate any impacts on our environment.

The National Academy of Sciences reports that desalination may be less detrimental to the environment than many other types of water supply, though they caution that more research is needed to draw definitive conclusions. Even with more certainty about environmental impacts, costs may continue to be a challenge for desalination compared to other sources. Advancements in technology will likely help contain costs of seawater desalination over time, but the possibility of higher energy costs due to increased global demand could put increased upward pressure on the price of desalinated seawater in the longer term.

Below is a summary of Equinox Center's findings and recommendations regarding seawater desalination as a potential source for the San Diego region.

Findings

- The quality of water from seawater desalination is quite high--better than our current treated imported water supply.
- Seawater desalination would provide a drought-proof water source and reduce the region's dependence on imported water and other sources (groundwater, surface water) that will likely be affected by climate change.
- Seawater desalination projects could have economic benefits to the region as the process employs technology that is locally manufactured in San Diego County.
- Seawater desalination generally enjoys public support in the region, although there are some concerns about some seawater desalination projects resulting in the privatization of our drinking water supply.
- On average, desalinated seawater currently has a higher marginal cost compared to other sources, and this could potentially have a negative economic impact on the region if water prices increase significantly as a result of adding this source in large quantities to the region's supply.

- The energy intensity of seawater desalination is higher than other water sources. If extensive development of seawater desalination in San Diego County is pursued, it may jeopardize the region's climate and air quality goals. The use of renewable energy sources to supply power to desalination plants could help mitigate this 9issue.

- The environmental impacts of seawater desalination are dependent on the siting of the facility, the design of the plant and technology used, and the characteristics of the surrounding habitat and ecosystem. With good design that utilizes the most advanced technologies, many of these impacts can be mitigated.

- Many of the known marine impacts can be reduced or mitigated, but there is still uncertainty about longer term impacts of brine disposal and entrainment on sensitive marine ecosystems. More studies will need to be done over time to assess this issue.

Provided that the best possible design and environmental mitigation strategies are employed, desalinated seawater can be a viable water source for San Diego to add to its local portfolio.

Recommendations on Design and Implementation

- ***Siting Plants.*** Project proposals should comply with or exceed the California Coastal Commission's requirements to protect coastal land and ensure that facilities will not cause significant visual impact, or loss of access to beach or coastal areas and habitat.

- ***Energy Efficiency and Renewable Energy***. To reduce impacts on air quality and to help the region reach its climate goals, desalination facilities should install the most energy efficient technology available, incorporate renewable energy sources and mitigate against any remaining climate impact.

- ***Minimize and Monitor Marine Impacts***. Seawater desalination projects should use the most advanced technology available for seawater intakes and brine disposal. Baseline studies for each proposed seawater desalination plant site and rigorous monitoring programs should be implemented at the onset of a project. If necessary, processes or equipment should be adjusted to protect fragile marine environments based on monitoring data.

Recommendations on Planning

Desalination plants are large infrastructure projects that demand more energy and capital outlays than other local water sources. Due diligence is needed to ensure our region is factoring into its investment decisions the full potential of other less expensive local options with significant yield, such as conservation and recycling.

Similar to the Australian National Water Initiative, the San Diego region should consider creating a blueprint for a water supply strategy that optimizes economic, environmental and social outcomes. Some of the components of the plan would include the following:

- ***Better Understand How Much the Region Can Reduce its Demand for Water Through More Aggressive Conservation and Water Efficiency Efforts***. Using less water is the least expensive and the most environmentally friendly way to address water supply challenges, but the analysis of how much more we could conserve, and how to get there, is currently missing from the dialogue. A better understanding of this issue for the business, residential and agricultural sectors would help drive more accurate investment decisions.

- ***Determine the Value of Reliability and Availability in the Region's Water Supply***. What is the real risk of water supply disruptions or shortfalls, and what are customers in the region willing and able to pay to increase water reliability.

- ***Weigh Environmental Impacts and Benefits of All Water Supplies***. Human use of any water supply will have some environmental impacts. Ultimately, consideration of the potential impacts and benefits of desalination will need to be weighed against the impacts and benefits of other water supply alternatives (for example, it could be argued that localized environmental impacts from desalination would be less than impacts from water supplies pumped from the Sacramento-San Joaquin Bay Delta, but this analysis has not been done).

- ***Engage in Transparent, Regional Dialogue About Our Water Future***. Water managers, key stakeholders, regional planners, local decision makers and community members should *together* determine the region's water values and priorities. What does the region want its water supply to look like from the view of reliability, cost, quantity and quality? How do we want to weigh the factors in this report when making decisions about our future water supply? One opportunity to engage in dialogue is through the San Diego County Water Authority's new Urban Water Management Plan, a draft of which will be released in early 2011 for public comment.

*In conclusion, **while it is not a panacea for our region's water challenges, desalination can be a viable water source to include in San Diego County's water portfolio**. Currently, the SDCWA is in discussions with Poseidon to determine whether a water purchase agreement can be designed to benefit the region. Before considering additional large seawater desalination facilities beyond Poseidon, the region would benefit from an open, information-based dialogue to create a blueprint for the region's water future that would better define the region's water priorities and the appropriate role for more desalination projects in the region.*

*The region has an opportunity to not only diversify its water portfolio, but to also optimize it, like a financial portfolio. **An optimized water portfolio would effectively provide the greatest yield at the lowest cost, while factoring in the variables of reliability, water quality, risk, environmental impact and energy. Desalinated seawater could be a reliable, drought-proof part of our portfolio, as long as any environmental impacts are minimized and mitigated and the region is willing to pay more for the reliability it provides.***

Appendices

I. Lessons Learned: Two Case Studies

Tampa Bay, Florida

In March 1999 plans for the 25 MGD Tampa Bay Seawater Desalination facility in Florida, developed by Poseidon Resources, were approved. At the time it was one of the largest seawater desalination plants ever proposed for the United States. Aided by Florida's extremely low energy costs and lower than typical seawater salinity, the original agreement called for desalinated water to be delivered at an unprecedentedly cheap wholesale cost of $557.20/acre-foot or $0.45/cubic meter for the first year. Over 30 years, the average cost was projected to be $677.77/acre-foot or $0.55/cubic meter. In 2004, the project revised its estimate up to $827.66/acre-foot of water produced. In 2010, the actual cost was $645.18/acre-foot, with costs expected to increase to $993.84/acre-foot in 2011 due to a steep increase in energy costs (Vattner 2010).[2]

Touted as a breakthrough in low-cost desalination, getting the plant into operation was rife with problems caused by contractor bankruptcies unrelated to the project. The plant finally went on-line in 2007 but only in February 2010 did the plant meet the operating performance milestones required for co-funding by the Southwest Florida Water Management District of producing 25 MGD for 120 consecutive days and of averaging 20 MGD for 12 consecutive months.

The most important lesson from Tampa Bay is that the developer must choose partners that are technically competent, experienced in seawater desalination and financially sound. (Pankratz)

Much of the difficulty associated with the plant was the result of the mix of partners involved. According to Tom Pankratz, a desalination consultant and editor of the Water Desalination Report, who reviewed documents from the project and subsequent lawsuit, the most important lesson from Tampa Bay is that the developer must choose partners that are technically competent, experienced in seawater desalination and financially sound.

The original contractor for the project was S&W Water, LLC, a consortium between Poseidon Water Resources LLC and Stone & Webster. However, in 2002, with the project fully designed, permitted and almost a third of the construction complete, Tampa Bay Water, the local public water utility, decided to buy the project outright from Poseidon. The plant failed several performance tests in 2003. In 2004, Tampa Bay Water brought in Acciona Agua and American Water to get the plant up and running. The new partners made significant changes to the original design, and in 2009 the plant was running at a capacity of 16 MGD. However, the Tampa Bay Water Authority recently announced that because of adequate rainfall and the expense of running the plant due to higher energy costs, in 2011 the plant will only be producing 4 MGD.

Poseidon is also the developer of the Carlsbad plant. This time, Poseidon chose Israeli Desalination Engineering (IDE), which has built large seawater desalination plants in Israel, to be in charge of process engineering. However, as noted elsewhere, some financing issues have recently cropped up which put the viability of the plant into question.

Perth, Australia

[2] These costs reflect ***variable operating costs*** only, unlike FBEI estimates appearing elsewhere in this report, which include capital costs and financing costs. 1 acre-foot=325,851 gallons.

Driven by the worst drought on record, authorities in Perth working with Multiplex-Degrémont Joint Venture built the country's first large-scale desalination facility. The $387 million, 38 MGD plant was constructed in 18 months.

The Perth Seawater Desalination Plant (PSDP), the largest outside the Middle East, is increasingly regarded as a model for future sustainable seawater desalination plants globally (Crisp 2008). It has addressed many of the biggest criticisms of seawater desalination: high cost and energy consumption (potentially of fossil fuels), and impact on the marine environment. Despite this, the additional cost for the average residential customer is $34 per year, or less than $0.60 per week.

The Perth, Australia plant incorporates the most advanced technology to minimize climate, air quality and marine environment impacts, while still being cost-effective.

A recently completed 82 megawatt (MW) wind farm supplies over 272 gigawatt hours (GWhr) of energy per year to Perth's electricity grid, of which PSDP will consume only 185 GWhr. Furthermore, the PSDP's novel, low energy consumption design, incorporating energy recovery devices, requires less than 4810.6 kilowatt hours per acre-foot (kWh/acre-foot). The theoretical minimum amount of energy required to remove salt from a liter of seawater using RO is around 1233.5 kWh/acre-foot, but the industry's best practice is 3700.5 kWh/acre-foot, with some plants using up to 30837.6 kWh/acre-foot.[3]

To protect its marine environment, PSDP uses slow speed open intakes (Water Corporation 2010) and returns the brine 470 meters into the ocean via a 40-port diffuser, with nozzles spaced at five meter intervals. The mechanism is intended to ensure that the salinity of the discharge is effectively no different from the naturally occurring seawater. Extensive real-time monitoring in Cockburn Sound will continue together with annual marine habitat mapping to ensure that any long-term impacts of the project continue to be managed.

II. Reverse Osmosis and Thermal Desalination

- Membrane technologies such as RO that can desalinate both seawater and brackish water, and can also remove microorganisms and many organic contaminants, generally have lower capital costs and require less energy than thermal systems. RO is the technology being proposed for both of the San Diego County plants currently under consideration.

  - ***Reverse Osmosis****.* Reverse osmosis uses pressure on saltwater to force fresh water through a semi-permeable membrane, leaving the salts behind. The amount of desalinated water that can be obtained ranges between 30% and 85% of the volume of the input water, depending on the initial water quality, the quality of the product needed, and the technology and membranes involved. The energy requirements for RO depend directly on the concentration of salts in the feedwater and, to a lesser extent, on its temperature. Because no heating or phase change is necessary for this method of separation, the major use of energy is for pressurizing the feedwater. As a result, RO facilities are most economical for desalinating brackish water. The cost of producing fresh water increases as the salt content of the source water increases. Nonetheless, for all considerations of large seawater desalination facilities—capital expenditure, operations & maintenance, and cost per 1,000 gallons of treated water based on 20 to 30 years of operation—**Sea Water Reverse Osmosis (SWRO)** is less expensive than

[3] 1 cubic meter=0.0008107 acre-foot

thermal methods. In fact, for both seawater and brackish water, RO has become the world's fastest growing desalination method.

- ***Thermal Processes****.* In the simplest approach, water is heated to the boiling point to produce the maximum amount of water vapor. The concept of distilling water with a vessel operating at a reduced pressure has been used for well over a century. Until advances were made in membrane technology, thermal processes were the primary technology used for desalinating seawater, primarily in the Middle East. Thermal desalination systems can produce water with much lower salt content than membrane systems, typically less than 25 parts per million (ppm) total dissolved solids (TDS) compared to less than 500 ppm in membrane systems. Just over 40% of the world's desalinated water is made using thermal processes.

III. Intake Options and Impact on Marine Life

Intake systems fall roughly into two types: open ocean (includes surface intakes and submerged intakes) and indirect intakes such as subsurface or beach wells. Historically, it has been seen as advantageous for seawater desalination plants to co-locate with seaside power plants in order to use the same surface intake mechanism the power plants use to take in water for their once-through cooling (OTC) systems. However, open ocean intakes often used for OTC systems, frequently incite public opposition due to the damage they can cause to marine life.

The number of marine organisms trapped on intake infrastructure varies considerably with the intake design, the volume and velocity of feedwater and the use of mitigation measures developed to minimize the impact.

In some cases, marine organisms, such as juvenile and adult fish, invertebrates, birds, and even mammals, are killed on the intake screen (*impingement*). The number of impinged organisms varies considerably with the intake design, the volume and velocity of feedwater and the use of mitigation measures developed to minimize the impact. For example, if intake velocities are sufficiently low, fish may be able swim away to avoid impingement. The fate of impinged organisms also differs among marine species, age, and water conditions. Some hardy species may be able to survive impingement but for other less robust species or juveniles the survival rate may be less than 15% (Pankratz 2010).

Entrainment occurs when organisms small enough to pass through the intake screens, such as plankton, eggs, larvae, and some fish, are killed during processing of the salt water. Impingement and entrainment reduce the numbers of eggs that become juvenile fish, and the number of adults that are available for breeding.

Recent improvements to open ocean and submerged intakes have been shown to reduce impingement by up to 80% (Pankratz 2010), and if a desalination plant co-locates with a power plant and uses the same intake system, it minimizes additional impingement and entrainment.

It is important to note that California regulators have ruled that OTC systems must be phased out at power plants. The Carlsbad desalination plant has a permit to use the Encina Power Station's OTC system to draw 300 MGD, even if the power station stops using it. However, regulators could apply the same ban to desalination activities in the future and Poseidon would have to reengineer its intake mechanism (Luster 2010).

Subsurface intakes, which include infiltration galleries and horizontal and vertical beach wells, are considered by many to be the environmentally superior option (Pankratz 2010).

This design can reduce or eliminate marine life impingement and entrainment by using sand as a natural filter. Desalination plants using this design also require less chemical pre-treatment of the feedwater. Beach wells, however, have some limitations; they require a gravelly or sandy substrate and appear to have limited intake volumes (Pankratz 2010). They can also damage freshwater aquifers and the beach environment.

SDCWA is studying two intake options for the proposed Camp Pendleton plant: an open ocean wedge-wire screen and deep infiltration gallery tunnel collector wells (Yamada 2010). Studies show that the wedge-wire screen technology can reduce impingement and entrainment by up to 80% from traditional intake technology, but SDCWA will be conducting site specific studies.

***Image 1**: Open-Ocean Wedge-Wire Intake Screen (Lopez 2010)*

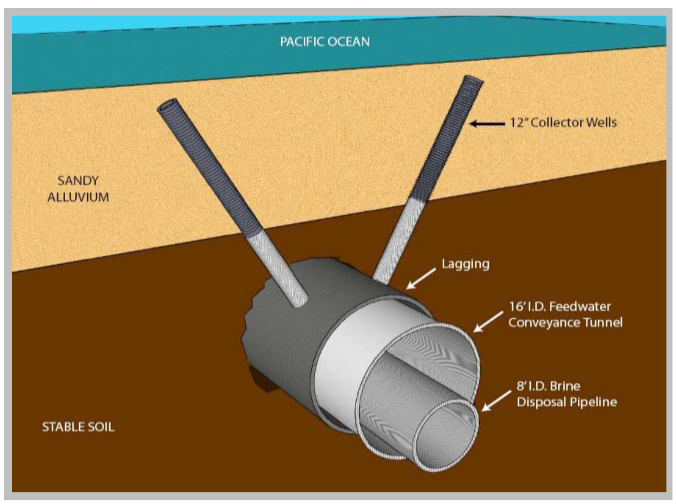


***Figure 1:** Graphic of a deep-infiltration gallery (DIG) tunnel collector well (Lopez 2010)*

The infiltration gallery design would consist of approximately 30-90 deep-infiltration gallery (DIG) tunnel collector wells installed in a trench on the ocean floor that is then backfilled with a gravel pack or filter materials after the screens are installed into the ocean bottom. Such wells are designed to reduce marine life impact and reduce the need for pre-treatment of seawater, but they are also more costly to install. (Camp Pendleton Seawater Desalination Project Feasibility Study, SDCWA)

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