

UNIVERSITY OF DENVER

Water Treatment Options for San Diego County

Comparing Alternative Water Sources

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Abbreviations

AF acre foot

AFY acre foot a year

BLM Bureau of Land Management

CBA Cost Benefit Analysis

CDP Carlsbad Desalination Plant/ Project

DoI (US) Department of the Interior

GPCD gallons per capita per day

MGD million gallons per day

NPV net present value

O&M operations and maintenance

SDR social discount rate

RO Reverse Osmosis

SDC San Diego County

SDCWA San Diego County Water Authority

TDS total dissolved solids (particulate matter dissolved in water)

TSS total suspended solids (particulate matter in water)

USGS United States Geological Survey

UV ultraviolet light (treatment process)

Executive Summary

Population and climactic pressures in the County of San Diego will cause water shortages in the next 15 years if no action is taken. The following memorandum examines three alternative approaches to filling this water gap through infrastructure projects. Given the net present value and amount of water the projects create it is this memorandum's recommendation that the County moves forward with overhauling its wastewater treatment facilities. Over time it will prove to be the more financially reasonable option not only for the water authority but also rate payers, urban, and agricultural users.

Problem Definition

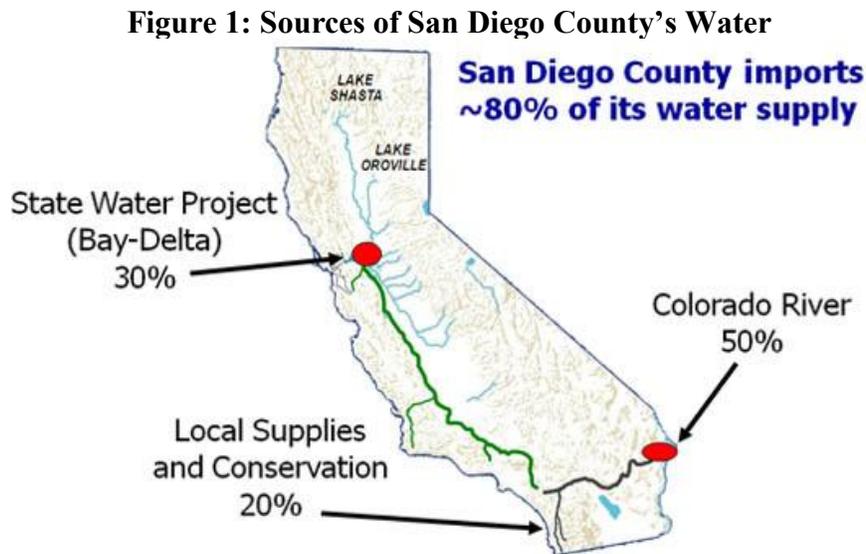
Due to rapidly growing population, increased climactic variability, and higher competition for water supplies, the County of San Diego County must find new sources of water to meet its future needs.

Introduction

In 2008 the San Diego County Water Authority released its Annual Strategic Plan regarding the future of water planning and delivery in the region. The most important components of the plan are: increase water conservation, recycling, and diversification of sources.¹ Due to a combination of price increases, drought, and conservation successes, the goal of reducing per capita water consumption was met in 2010 and use levels have largely stabilized. This has increased the focus onto water source diversification. Currently, 80% of San Diego's water is imported from outside the region. Domestic sources account for 20% of the water

¹ San Diego County Water Authority. Strategic Plan. Strategic Plan 2008. San Diego, California, April 28, 2008. <http://www.sdcwa.org/strategicplan/documents/strategicplan.PDF>.

supply through small streams and recycling, 50% is from the Colorado River, and the remaining 30% is from the Bay Delta in Northern California (via the State Water Project)(Figure 1).² The fact that San Diego obtains its water from outside its borders has become an increasing problem as drought and climate change threatens the deliverability of water. This is especially true of those, like San Diego County, at the end of the water basin.



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The following memorandum will begin with an outline of the methodology and key assumptions of the analysis. This is followed by general background information as well as forecast of San Diego's water and population. The memorandum will then proceed with background information on policy options and three alternatives for the county to consider. These alternatives are then compared in a cost benefit analysis too include monetary considerations for final recommendations.

² San Diego Water Authority. "San Diego County's Water Sources." San Diego Water Authority, January 17, 2013. <http://www.sdcwa.org/san-diego-county-water-sources>.

³ San Diego Water Authority. "San Diego County's Water Sources." San Diego Water Authority, January 17, 2013. <http://www.sdcwa.org/san-diego-county-water-sources>.

Methodology

The analysis of this memo attempts to quantify financial components of water projects as well as formulate a metric in an understandable method for both policy makers and citizens. This memo conducts a cost benefit analysis of water treatment techniques to estimate which programs are the most cost effective (relative to current water prices), to provide additional freshwater supplies to San Diego County, California. I have explicitly chosen my alternatives as they are the are being considered by the County of San Diego as well as others throughout the country. What I shall do differently than SDC is try to estimate, numerically, all options proposed to the county rather than just the one option chosen in 2012. The strategic plan mentioned in the beginning of this memo was written in 2008, long after the county took steps to implement the Carlsbad Desalination Project (that process began in 1999).

My method in researching and weighing the alternatives is to judge the project mainly on its financial cost, relative to its benefits. However, given that water projects have previously been very contentious this analysis attempts to also link feasibility in terms of public acceptance. While the most important benefit is producing an alternative that does not dramatically raise water prices issues of environmental protection, security of the resource, and political acceptance are also included in the political considerations section.

Assumptions

My first assumption is that this memo is conducted at the county level perspective. The policy options presented are for the consideration of the San Diego County Water Authority (SDCWA). The SDCWA is made up of 24 municipalities, cities, water districts, irrigation districts, a public utility, and one military base (See Appendix 1: Chart 1). The most impactful policy would have to come from the state level as greater control over water resources are made

in Sacramento. However, constraints on both California and federal authorities restrict such sweeping policies. In the past the federal government, through the Bureau of Land Management or Army Corp of Engineers, would have created the large scale water projects. However, this era is largely over. This is because all the ‘good’ sites have been built upon, recreational users and citizens want more free flowing rivers, there are very few federal subsidies, and the power of environmentalists have largely halted any such projects.⁴ In addition, the State of California is largely paralyzed politically, as coalitions of agricultural users (75% of water use in the state)⁵ and northern municipalities are against any further appropriations to the southern part of the state. This requires more localized action such as conservation and smaller scale-local projects.

The second assumption of this memo is that ‘traditional’ methods of conservation will not be enough to reduce water usage levels to meet future needs. This is due to three main factors. The first issue is that population pressures will continue to burden the water supplies.⁶ The City of San Diego estimates that water demand in the city will increase 50% (from 2002) by 2030.⁷ The second is that since the 1990s San Diego and other cities have completed many efforts that have reduced the gallon per capita per day (GPCD) consumption of water. Between 2007 and 2012 alone, water consumption has decreased by about 20%. Further measures would have to become extreme like Las Vegas’ ban on lawns for new homes or at the least a major shift in consumer behavior and culture. Such a transformation is unlikely in a short time and even in the most extreme drought conservation could not account for more than 7% of water use.⁸

⁴ Davis, Sandra. “The Politics of Water Scarcity in the Western United States.” *The Social Science Journal* 38 (2001): 527–542.p.531.

⁵ Postel, Sandra, and Brian D. Richter. *Rivers for life: Managing Water for People and Nature*. Washington: Island Press, 2003.p.101.

⁶ San Diego, City of. *City of San Diego Long-Range Water Resources Plan (2002-2030)*. Strategic Plan for Water Supply`. San Diego, California: City Council of Sand Diego, December 9, 2002.

<http://www.sandiego.gov/water/pdf/lrwrplan070604.pdf>. Section 1 page 4.

⁷ *Ibid.*Section.1 page 4.

⁸ *Ibid.*Section 3 page 1.

Furthermore, conservation and urban pricing schemes have had their desired effect on per capita consumption but savings flattened by 2010. Finally, a solution that other states such as Colorado and Utah have applied, buying water rights from agricultural producers, is unlikely to succeed due to the nature of California's economy. Unlike Colorado or Utah the profits of agriculture in this region are significantly higher than other areas of the country and water is valued higher financially and socially (half of the nation's fruits, nuts, and vegetables are grown in central and southern California)⁹. In addition, some purchases within the county already occurred in response to droughts in the 1990s but were accompanied with restrictions on future sales.

Background

Climate and Hydrology of California

The climate of California varies greatly from north to south. In the less populated northern portion of the state, rainfall averages between 30-60 inches of precipitation a year.¹⁰ The southern half typically receives 5-20 inches. (See Figure 2)¹¹ The gap between population and precipitation is particularly troublesome. While the population of Southern California continues to increase by about 200,000 people each year, its water supplies are not.¹² Overall 70% of rainfall is in the north, whereas 80% of the demand is in the urban/ suburban south and central agricultural valleys.¹³ For the last 70 years this discrepancy has been mitigated by a series of dams and canals (Figure 3).

⁹ Bourke, Joel K. "California's Pipe Dream: A Heroic System of Dams, Pumps, and Canals Can't Stave Off a Water Crisis." National Geographic, April, 2010.p.142.

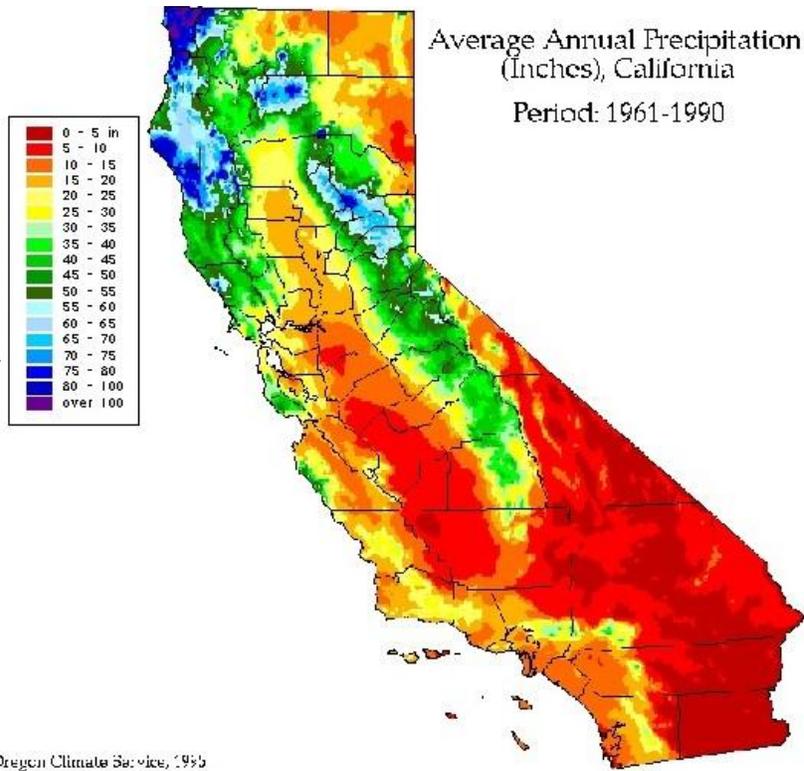
¹⁰ NOAA

¹¹ Ibid

¹² Bourke, Joel K. "California's Pipe Dream: A Heroic System of Dams, Pumps, and Canals Can't Stave Off a Water Crisis." National Geographic, April, 2010.p.141

¹³ Ibid.p.142.

Figure 2: Average Precipitation: California (San Diego County is the most southwestern)



The most important source of San Diego’s water, The Colorado River, is widely acknowledged as over-allocated, especially in times of drought.¹⁴ Some estimates state that structural over allocation (promising more water than the system can replenish or provide in a given year) has occurred since 1920, when the first contracts were written. Originating in Colorado, Wyoming, and Utah; the Colorado River supplies water to some of the most rapidly expanding populations in the country. Southern California, Las Vegas, NV, Phoenix, AZ, and Tucson, AZ all obtain a majority of their water needs from this river (Appendix 1: Figure 1). In 2010 Lake Mead and Powell (the most important lakes/storage points in the system) were at their lowest levels in their history because of a persistent 11 year drought. Additionally, due to

¹⁴ US Department of Interior, Bureau of Land Management. Colorado River Basin Supply and Demand Study. Washington DC, USA, June 2011.

substantial pressure from upper basin states,, Mexico, and environmentalists, California agreed in 2010 to reduce its annual withdrawal by 4.4 million acre feet by 2015.¹⁵ According to western water law those parties (states, farmers, or municipalities) that were the last to lay claim to water sources are the last to gain any portion of the water during a time of drought. Los Angeles was a large player when the dividing of the Colorado began. Comparatively, San Diego, who was late in the water grab, will bear one of the most significant portions of this burden.

Figure 3: Canal / Aqueduct System of California

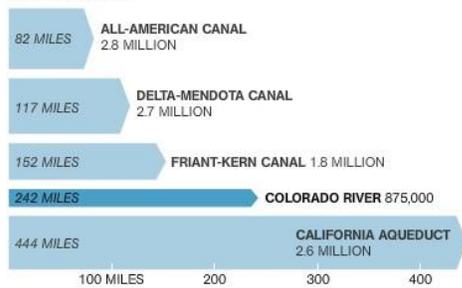
REPLUMBING CALIFORNIA

With 70 percent of water supplies in the north and 80 percent of demand in its mid-section and south, California built monumental waterworks in the 20th century to move water from the wettest to the driest parts of the state. Rising human demand now vies with environmental needs such as sustaining fish, wetlands, and rivers.

LARGEST AQUEDUCTS

More than 2,400 miles of canals, pipelines, and aqueducts carry water to the state's thirsty regions.

WATER DELIVERED IN 2005
LENGTH (acre-feet)



SEAN MCNAUGHTON, NG STAFF
SOURCES: CALIFORNIA DEPARTMENT OF WATER RESOURCES; BUREAU OF RECLAMATION; AMERICAN FARMLAND TRUST



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The second water resource San Diego receives its water from is also stressed. This is largely due to increased requests from agriculture as well as decreased flows due to longer and deeper periods of drought. Climate change is widely believed to be a force that will exacerbate

¹⁵ Davis, Sandra. "The Politics of Water Scarcity in the Western United States." *The Social Science Journal* 38 (2001): 527-542.p.533.

¹⁶ Bourke, Joel K. "California's Pipe Dream: A Heroic System of Dams, Pumps, and Canals Can't Stave Off a Water Crisis." *National Geographic*, April, 2010.

these scenarios. The Colorado River will likely see between 11-45% decreases in its volume.¹⁷ The Sierra Nevada Mountains (which contain the snowpack and melt for the deltas of Northern and Central California) will decrease their supply between 25-40%.¹⁸ Again, due to the water laws of California, San Diego will have little room for recourse in securing these waters during a long period of drought. The problem of water stress in the southwest is not new but since it is where a high concentration of farming and population growth occurs competition will only expand. Compared to many in cities in the US, the Southwest has very low levels of precipitation which leads to a high rate of consumption for both agriculture and personal use (Appendix 1: Chart 2).

Population Stresses

Even with drastic reductions in personal consumption, San Diego County (SDC) as a whole has not reduced consumption enough to balance its needs. A large part of this is due to the scale of population growth.¹⁹ According to the US Census Bureau between 2000 and 2010 the population of California increased 10% on average compared to the US rate of about 8%.²⁰ Numerically, this is significant as California is the most populous state in the nation. San Diego County doubled its population between 1980 and 2010 to about 3.1 million.²¹ According to the

¹⁷ Adler, Robert. "Climate Change and the Hegemony of State." *Stanford Environmental Law Journal* 29 (2010): 1-61. <http://web.ebscohost.com/ehost/pdfviewer/pdfviewer?vid=10&hid=12&sid=475d524b-51cd-4f4c-8a73-598af7226a97%40sessionmgr14> (accessed November 17, 2010),p.14.

¹⁸ O.Hadley et al. *Measured Black Carbon Deposition on the Sierra Nevada Snow Pack and Implication for Snow Pack Retreat.*, *Atmos. Chem. Phys.*, 2010, vol. 10:7505-7513, available from: <http://www.atmos-chem-phys.org/10/7505/2010/acp-10-7505-2010.pdf>

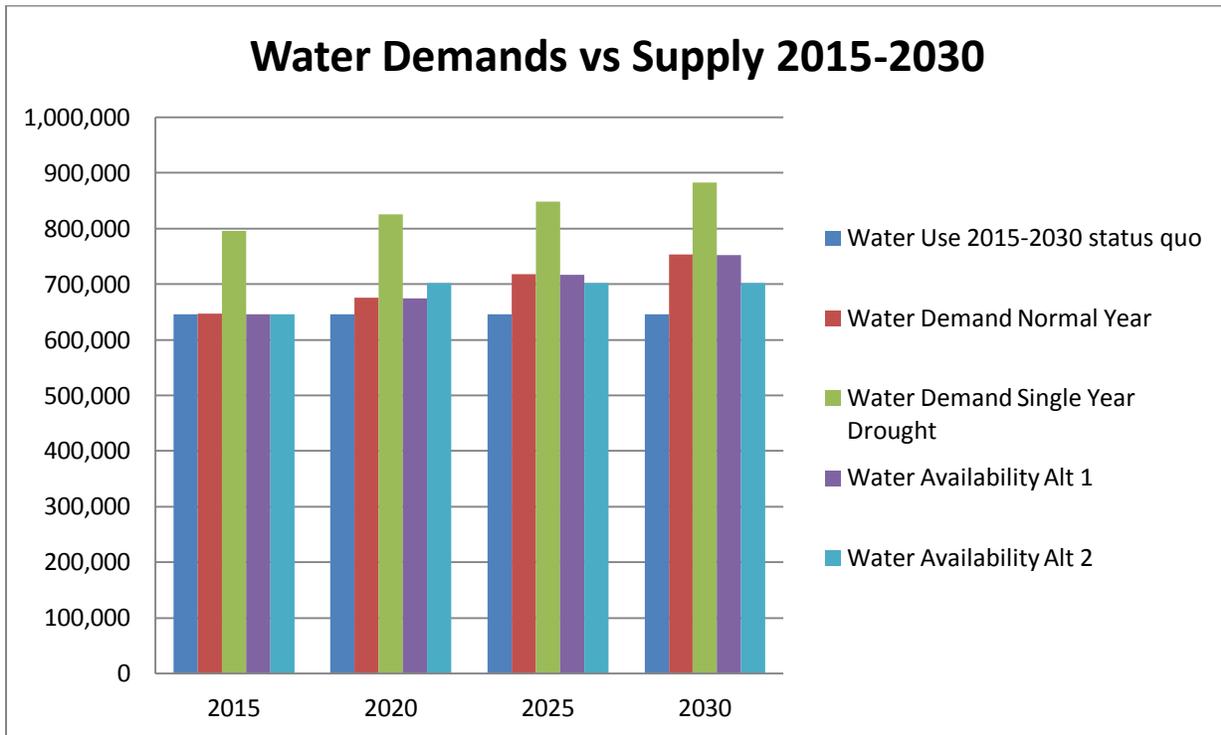
¹⁹ Walton, Brett. "The Price of Water: A Comparison of Water Rates, Usage in 30 U.S. Cities," April 26, 2010. <http://www.circleofblue.org/waternews/2010/world/the-price-of-water-a-comparison-of-water-rates-usage-in-30-u-s-cities/>.

²⁰ US Census Bureau. *State and County Quick Facts: California.* United States Census 2010. Washington DC, USA: United States Census Bureau, January 10, 2012. <http://quickfacts.census.gov/qfd/states/06000.html>.

²¹ *Ibid.*

most recent census, San Diego is ranked the 8th most populated city in the United States.²² The City of San Diego estimates that in normal years demand for water will increase by 63,000 AFY between 2002 and 2030; in dry years the increase in demand will be 120,000.²³

Graph 1: Water Consumption Demands vs. Supplies 2015-2030



In response to current water deficits, many communities are increasing groundwater extraction to supplement the more erratic surface water supplies. This, in turn, has created a situation where groundwater recharge cannot keep up with extraction. Due to over withdrawal, some groundwater sources are becoming increasingly saline (containing high salt and mineral concentrations) as seawater seeps up the water table or salinity becomes more concentrated.

Beginning in the 1990’s the SDCWA began to investigate desalination as a means to solve their

²² US Census Bureau Texas Dominates List of Fastest-Growing Large Cities Since 2010 Census, Census Bureau Reports. Newsroom. Washington DC, USA: United States Census Bureau, June 28, 2011. <http://www.census.gov/newsroom/releases/archives/population/cb12-117.html>.

²³ San Diego, City of. *City of San Diego Long-Range Water Resources Plan (2002-2030)*. Strategic Plan for Water Supply. San Diego, California: City Council of Sand Diego, December 9, 2002. <http://www.sandiego.gov/water/pdf/lrwrplan070604.pdf>. Section ES, page 2.

water shortage. Desalination, as a fiscally viable option, highlights the sense of urgency in the region. In the following section a comparison of traditional methods of water delivery and newer more expensive methods highlight this trend.

Policy options

For the majority of the last century the United States has been heavily reliant on large water transportation projects to meet its water needs. Water transportation, treatment, and related activities account for 20% of all of California's electricity usage.²⁴ As these projects are no longer on the table, new methods and technologies have slowly filled the policy gap. Water treatment and reuse was one of the first alternatives municipalities looked to. Wastewater, agricultural runoff, and other forms of discharge have been treated for many years due to environmental regulations, and are increasingly recycled for other uses. A more recent and controversial development is desalination. Both techniques are used around the world to supply water while maintaining high quality levels. One of the best comparisons to Southern California in terms of water needs is Australia. Like Southern California, Australian is an arid environment with a rapidly increasing population as well as strong agricultural sector. For the past 20 years Australia has built both wastewater plants as well as desalination plants near most of its major cities to reduce water stress.

In the United States the trend to embrace these technologies is already underway. The USGS estimates the US will spend more than \$70 billion over the next 20 years on desalination

²⁴ Equinox Center, and Fermanian Business and Economic Institute. San Diego's Water Sources: Assessing the Options. San Diego, CA USA: Equinox Center, 2010.
<http://www.equinoxcenter.org/assets/files/pdf/AssessingtheOptionsfinal.pdf>.p.13.

projects.²⁵ Since the 1950s the federal government, in conjunction with universities and private enterprise, have spent \$1.6 billion between 1950 and 1999²⁶ on research and development, particularly in reverse osmosis (RO) technologies. Investment is primarily through the Department of the Interior, the USGS, but also 6 other agencies including military projects.²⁷ Currently, desalination and wastewater treatment are at a turning point; the technologies are moving away from education and research and moving towards regular policy options.²⁸ Given these developments, this memo will compare the following policy options:

Alternative 1: Expand wastewater treatment facilities and have a portion of its highly treated water mixed into reservoirs and the ground as aquifer recharge.

Alternative 2: Go forward with the Carlsbad sea-water desalination plant (construction began January 2013).

Alternative 3: Construct a large scale (inland) groundwater desalination plant.

Or a combination of these policy options.

Wastewater Recycling

Wastewater recycling is a technology that is well established in the United States. Due to the requirements from the Clean Water Act and other pieces of federal legislation all wastewater must be treated before it reenters the water cycle. If water was not treated and released into rivers and streams the organic matter in the wastewater would decay in natural systems pulling oxygen from the system making it uninhabitable for the living species. In addition, heavy concentrations

²⁵ Alley, William M. Desalination of Water: Earth Science Perspectives Fact Sheet. Fact Sheet 075-03. Reston, VA, USA: US Geological Survey, US Department of the Interior, October 2003.p.1.

²⁶ Mielke, James E. Desalination R & D: The New Federal Program Government Report. Washington DC: Congressional Research Service, February 18, 1999.p.1.

²⁷ Government Accountability Office (US). Freshwater Programs: Federal Agencies' Funding in the United States and Abroad. Washington DC: Congressional Budget Office, March 2005p.1.

²⁸ Miller, James E. "Review of Water Resources and Desalination Technologies." Sandia National Laboratories no. SAND 2003-0800. Materials Chemistry Department (March 2003).

of materials that are found in wastewater can poison the natural systems in other ways.

According to the USGS “The major aim of wastewater treatment is to remove as much of the suspended solids as possible before the remaining water, is discharged back to the environment”.²⁹

For most of its history, wastewater was released back into nearby rivers and streams. In more arid regions the treated water was increasingly used for non-human consumption. This water is regularly labeled as ‘grey’ or ‘non-potable’ water and is separated from other water pipes and sources. For example, grey water is often used in urban areas to water grass in parks. Another use is non-human agriculture (such as animal feed crops like hay or corn). Upstream users typically mix their treated wastewater into natural rivers. The mixture is perfectly safe when properly treated and maintains the flow of rivers like the Colorado or Arkansas. Recently, some downstream municipalities have taken this process one step further. In Orange County, California the water authority has recently built a \$480 million dollar facility that takes water through a three step phase that turns wastewater into drinkable water (potable).³⁰ The plant’s capacity is roughly 70 mgd and will be expanded by another 30 mgd in the next three years.³¹ Although the water authority could put this water directly into the normal supply, it has chosen to use percolation to allow it to filter through, and then be stored in underground aquifers. The benefit to this is not only is the water available but it keeps seawater from seeping into the water table and improves groundwater quality.³² Colorado Springs, CO and other cities in the south west have implemented similar technologies. More upstream users (including Colorado Springs)

²⁹ US Geological Survey (USGS). Wastewater Treatment Water Use. Washington DC, USA: US Geological Survey, US Department of the Interior, January 10, 2013. <http://ga.water.usgs.gov/edu/wuww.html>.

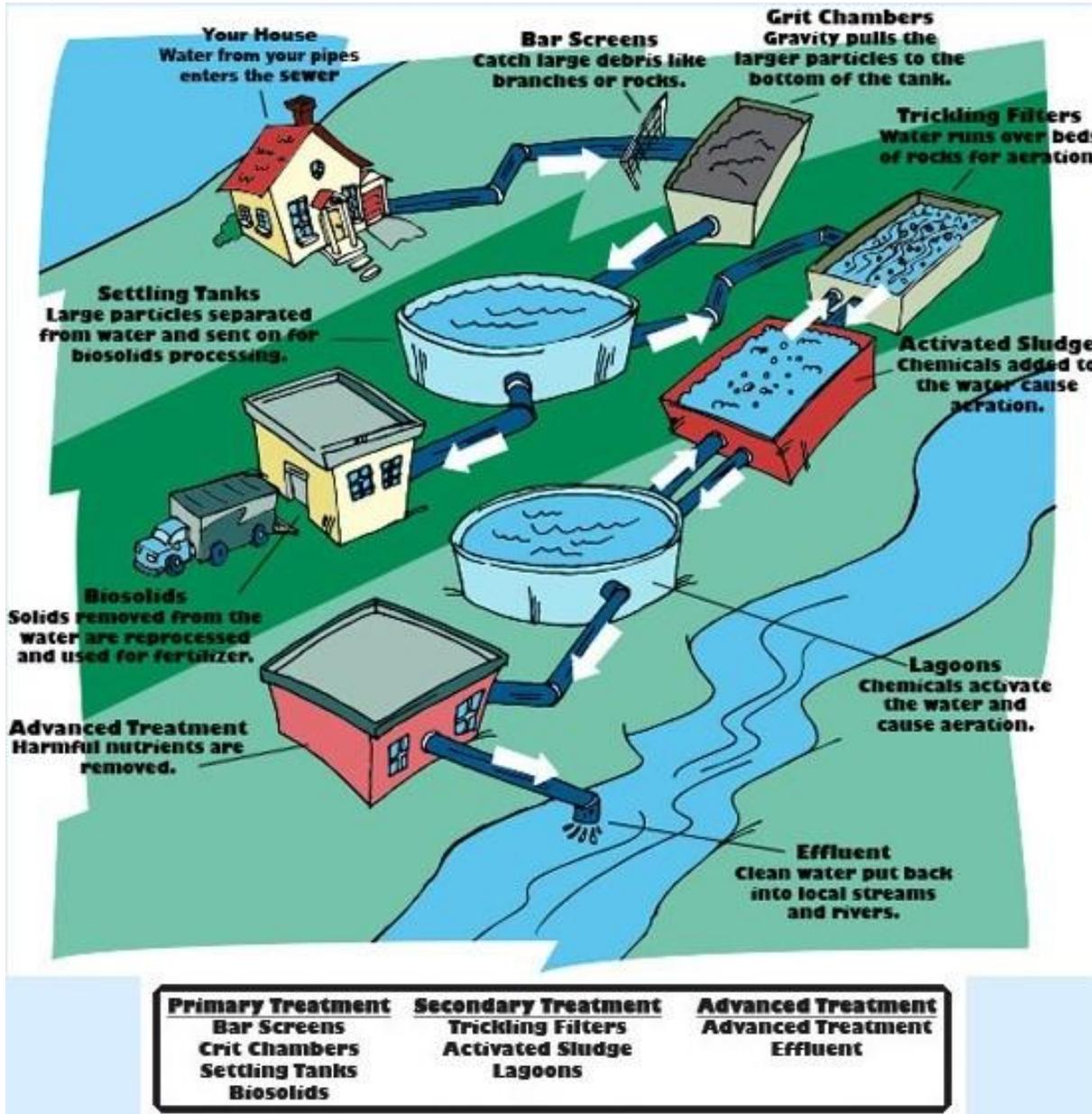
³⁰ Walsh, Bryan. “Seage That’s Clean Enough to Drink.” Time, December 16, 2008. <http://www.time.com/time/health/article/0,8599,1866469,00.html>.p.1.

³¹ Orange County Water District. “OCWD Board of Directors Approves Construction to Expand World Renowned Groundwater Replenishment System,” March 30, 2011.p.1

³² Ibid.p.1-3.

increasingly use this technology as a means to keep in line with EPA regulations and to reduce the threat of lawsuits. So far this highly treated water is used for aquifer recharge, non-potable uses, added stream discharge but not drinking water.

Figure 4: The Wastewater Treatment Process



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³³ Image from: <http://www.rewaonline.org/treatment-process.php>.

Desalination: Why Now?

Desalination is the process by which salt and other minerals are extracted from saline (salty) water to create fresh drinking water. In his review for the Sandia National Laboratory (Albuquerque, NM), James Miller identifies six major types of desalination for commercial use (see Appendix 1: Chart 3). Of the six, the most prevalent in the United States is reverse osmosis (RO). RO is the most common because it is one of the most energy efficient desalination techniques. The technology originated in mining and extraction industries for treating brackish (slightly salty) groundwater. For many years the technology was not widely used for municipal use because Ph levels quickly broke down the expensive membranes and even with subsidies could not compete economically to traditional water sources. But recent advances in pretreatment and membrane technology have made RO a viable option for both ground and seawater desalination.³⁴ Since 1990 water works analysts have estimated the membrane and other technological improvements have cut the cost of seawater RO by about half.³⁵ In addition, economic factors in the desalination process as well as in the water market, have made it a realistic option for communities seeking other water sources.

As the technology behind RO improved it has become more a common and economically reliable process. Furthermore, three factors have changed how investors and plant managers plan and design their desalination plants. First, planners have a better understanding of the economies of scale of their projects. Previous desalination plants, such as the Tampa Bay plant, were larger than the need of the community and operated well below capacity and at a higher cost to rate

³⁴ Miller, James E. "Review of Water Resources and Desalination Technologies." Sandia National Laboratories no. SAND 2003-0800. Materials Chemistry Department (March 2003). p.21.

³⁵ Betts, Kellyn. "Desalination, Desalination Everywhere." Environmental Science & Technology, July 1, 2004.p.247.

payers and municipalities.³⁶ Based on the needs of the community, project managers are now better able to formulate a plant size that fits the need of location.

Chart 4: Total Dissolved Solids (of Salt) Classification³⁷

TDS		TDS	
500 or less	EPA required for drinking water	Less than 35,000	Average for Pacific Ocean
1,000	Considered Saline	37,600	Average for Atlantic
3,000	Too salty to consume	40,800	Average for Sardinia
5,000	Medium brackish ground water	44,000	Average for Red Sea
5,000-15,000	High Brackish Groundwater	100,000	Brine (so salty it is a contaminant)

The second economic breakthrough was understanding the economics and technical requirements of electricity in desalination plants. Previously, energy costs were grossly underestimated in the formulation of plant contracts and cost estimates (Appendix 1: Figure 2 & 3). The result was a much higher bill to consumers due to higher than planned energy requirements (which are one of the most important cost inputs).³⁸ The third economic factor in making desalination more affordable is greater confidence from the market place.³⁹ As the technology has become more established and information more reliable, lenders are able to give better interest rates. This has resulted in better bond sales for privately funded projects and greater competition in the contracting and investment process.⁴⁰ The Carlsbad Plant in San Diego

³⁶ Miller, James E. "Review of Water Resources and Desalination Technologies." Sandia National Laboratories no. SAND 2003-0800. Materials Chemistry Department (March 2003). p.15.

³⁷ Miller, James E. "Review of Water Resources and Desalination Technologies." Sandia National Laboratories no. SAND 2003-0800. Materials Chemistry Department (March 2003).

³⁸ *ibid.*p.15.

³⁹ *Ibid.*p.26.

⁴⁰ Bennett, Anthony. "Innovation Continues to Lower Desalination Costs." *Filtration and Separation*. Feature (August 2011): 24-27.p.25.

is a prime example of this. A favorable bond rating reduced the interest rate payments to less than 5% resulting in a 30 year debt savings of \$200 million.⁴¹

The final reason desalination is a more attractive option is the fact that the water market for traditional sources of water has ‘caught up’ with desalination and other water treatment technologies.⁴² As already explained, population pressures and greater competition for water resources has significantly limited transfer opportunities. In addition, the billions of dollars spent on maintenance of thousands of miles of pipelines and canals have made many water managers wary of maintaining or building new pipes. Finally, a less discussed reason for wanting to diversify towards technologies that are closer to the city is the threat of natural disasters. Highlighted in a special April 2010 article in National Geographic, all of the pipelines carrying California’s water lay on some of the most active earthquake fault lines in the world. One fault line in the north of the state, the Hayward Fault has a two in three chances of being hit by a major (and overdue) quake in the next 30 years.⁴³

Alternatives

Alternative 1: Wastewater Treatment: Retrofit

In 1946 the federal government mandated all municipalities treat their waste water due to declining conditions in many bodies of water. Over the next 60 years San Diego County built over 30 wastewater treatment facilities to service the communities of the county. The most

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⁴² Miller, James E. “Review of Water Resources and Desalination Technologies.” Sandia National Laboratories no. SAND 2003–0800. Materials Chemistry Department (March 2003). p.24.

⁴³ Bourke, Joel K. “California’s Pipe Dream: A Heroic System of Dams, Pumps, and Canals Can’t Stave Off a Water Crisis.” National Geographic, April, 2010.p.144.

important of all of these facilities is the Point Loma facility.⁴⁴ Point Loma is on the coast of the City of San Diego and treats the wastewater of 2.2 million SDC residents. The plant was built with considerable excess capacity to accommodate the rapidly growing population. Of the 240 mgd capacity approximately 160 mgd is treated on a daily basis.⁴⁵ The facility is one of the most advanced in the country as it is not only energy self sufficient but actually provides electricity to the power grid.⁴⁶ In addition, the plants TSS removal rate is 11% higher than primary treatment requirements.⁴⁷ Normally any wastewater is required to have a minimum of two treatments and if necessary a third time. Due to the high level of screening in the first treatment and the fact that the byproduct of wastewater is dumped into a deep ocean zone, the Point Loma plant has received a waiver for secondary treatment since 1995.⁴⁸ As a part of this exemption the city was required to calculate the cost of updating the plant to meet current regulations. The 2005 Water Reuse Study estimated modifications to the plant would require spending over \$3 billion.⁴⁹ Much of this is due to location of the plant on a narrow and rocky strip of land that does not allow for much expansion.

Given the water scarcity in the San Diego region the 160 mgd that is discharged into the ocean is a considerable amount of wasted recycling potential. If it recycled 160 mgd it would equal 179,222 afy or about a 1/3 of the water need of the county in 2012.⁵⁰⁵¹ While reclaiming all

⁴⁴ San Diego County Water Authority. History and Background: Wastewater General Information. San Diego, CA USA: San Diego County Water Authority, January 2013. <http://www.sandiego.gov/mwwd/general/history.shtml>.

⁴⁵ Ibid.

⁴⁶ WE&T Magazine. "Plant Profile: San Diego." WE&T Magazine, August 2007. http://www.wef.org/publications/page_wet.aspx?id=4765&page=plant.

⁴⁷ Ibid.

⁴⁸ Ibid.

⁴⁹ American Assembly and the City of San Diego. *City of San Diego Water Reuse Study 2005. Water Reuse Goals, Opportunities, and Values*. San Diego, California: American Assembly and the City of San Diego, October 6, 2004.p.11.

⁵⁰ WE&T Magazine. "Plant Profile: San Diego." WE&T Magazine, August 2007. http://www.wef.org/publications/page_wet.aspx?id=4765&page=plant.

⁵¹ San Diego County Water Authority. Water Use Annual Report. San Diego, CA USA: San Diego County Water Authority, January 2013. <http://www.sdcwa.org/water-use>.

of the water that goes into the plant is unlikely, if even 100 afy of that amount could be reclaimed it would be significant. Neighboring Orange County uses regular treatment then microfiltration, reverse osmosis, and finally an UV treatment to make water pure enough for drinking.⁵² The facility cost \$480 million and provides 70 mgd of water (or 31,000 afy) and is to be expanded.⁵³ The county could use this as an example and update their wastewater infrastructure away from the high ocean outfall model.

In 2012 the SDCWA and City of San Diego examined how a lower reliance on Point Loma and higher treatment level in all the other wastewater plants could lead to a more economical option. Under the plan proposed by the 2012 San Diego Recycled Water Study experts estimated there was a way to increase infrastructure outside of Point Loma to reduce the volume where a smaller retrofitting could still meet regulations. Through increasing the capacity at regional treatment sites, reservoirs, and pumping stations the city could recycle water to a potable level and provide both drinking and agricultural water. Labeled Integrated Reuse Alternative 3 by the report (IRA3) it would reduce the Point Loma treatment by close to 100 mgd and instead recycle the water adding an additional 96,108 AFY to the city's supply.⁵⁴ This plan would include the necessary changes to Point Loma and would spread the projects out through 2021 (which would give the city the flexibility to cancel a project if necessary). While still expensive the cost benefit analysis displays additional fiscal merits of the option.

⁵² Orange County Water District. "OCWD Board of Directors Approves Construction to Expand World Renowned Groundwater Replenishment System," March 30, 2011.

⁵³ Ibid.

⁵⁴ City of San Diego, Public Utilities Department. *San Diego Recycled Water Study*. San Diego, CA USA, March 2012.p.8-9.

Alternative 2: Desalination of Sea Water

Beginning in 1999 the SDCWA began to examine seawater desalination as a policy option to increase water availability in the region. Soon after, the site near the City of Carlsbad was chosen as the location for the proposed desalination plant due to its proximity to the ocean, a power plant, and existing pipeline infrastructure. The Carlsbad Desalination Project (CDP or Carlsbad) is a joint public private venture between the SDCWA and Poseidon, a Connecticut based water infrastructure company. Once completed, the project will provide up to 56 MGD (close to 10% of SDC water needs). There are multiple factors to why the plant took so long to fully implement (which eventually did in late 2012). The first is the public outreach phase where water rate payers and member groups of the SDCWA are convinced of the necessity of this project. Some, especially irrigation districts, did not feel the same sense of urgency as cities like San Diego (who has a 40% voting power on the board).⁵⁵ The second reason was the burden of proof in the environmental impact assessment period. Along with federal regulations California has strict mandates that any major project must follow. Finally, the statistics involved were heavily scrutinized and revisited as previous projects (nationally) had poor calculations leading to higher and unplanned costs.

In late 2012 the selling of bonds commenced and details of the deal were finalized. Under the agreement Poseidon and SDCWA signed a 30 year contract worth \$984 million. Construction is to begin in early 2013 and completed by 2016 whereupon interest payment would start to be charged. Repayments on bonds begin in 2021. Of the \$984 million, 80% of the money is raised by bonds; the remaining 20% is immediate capital from both Poseidon and the SDCWA. The majority of the fixed costs of the project are plant construction and financing costs (see graph

⁵⁵ Spagat, Elliot. "Huge California Desalination Plant Faces Key Test." US News and World Report, November 29, 2012. <http://www.usnews.com/news/us/articles/2012/11/29/huge-california-desalination-plant-faces-key-test>.p.1.

and figure). Other fixed costs are improvements and expansions to current water infrastructure (pipelines, power stations, and treatment facilities).

The price of water through this project is estimated to be \$1,917- 2,165⁵⁶ per acre foot of water, roughly twice the cost of water from current methods of water transportation from the Colorado River or Northern California.⁵⁷ The City of San Diego estimates the average bill of water users to rise at least \$5-7 a month.⁵⁸ For the 30 year repayment period the price of water will increase by a rate of 2.5% due to debt servicing charges alone. In addition to these rates, the price of water will also be affected by the amount of annual water deliveries (48,000 AF/year or 56,000 AF/year) and the rate at which bonds were sold (Appendix 3). Meaning, the more the city buys and the better the bond rate, the lower the cost to consumers. Under the contract, after 10 years the city may buy out the project and avoid steeper escalation of fees. However, if repayment is completed according to the 30 year contract schedule by 2046 water rates would jump back down to at cost pricing.

Alternative 3: Desalination of Groundwater

Currently, 66% of California residents and 40% of total water usage in the state is from groundwater sources.⁵⁹ Agriculture uses the greatest percentage of groundwater followed by industrial uses such as cooling for power plants and in oil and natural gas extraction.⁶⁰ Groundwater use is more economical for these purposes because the quality of the water does

⁵⁶ San Diego County Water Authority. *\$734 Million Carlsbad Desalination Project Financing Closes*. Press Release. San Diego, CA USA: San Diego County Water Authority, December 24, 2012.

⁵⁷ Spagat, Elliot. "Huge California Desalination Plant Faces Key Test." US News and World Report, November 29, 2012. <http://www.usnews.com/news/us/articles/2012/11/29/huge-california-desalination-plant-faces-key-test..p.1>.

⁵⁸ Ibid,

⁵⁹ Planert, Michael, and John S. Williams. "Groundwater Atlas of the United States: California, Nevada." United States Geological Survey, 1995. http://pubs.usgs.gov/ha/ha730/ch_b/index.html.p.2.

⁶⁰ Alley, William M. Desalination of Water: Earth Science Perspectives Fact Sheet. Fact Sheet 075-03. Reston, VA, USA: US Geological Survey, US Department of the Interior, October 2003.p.3.

not have to be as high (which requires less treatment, and thus, less money).⁶¹ Slowly, as water has become more expensive, more municipalities are treating groundwater for consumptive use. The main difficulty with groundwater projects is that groundwater sources are considerably less understood than surface water, with the last nationwide analysis conducted in the 1960s⁶². The knowledge gap is especially acute in saline sources of groundwater. While the freshwater aquifers of the Great Plains have been studied for many years, considerably less data has been collected for saline and coastal aquifers. Due to increasing pressures on water resources efforts are underway to increase the data in this field. For example, some 75% of New Mexico's groundwater is too saline for human consumption.⁶³ However as that area has also grown there need for information on groundwater has increased. In the last 50 years the most important basins and most water stressed regions have been reassessed by the USGS.

In Southern California, the USGS concluded that groundwater options are very limited.⁶⁴ Groundwater desalination takes considerably less electricity than seawater because the salt TDS is significantly lower. However, the process of desalinizing can become more expensive due to transportation (energy and pipelines), pretreatment, as well as membrane replacement needs. Membrane replacement and pretreatment is particularly an issue if there is a high concentration of salt but also sulfate, carbonate, and silicate.⁶⁵ An additional concern for groundwater treatment arises if there are concentrations of arsenic, uranium, and other toxic sediments that will often collect in deeper aquifers. In the SDC aquifers there is a very high concentration of non salt

⁶¹ Ibid.p.1.

⁶² Alley, William M. Desalination of Water: Earth Science Perspectives Fact Sheet. Fact Sheet 075-03. Reston, VA, USA: US Geological Survey, US Department of the Interior, October 2003.p.1.

⁶³ Alley, William M. Desalination of Water: Earth Science Perspectives Fact Sheet. Fact Sheet 075-03. Reston, VA, USA: US Geological Survey, US Department of the Interior, October 2003.p.1.

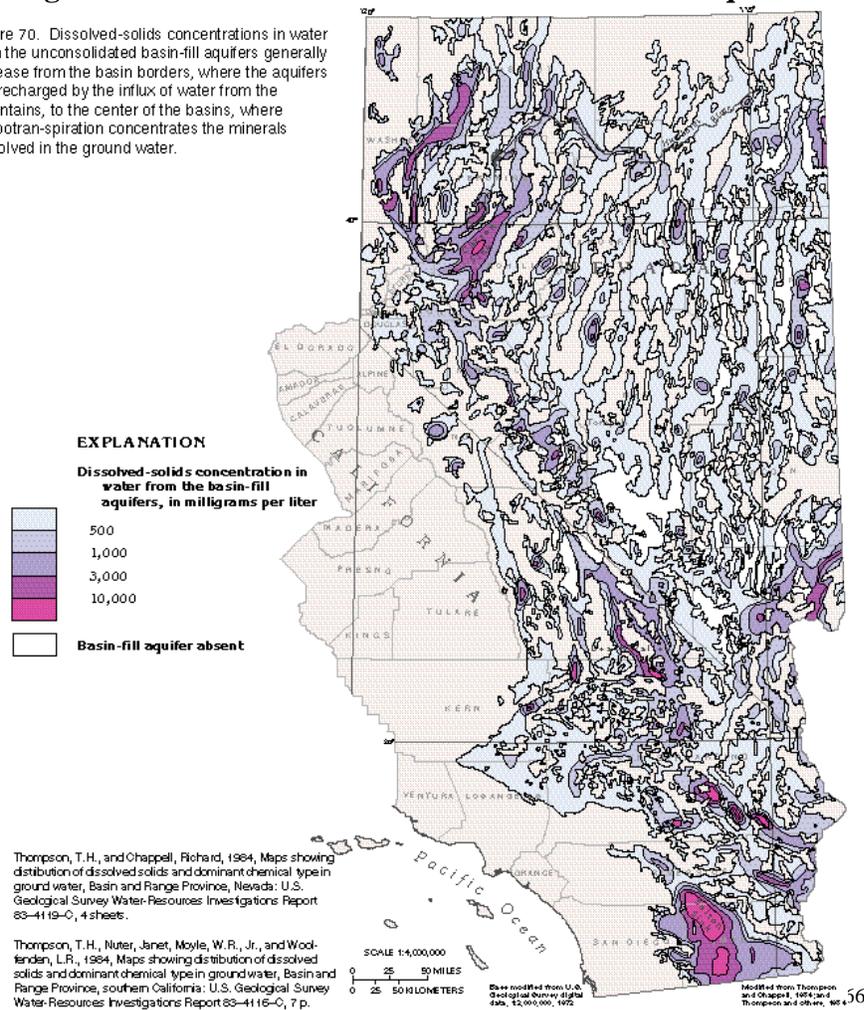
⁶⁴ Planert, Michael, and John S. Williams. "Groundwater Atlas of the United States: California, Nevada." United States Geological Survey, 1995. http://pubs.usgs.gov/ha/ha730/ch_b/index.html.p.1.

⁶⁵ Alley, William M. Desalination of Water: Earth Science Perspectives Fact Sheet. Fact Sheet 075-03. Reston, VA, USA: US Geological Survey, US Department of the Interior, October 2003.p.2.

particulate matter due to its geography. Geologically, the groundwater sources are poor because of their location at the end of a drainage basin as well as along an uneven water table. The aquifers of SDC have some of the highest TDS concentrations in the California and Nevada aquifers (Figure 5). Some of these solids are due to agricultural runoff. Another significant source is these aquifers are close to active geological fault lines causing high underground sediment run off.

Figure 5: Total Dissolved Solid Concentrations in Aquifers

Figure 70. Dissolved-solids concentrations in water from the unconsolidated basin-fill aquifers generally increase from the basin borders, where the aquifers are recharged by the influx of water from the mountains, to the center of the basins, where evapotranspiration concentrates the minerals dissolved in the ground water.



⁶⁶ US Geological Survey. "Ground Water Atlas of the United States: California, Nevada: Basin Range Aquifers." United States Geological Survey, 1995. http://pubs.usgs.gov/ha/ha730/ch_b/B-text2.html.

Furthermore, the viability of using an underground aquifer is dependent on its geology/hydrology, its connection to surface water basins, and the level of particulates in the water. San Diego County currently consumes 18,806 AFY from ground water sources.⁶⁷ Of the seven groundwater projects currently in use only one has to desalinate the water pumped. The rest have low enough TDS concentrations that they can simply mix it with surface sources and maintain salinity levels below EPA guidelines. In terms of extraction, the fresh groundwater sources are mostly tapped. Therefore, the trend for groundwater in SDC indicates desalination and purification may be a more common source in the future. SDC currently has four additional projects that will be online by 2015, three of which will have to desalinate the pumped water.⁶⁸ In addition, there are another 10 potential projects being considered where $\frac{3}{4}$ of the water will have to be desalinated.⁶⁹ Assuming the projected yields are accurate, the total groundwater extraction will increase to 43,074 AFY between 2015 and 2035.⁷⁰ One report estimates that the maximum potential of the most significant groundwater resources in the area is at maximum 48,000 AFY.⁷¹ While this is encouraging it will likely be more very expensive relative to the increased water produced. This is due to number of infrastructure projects as well as the operational and environmental costs associated with inland treatment. Simply, the economies of scale mixed with the quality of water make these options less economical. It also makes action on the county level more difficult as remaining opportunities and benefits will be highly localized.

⁶⁷ San Diego County Water Authority. "Groundwater." San Diego County Water Authority, January 24, 2013. <http://www.sdcwa.org/groundwater>.

⁶⁸ Ibid.

⁶⁹ Ibid.

⁷⁰ Ibid.

⁷¹ San Diego, City of. *City of San Diego Long-Range Water Resources Plan (2002-2030)*. Strategic Plan for Water Supply. San Diego, California: City Council of Sand Diego, December 9, 2002. <http://www.sandiego.gov/water/pdf/lrwrplan070604.pdf>. section 3, page 18.

A second and equally important factor as TDS concentrations is that the groundwater resources of SDC are diminishing due to over extraction and low levels of recharge. One of the most comprehensive analyses of the groundwater basins in SDC was released by the USGS in 2012. It studied the geology of the region and how it affects local hydrologic systems. Among its findings was that roughly 1.5% of precipitation recharges underground sources each year.⁷² This means that although there is not as high of groundwater extraction as other parts of the country the ability of the system to replenish those sources is very low. The report also noted that of all the water in the drainage area (both above and below ground) 40% is slow moving, underground channels that move from the mountains into the ocean.⁷³ This water is important because it keeps seawater from seeping into the water table. Seawater intrusion is a major problem along many other coastal regions such as Florida and Orange County, California. The USGS concluded that this underground flow is important for the quality of all coastal underground sources.⁷⁴

Due to these factors any large scale project (on the same level as the Carlsbad project) is highly unlikely. While the 14 considered projects may be appropriate alternative for individual communities they will yield a lower benefit than for the SDCWA as a whole. It is for this reason that the county never completed a final study of these options. In addition, there are many gaps in understanding the interconnected nature of these smaller aquifers (both saline and fresh). More broadly given the experience of Orange County and other many water managers are hesitant to increase dependence on relatively finite and delicate groundwater resources. It is for these reasons that groundwater is not considered a serious alternative for policy makers, nor this memorandum.

⁷² Flint, L.E., A.L. Flint, B.J. Stolp, and W.R. Danskin. "A Basin-scale Approach for Assessing Water Resources in a Semiarid Environment: San Diego Region, California and Mexico." *Hydrology and Earth System Sciences* 16, no. 2012 (October 26, 2012): 3817–3833.p.3829.

⁷³ Ibid.p.3827-8.

⁷⁴ Ibid.p.3827.

Cost Benefit Analysis

The following cost benefit analysis examines the terms and conditions of the Carlsbad Desalination Project (Alternative 2) *post hoc*. Alternative 1, the waste water system retrofit, is conducted *ex ante*, meaning before the construction of the project. This is because the county investigated and implemented the Carlsbad project before the research on wastewater systems was complete. Alternative 3 is not quantified in this analysis because given the conditions of groundwater resources the option is simply not available on the scale as the other two alternative and is not considered an option for the county.

Social Discount Rate

The social discount rate (SDR) for water projects is calculated and released by the US Department of the Interior (DoI) each year. The SDI is useful in calculating the value of a project not only in present monetary terms, but rather in the value of the projects benefits in the future. Water projects are a perfect examples of why the SDR is important. As this CBA will demonstrate the investment made today in infrastructure has higher value in the future. The rate used in this memorandum is 3.75 as it is the value given by DoI for the year of 2013.⁷⁵ The DoI in the last few years has reduced the SDR for water projects highlighting the sense of urgency to create water infrastructure. In 2011 the rate was 4.125, in 2012 it was 4.0.

⁷⁵ US Department of the Interior *Change in Discount Rate for Water Resources Planning*. Lanham, United States, Lanham: Federal Information & News Dispatch, Inc, 2013, <http://search.proquest.com/docview/1317473696?accountid=14608>.

Price Elasticity

Another important factor to consider in the following calculations is the price elasticity of water. The price of water is a controversial topic. Most economists who have studied water acknowledge that water is undervalued due to subsidies and other non-market forces. While this is not the subject of this paper it does matter. When calculating for benefits to agriculture and urban users, price elasticity was factored into the Jenkins et. al study (2003) from the University of California, Berkley as well as conservation and water savings estimates from the City of San Diego Long Range Study of 2002. Generally, San Diego non-agricultural users had a elasticity between -.2 and -.5 depending on the season.⁷⁶ Furthermore, the Jenkins study looked at two decades of literature to provide these estimates into their cost scarcity model. Agriculture is more subsidized and their elasticity is less understood as those owners of water are somewhat insulated from drought and price shocks. After strong population growth and drought conditions in the 1990s and 2000s low value agriculture was largely abandoned and their water rights were absorbed by the SDCWA. Given these considerations and the highly technical nature of this line of resource economics I assume the estimates from these studies are correct.

Costs: Initial Capital & End of Line Water Rate

The initial capital, operations and maintenance (O&M), and financing costs are analyzed over a 30 year period beginning in 2016 to estimate the costs. The reason this date is chosen is because it is when the financing and construction of the Carlsbad project will be completed. The wastewater alternative was presented to the city to begin in 2015 and completed by 2030. The

⁷⁶ Jenkins, Marion, Jay Lund, and Richard Howitt. "Economic Losses for Urban Water Scarcity in California." *American Water Works Journal* 95, no. 2 (February 2003). <http://0-search.proquest.com.bianca.penlib.du.edu/docview/221605700>.

data analyzed is taken from the contracts of the two projects and disaggregated so that the reader may better understand how the end of line water price is reached. The end of line price of water (\$/AF) reflects how much it costs to produce (this include transporting, treating, and financing of water) but not of the initial capital requirements. The Carlsbad project was more easily disaggregated. The wastewater study was mostly disaggregated but some of the costs and savings were only given as lump sums. This is how they are reflected in the following analysis as well. Given the cost escalation was included in the costs and prices it should have no affect on the quality of the results.

Cost Matrix

	Capital Construction	O & M between 2015-2045 (total)	Financing and Debt Charges	Total Costs between 2015-2045	End of Line Water Price
Alt 1 Point Wastewater Retrofit 96,108 AFY	2,160,900,000	3,026,700,000	294,620,864	5,482,220,864	1,200
Alt 2 Carlsbad Desalination 56,000 AFY	904,000,000	1,899,047,729	209,868,968	2,886,178,761	1,917-2,165

Benefits

The Benefits of these projects include environmental considerations, O&M savings, capital improvements savings, cost avoidance of water scarcity, the addition revenues to SDCWA via new rate payers, and savings to agriculture producers. The latter subject is based upon the assumption that in a time of drought the city will normally reduce potable water flows to agriculture by up to 30%. This is in their drought plan and legal agreements. In the wastewater project the improvements made to the system’s infrastructure reduce costs down the road as the

county no longer has to update that infrastructure. In addition, not having to treat as much wastewater in the Point Loma plant also reduces the cost of the entire system by reducing how much secondary capacity the Point Loma plant needs as well as a reduction in electricity it takes to send the wastewater to the plant. The environmental benefits are based on a study from EPA and Californian government which estimate by treating the wastewater it reduces the amount of salt and other particulates that reach lawns, golf courses, and the natural environment. The benefit is about \$100 /AF is through better quality in the water systems and less coercive affects on the infrastructure that carries the water.

Finally, the benefits to urban users are estimated in two ways. The first calculates how many people will not have access to water given the population growth estimates. On average a individual in SDC will use 0.179 AFY of water and pay the water authority \$1,020 in utilities. If that water is not there to be consumed the water authority misses out on those ratepayers. While it is not a precise measure it is appropriate to estimate a benefit to the SDCWA. The final benefit comes from a previously described model from the University of California, Davis which utilized wiliness to pay models to estimate the cost to urban (both residential and industrial) users of water of water scarcity. This study estimates that the loss for San Diego County is roughly \$5 a resident when scarcity forces a reduction of consumption or a more general change in behavior.⁷⁷ All of these benefits are calculated until 2030 when population and water availability data are no longer forecasted.

⁷⁷ Ibid.p.1.

Benefits Matrix

	Savings in Capital & O&M	Environment Benefits	Agricultural Benefits	Urban Benefits	Total Benefits
Alt 1 Point Loma Retrofit	1,735,284,146	267,534,300	4,412,578,562	3,017,994,896	5,020,813,342
Alt 2 Carlsbad Desalination	0	0	2,366,912,230	256,996,765	2,623,908,995

Net Present Value

Once the net costs were calculated the data was inserted into the Net Present Value function of Microsoft Excel to use the social discount rate to calculate the value of these projects in terms of 2046 value. While Alternative 1 may have a net cost its NPV in 2046 is positive. This is because if implemented, SDC would not experience water shortages in a normal year. This alternative produces enough water for future populations, and agricultural users whereas the Carlsbad Desalination Project only meets needs until roughly 2025 when once again shortages are predicted. Due to this gap its NPV is negative.

Net Cost versus Net Present Value

	Costs	Benefits	Net Cost	Net Present Value	End of line Price
Status Quo	(3,078,735,245)	0	(3,078,735,245)	(6,780)	n/a
Alternative 1 96,108 afy	(5,482,220,864)	5,020,813,342	(461,407,522)	8,488,607	1,200
Alternative 2 56,000 afy	(2,886,178,761)	2,623,908,995	(262,269,766)	(115,295,618)	1,917-2,165

Political and Public Considerations

One of the characteristics that stand out in the decisions made in San Diego County is the support for a large scale desalination plant before other alternatives. While the County is largely

pursuing an ‘all above’ approach, the commitment to the Carlsbad Desalination plant highlights some of the politics of the project as well as in the Water Board. The Carlsbad project is one of the most expensive options. In addition, it has required a significant amount of effort and strong support by the County. This project was delayed heavily since first proposed in 1999(having the final legal and environmental hurdles only completed in late 2012). In order to gain favorable financing conditions (to keep costs lower) the Water Authority had to show unconditional support for the project. In a way it succeeded as evidenced by the reduction of the cost by hundreds of millions of dollars due to a favorable bond sale.⁷⁸ However, this may suggest that path dependency played a part in the decision making process. Other, less expensive projects, were not given as much consideration or public support they might have enjoyed had the Carlsbad project not been implemented. San Diego (the city) was the most aggressive in pushing for the project and since they have a 40% voting share on the board, they have a lot of influence on the decisions made by the Water Authority.

It is not unreasonable to also assume prestige over having the largest desalination facility in the western hemisphere may also have played a role in the decision making process. While this is difficult to prove, projects (like the Point Loma Wastewater Plant) suggest San Diego has a history of a ‘think big’ decision making. On both the city’s website and much of the literature discussing the projects in southern California large and unusual projects receive a heavy amount of attention. Sometimes policy makers, financiers, and the public have a bias towards bigger projects. Since 2005 bonds and water rights have been one of the most valuable commodities in California. This in large part due to legislation and voter approved action to modernize and expand the state’s water infrastructure. The Pacific Institute noted that between 2005 and 2010

⁷⁸ San Diego County Water Authority. *\$734 Million Carlsbad Desalination Project Financing Closes*. Press Release. San Diego, CA USA: San Diego County Water Authority, December 24, 2012.

more water bonds were sold than the previous 100 years combined (Appendix 1: Figure 4).⁷⁹

Business and investors may also be part to blame. Speculation on water prices and heavy trading has made water perform better than many commodities and traditional investments. The American Water Works Association has noted a strong upward price trend in Australia, the Rio Grande, as well as the Colorado River (whose water rights have outpaced the Gold Spot, S&P 500, CRB Commodities index, and others).⁸⁰

One final political consideration is that San Diego has a history of messy public relations campaigns concerning water. In 1999 the city shut down plans to expand wastewater treatment after public outcry. Due to poor communication and a lack of city-citizen outreach a project to expand waste water treatment failed to be implemented. There were complaints that people didn't know about the project until too late in the process and that poor minority communities were targeted by the city as guinea pigs. Since then the city has spent millions of dollars in outreach and planning for future wastewater projects. Most of the wastewater proposals in this memo are from reports initiated by the 2005 Water Reuse Study. It was conducted by the city to essentially 'try again' at developing wastewater purification. That study and others recognize the city is doing a better job at communicating and that water stress has granted the city more flexibility in adopting these policies. The city has created a "water purification facility" and for over a year tested the treatment facilities as a part of public awareness and acceptance campaign. The change of language as well as the slow pace of development will likely make it easier for these projects to gain steam in the future.

Overall, public sensitivities are most connected to the price of water and public utilities. SDCWA can only increase its prices every other year. For the last few years this rate increase is

⁷⁹ Christian-Smith, Juliet, Lucy Allen, Eli Moore, and Peter Gleik. *The 2010 Californian Water Bond: What Does It Say and Do?* Oakland, California: Pacific Institute, August 2010. P.6.

⁸⁰ Maxwell, Steve. "Historical Water Prices." *American Water Works Journal*, April 2010.p.26.

near the national average of 9-10%.⁸¹ The Pacific Institutes estimates that between 2000 and 2030 ratepayers in California will increase by 39% due to natural rate increase but also because many infrastructure projects from the 1980s onward must be paid for by 2030 by law⁸². In a separate extensive study by the City of San Diego public sentiments appeared mostly neutral on any new water project.⁸³ Desalination, wastewater reclamation, and conventional groundwater extraction all scored the same and lower than conservation but higher than increased import of water from outside the county. This appears to highlight that citizens understand the stress on their water but may be somewhat uncertain about the treatment choices.

Project Feasibility

In the following matrix each of the alternatives proposed in the previous section are given a score from 1 to 5 with one being less favorable and five being more favorable. These scores are extracted from previous studies by the city, county, and independent research institutions. The reports are consistent in scoring these alternative (or projects previously proposed with very similar characteristics). For example, security scores were high for wastewater treatment as well as desalination is readily available during a natural disaster. Groundwater is low because of fears that wells will need to be dug deeper and that supplies are both tapped out and less understood.

⁸¹ Walton, Brett. "The Price of Water: A Comparison of Water Rates, Usage in 30 U.S. Cities," April 26, 2010. <http://www.circleofblue.org/waternews/2010/world/the-price-of-water-a-comparison-of-water-rates-usage-in-30-u-s-cities/>.

⁸² Gleick, Peter, Heather Crooley, and David Groves. *California Water 2030: An Efficient Future*. Oakland, California: Pacific Institute, September 2005. http://pacinst.org/reports/california_water_2030/ca_water_2030.pdf.p.29.

⁸³ San Diego, City of. *City of San Diego Long-Range Water Resources Plan (2002-2030)*. Strategic Plan for Water Supply. San Diego, California: City Council of Sand Diego, December 9, 2002. <http://www.sandiego.gov/water/pdf/lrwrplan070604.pdf>. Section 6, p.15

	Water Availability ⁸⁴	Cost Efficiency ⁸⁵	Environment ⁸⁶	Water Quality ⁸⁷	Security ⁸⁸	Public Acceptance ⁸⁹	Total Score ⁹⁰
Alt 1	5	2	5	3	4	3	22
Alt 2	5	1	2	4	4	3	19
Alt 3	2	4	3	2	2	4	17

Weaknesses and Limitations

One of the main weaknesses and limitations of this analysis is the speculative and uneasy nature of trying to make both population and precipitation projections. In particular, climate change will have a significant impact on San Diego’s water sources. However, that variability is a factor that is difficult to plan for let alone estimate. These factors matter because they affect the available water resources as well as how they are priced. Many of the assumptions about how much water the county needs and will have in the future differ from source to source. I attempted to use the estimates that were most credible but every factor cannot be accounted for. Another forecasting issue that can have a significant impact on the cost benefit analysis is energy prices. Desalination’s long term cost is heavily dependent on energy costs. While both alternatives calculate their O&M costs on escalating energy prices the actual could be much higher for some unforeseen event. Or it could be that technologies such as fracking could do the reverse.

⁸⁴ Equinox Center, and Fermanian Business and Economic Institute. San Diego’s Water Sources: Addressing the Options. San Diego, CA USA: Equinox Center, 2010.

<http://www.equinoxcenter.org/assets/files/pdf/AssessingtheOptionsfinal.pdf>.p.15.

⁸⁵ Ibid.

⁸⁶ San Diego, City of. *City of San Diego Long-Range Water Resources Plan (2002-2030)*. Strategic Plan for Water Supply. San Diego, California: City Council of Sand Diego, December 9, 2002.

<http://www.sandiego.gov/water/pdf/lrwrplan070604.pdf>.

⁸⁷ Ibid.

⁸⁸ Ibid.

⁸⁹ Ibid.

⁹⁰ Ibid.

The second limitation of this analysis is that despite the author's best efforts some of the data may have been misinterpreted and misrepresented in the analysis. For Alternative 1 the data came from a report from the City of San Diego where much of the information was highly aggregated and condensed into an end of line price tag. While the majority of information was expanded into line item detail there is a chance that in this analysis factors were overlooked. In Alternative 2 the opposite issue occurred. The information was very technically presented and the financial details required meticulous attention to make readable. The same problem arises when trying to understand the very technical and complicated requirements for understanding the relationship between electricity production and water treatment. Although the author spoke to sources near the project misunderstanding a contract and requirements can still occur and leave room for error. In addition, because the author does not work regularly with these types of contracts some details like special considerations may have been overlooked. For example, while speaking to Colorado Springs Utilities it became clear that often a 'first project of its kind' has special agreements like O&M deals that are not normal. The costs of running Carlsbad could very well be higher but because Poseidon is giving the city a deal not reflected in the documents. While under Poseidon operations the company has access to cheaper recycling options for bulbs and membranes, for example. When they leave and SDCWA takes full charge this is a cost they will then have to incur.

Beyond technical details this memorandum falls into a familiar pattern of questionable policy decision making that looks for quick solutions rather than root causes. Although agricultural transfers and price elasticity were mentioned and briefly addressed, one of the underlining issues that is never pursued in policy decisions is the reality that it is fundamentally unsustainable to have this county as an epicenter for agricultural production. In addition, the

lifestyle in southern California also does not match the climatic variables of the land. Las Vegas has reluctantly begun to address this by banning the creation of lawns on new homes. In addition, the issue of balancing agricultural needs (and food production demands) with an expanding population, and environmental concerns is largely ignored. While California does a good job at protecting the environment the county has a large amount of endangered biodiversity that is not always calculated into cost benefit matrixes. This memo does not try to place a higher value on one or another but such questions do need to be addressed in debates over water policy.

Finally, one of the other limitations to this analysis is understanding the political and social issues in the county. While the author has researched local newspapers and histories around these projects the political situation in the county itself could be much more complex. The approach is greatly with an 'outsider looking in' perspective. Furthermore, while a significant effort was made to exclude and personal biases in the construction or measurement of policy options personal biases may still matter. Having both an environmental background as well a perspective from an upper basin state may alter what seems reasonable or rational. One of the benefits of a quantitative analysis is that it can remove some of these issues but it is important to still acknowledge bias where necessary.

Water within the Larger Policy Debate

One of the challenges in the underlining premise of this memorandum is that there is a struggle in the county between human capacity to create its ideal environment and the realities of the land. San Diego, as well as the entire southwest, is a man made climate. We have altered the natural environment to extract many of its benefits beyond what is within its natural capacity. It is true that San Diego has a climate that is excellent for growing crops like avocados and

strawberries. However, the scale of that industry as well as the desire to live the lifestyle San Diegans enjoy is only possible because of the massive import of water from outside sources. As the county's population has grown the ability of the water authority to meet expectations is increasingly strained. SDC is now at a crossroad where it needs to decide if this expensive, water intensive lifestyle is reasonable and if it is the responsibility of policy makers to end this unsustainable lifestyle. The large stress on water resources suggests the time of cheap and readily available water is over. Through the desalination plant the city (and its citizens) has indicated that they are willing to pay more for water if they can maintain their current comforts. Over time options for increasing water will be significantly limited and even technological innovation will not be able to bridge the gap between expectation and reality.

It is within this line of interpretation that water is another example of current policy debates about what type of action policy makers should take. In the last 20 years the county has put pressure on consumers to try to alter behavior towards greater water conservation. The water authority was successful at it. By incentivizing water saving irrigation systems as well as efficient in-home water fixtures the city was able to reduce urban per person consumption by 20%. As stated previously, these efforts will not provide enough water savings to meet future needs. Water is very similar to policy debates where experts are questioning whether politicians, or in this case the water authority, should take more assertive action to avoid larger problems in the future even if it means upsetting citizens. Should it regulate how much water can be sold to an individual or continue to try and price people out (like sodas in New York)? At this point the SDCWA has chosen to use tactics such as tiered pricing and price increases to *encourage* less water consumption. However, these options are insufficient to address the broad valuation of water in the economy, the social and environmental welfare of the county. It is likely that in the

future a city councilman will have to argue that having a lawn is not as important as having farms or healthy freshwater habitats. This is already happening in other communities.

The future quality life of the county depends on the choices policy makers formulate today. Like Albuquerque, Las Vegas, and Tucson, San Diego will have to make choices for the future. It is almost certain that a strong case will be made supporting collective sacrifice (such as eliminating green grass lawns) in favor of collective water security for drinking and the economic health of the county. Cities like those previously mentioned made a point to not develop its city under the same dissolution as Southern California. Tucson made a strong point to embrace its desert climate as a cultural feature of the city. In a way all were forced into low water lifestyle because it could not bring water in from elsewhere. As San Diego continues its debate it can choose to create policy to meet its water reality or it may be forced into the same decision through a costly external shock like an earthquake or long lasting drought.

Recommendation

The recommendation of this memorandum to the County of San Diego is to seriously consider the wastewater treatment option. Even though the desalination plant is already underway both will likely be needed in times of drought to prevent any watering restrictions and agricultural transfers. Had the Carlsbad construction not already commenced the wastewater option would have served as a more appropriate alternative. In the long run it is able to produce more water at a significantly lower cost to ratepayers and the city alike. The desalination plant is less expensive in the near term because of the duties taken by Poseidon. However, after 2046 SDCWA will pay the full price of O&M which is an additional \$40,000 a year than they will pay

during construction. Furthermore, along with the cost per \$/AF the benefits of Alternative 1 will be felt more broadly among agriculture, rate payers, and the SDCWA.

One of the key elements to the feasibility of this option is the willingness of the populace to consume recycled water. Even though it is completely safe the 'gross' factor is a major concern. This concern was voiced multiple times by various southern California newspapers (and even the New York Times) when Orange County built and expanded its UV plant. However, as displayed by the second and third phases of current water reclamation projects better public outreach and communication on the part of the city has produced greater acceptance⁹¹. This is especially true when it come to the pricing of Alternative 2. Finally, acceptance and willingness to pay more for the project will feel the benefits through a longer period of time. Water reclamation is a reliable source and because of this proposals location it means the most amount of water will be able to reach the parts of the county that are most vulnerable.

⁹¹ Lee, Mike. "Perceptions of Purity Still Cloud City's Push to Reuse Wastewater." San Diego Union Tribune. San Diego, CA USA, July 12, 2005.
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Appendix 1: Figures for Additional Considerations

Chart 1: San Diego County Water Authority Members

Cities	Water Districts	Municipal Water Districts	Irrigation	Public Utility
San Diego	Helix	Carlsbad	Santa Fe	Fallbrook
Del Mar	Lakeside	Olivenhain	South Bay	
Escondo	Otay	Padre Dam	Vista	Military Base
National City	San Dieguito	Rainbow		Camp Pendleton
Oceanside	Vallecitos	Rincon Del Diablo		
Poway		Valley Center		
		Yuma		

Figure 1: Colorado River Basin



⁹² Scripps Institute of Oceanography, University of California San Diego. "Lake Mead Could Be Dry by 2021." Scripps News, February 12, 2008. <http://scrippsnews.ucsd.edu/Releases/?releaseID=876>

Chart 2: Select Cities with Water Consumption and Rates Precipitation

City	GPD	Inches per Year (precipitation)
San Diego	157	10.77
Los Angeles	154	15.14
Phoenix	115	8.29
Denver	87	15.81
Salt Lake City	180	16.5
Tucson	98	12.17
Columbus	53	38.52
Philadelphia	84	42.05
Memphis	96	54.65
Jacksonville	84	52.34

Chart 3: 6 Most Common Forms of Desalination⁹³

	Basic Process	Notes
Distillation		
Multi-Stage Flash	Uses multiple stages of thermal compression (high temperatures) to evaporate water and remove salt. Necessitates high energy and usually built by power plants to reuses wasted heat.	Most common in Arabian Gulf. Requires very high temperatures/ energy, water intake, high maintenance costs.
Multi-Effect Evaporation	Similar to above. Uses multiple stages where water solution is heated and the pure water that is produced flows into the next chamber and repeats.	Similar to above but compression is difficult to maintain, and set up costs are high.
Vapor Compression	System heats water into vapors that then passes through condenser to return vapor to water form.	Only good on small scale as the heat involved on large scale is inefficient.
Membrane		
Reverse Osmosis	Pressure forces water through membrane, removing TDS through sets of filters. Membranes are sensitive to chlorine and Ph levels.	Most common in US, least energy intensive, but requires high levels of pretreatment.
Electrodialysis	Charges ions in a membrane which condenses slats and separate them from water.	High energy use and upfront plant costs.

⁹³ Miller, James E. "Review of Water Resources and Desalination Technologies." Sandia National Laboratories no. SAND 2003-0800. Materials Chemistry Department (March 2003).

Figure 2: Electricity Needs per Given % Water Recovery

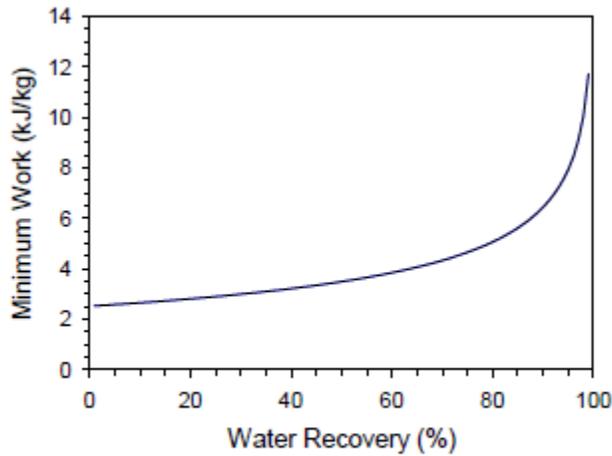
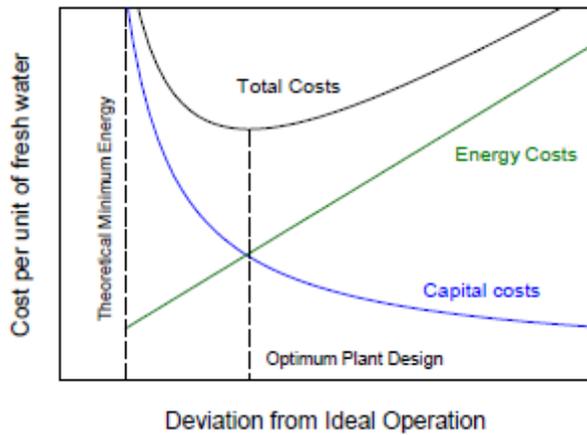


Figure 3. The theoretical minimum energy for desalting seawater as a function of freshwater recovery. Derivation from [24]. Calculation assumes infinite solubility of salt in water – precipitation of NaCl salt begins at about 90% recovery.

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Figure 3: Economies of Scale for Desalination

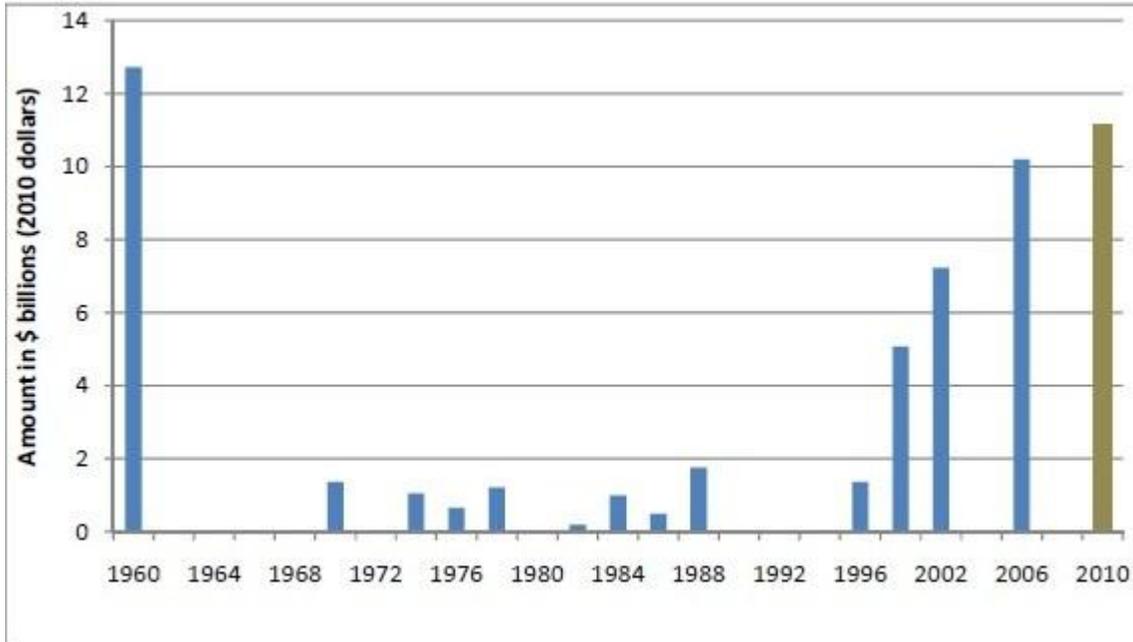


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⁹⁴ Miller, James E. “Review of Water Resources and Desalination Technologies.” Sandia National Laboratories no. SAND 2003–0800. Materials Chemistry Department (March 2003),p.15.

⁹⁵ Miller, James E. “Review of Water Resources and Desalination Technologies.” Sandia National Laboratories no. SAND 2003–0800. Materials Chemistry Department (March 2003),p.15.

Figure 4: Historical Comparison of Water Bonds (adjusted for inflation), billion dollars (2010)



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⁹⁶ Christian-Smith, Juliet, Lucy Allen, Eli Moore, and Peter Gleik. *The 2010 Californian Water Bond: What Does It Say and Do?* Oakland, California: Pacific Institute, August 2010.p.6.

Appendix 2: Cost Benefit Analysis

Alternative 1: Waste Water Treatment

Water Created AFY	16,802	16,802	16,802	36,965	44,582	44,582	96,108	96,108	96,108	96,108	96,108
Costs											
Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Capital Cost	-353,300,000			-455,400,000	-279,000,000		-1,073,200,000				
O & M	-17,600,000	-17,600,000	-17,600,000	-40,300,000	-53,700,000	-53,700,000	-108,700,000	-108,700,000	-108,700,000	-108,700,000	-108,700,000
Financing and Debt	-18,413,804	-18,413,804	-18,413,804	-18,413,804	-18,413,804	-18,413,804	-18,413,804	-18,413,804	-18,413,804	-18,413,804	-18,413,804
Benefits											
Avoided Capital Costs											
O & M PL Avoided Costs	51,037,769	51,037,769	51,037,769	51,037,769	51,037,769	51,037,769	51,037,769	51,037,769	51,037,769	51,037,769	51,037,769
Salt Credit \$100 AF	1,680,200	1,680,200	1,680,200	3,696,500	4,458,200	4,458,200	9,610,800	9,610,800	9,610,800	9,610,800	9,610,800
SDCWA Losses	48,861	9,967,668	9,967,668	9,967,668	9,967,668	5,003,043	5,003,043	5,003,043	5,003,043	5,003,043	410,306,591
Urban Loss Avoidance	16,825,955	16,825,955	16,825,955	16,825,955	16,825,955	17,675,000	17,675,000	17,675,000	17,675,000	17,675,000	18,519,120
Agricultural Products	279,228,808	279,228,808	279,228,808	279,228,808	279,228,808	140,152,504	140,152,504	140,152,504	140,152,504	140,152,504	356,041,372
sum for NPV	-40,492,211	322,726,596	322,726,596	-153,357,104	10,404,596	146,212,712	-976,834,688	96,365,312	96,365,312	96,365,312	718,401,848

96,108	96,108	96,108	96,108	96,108	96,108	96,108	96,108	96,108	96,108	96,108	96,108	96,108	96,108	96,108	96,108	96,108	total	
2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046			
-108,700,000	-108,700,000	-108,700,000	-108,700,000	-108,700,000	-108,700,000	-108,700,000	-108,700,000	-108,700,000	-108,700,000	-108,700,000	-108,700,000	-108,700,000	-108,700,000	-108,700,000	-108,700,000		Capital Cost	-2,160,900,000
																	O & M	-3,026,700,000
																	Financing & Debt	-294,620,864
																	Total Costs	-5,482,220,864
																	Avoided Capital Cost	102,075,538
51,037,769	51,037,769	51,037,769	51,037,769	51,037,769	51,037,769	51,037,769	51,037,769	51,037,769	51,037,769	51,037,769	51,037,769	51,037,769	51,037,769	51,037,769	51,037,769		O & M PL Avoided Cost	1,633,208,608
9,610,800	9,610,800	9,610,800	9,610,800	9,610,800	9,610,800	9,610,800	9,610,800	9,610,800	9,610,800	9,610,800	9,610,800	9,610,800	9,610,800	9,610,800	9,610,800		Salt Credit	267,534,300
																	SDCWA Losses	2,733,544,521
																	Urban Loss Avoidance	284,450,375
																	Agricultural Products	4,412,578,562
																	Total Benefits	9,433,391,904
-48,051,431	-48,051,431	-48,051,431	-48,051,431	-48,051,431	-48,051,431	-48,051,431	-48,051,431	-48,051,431	-48,051,431	-48,051,431	-48,051,431	-48,051,431	-48,051,431	-48,051,431	-48,051,431		Net Cost	3,951,171,040
																	NPV	\$8,488,670.98

Data Calculated and Extracted from Excel (2007) Spreadsheet by author

Alternative 2: Carlsbad Desalination Plant

Water Created AFY Year	56,000 2015	56,000 2016	56,000 2017	56,000 2018	56,000 2019	56,000 2020	56,000 2021	56,000 2022	56,000 2023	56,000 2024	56,000 2025	56,000 2026	56,000 2027	56,000 2028	56,000 2029	56,000 2030	56,000 2031
Costs																	
Posiden																	
principal capital	-691,000,000																
O & M fixed	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000
O & M variable	-4,848,000	-4,969,200	-5,093,430	-5,220,766	-5,351,285	-5,485,067	-5,622,194	-5,762,749	-5,906,817	-6,054,488	-6,205,850	-6,360,996	-6,520,021	-6,683,022	-6,850,097	-7,021,350	-7,196,883
SDCWA																	
principal capital	-80,000,000																
electricity fixed	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515
electricity variable	-21,225,000	-21,649,500	-22,082,490	-22,524,140	-22,974,623	-23,434,115	-23,902,797	-24,380,853	-24,868,470	-25,365,840	-25,873,157	-26,390,620	-26,918,432	-27,456,801	-28,005,937	-28,566,055	-29,137,377
Debt and Financing	-213,000,000	-32,944	-71,792	-73,528	-75,376	-75,824	-77,728	-79,744	-81,704	-83,776	-86,072	-87,976	-90,160	-92,456	-94,752	-97,104	-99,400
Benefits																	
SCDWA loss avoidance	12,983,964	12,983,964	12,983,964	12,983,964	12,983,964	12,983,964	3,914,434	3,914,434	3,914,434	3,914,434	3,914,434						
Urban Loss Avoidance	16,825,955	16,825,955	16,825,955	16,825,955	16,825,955	16,825,955	17,675,000	17,675,000	17,675,000	17,675,000	17,675,000						
Agriculture Benefits	363,725,646	363,725,646	363,725,646	363,725,646	363,725,646	363,725,646	109,656,800	109,656,800	109,656,800	109,656,800	109,656,800						
sum for NPV	-639,252,950	344,168,406	343,572,338	343,001,616	342,418,767	79,535,713	78,928,000	78,307,373	77,673,727	77,026,616	-54,880,593	-55,555,107	-56,244,128	-56,947,793	-57,666,301	-58,400,024	-59,149,175

56,000 2032	56,000 2033	56,000 2034	56,000 2035	56,000 2036	56,000 2037	56,000 2038	56,000 2039	56,000 2040	56,000 2041	56,000 2042	56,000 2043	56,000 2044	56,000 2045	56,000 2046	Water Created AFY Year	Total
															Costs	
															Posiden	
															principal capital	-691,000,000
-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	-22,712,000	O & M fixed	-726,784,000
-7,376,805	-7,561,225	-7,750,256	-7,944,013	-8,142,613	-8,346,178	-8,554,833	-8,768,703	-8,987,921	-9,212,619	-9,442,934	-9,679,008	-9,920,983	-10,169,008	-10,423,233	O & M variable	-233,432,545
															SDCWA	
															principal capital	-80,000,000
-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	-3,515	electricity fixed	-112,480
-29,720,124	-30,314,527	-30,920,817	-31,539,233	-32,170,018	-32,813,419	-33,469,687	-34,139,081	-34,821,862	-35,518,299	-36,228,665	-36,953,239	-37,692,304	-38,446,150	-39,215,073	electricity variable	-938,718,703
-102,032	-105,560	-107,184	-109,928	-112,728	-115,416	-118,328	-121,352	-124,320	-127,456	-130,648	-133,952	-137,256	-140,336	-144,200	Debt and Financing	-216,131,032
															Total Costs	-2,886,178,761
															O&M post contract	-72,353,820
															O&M 30yr total	-1,899,047,729
															Benefits	
															SCDWA loss avoidance	84,491,990
															Urban Loss Avoidance	172,504,775
															Agriculture Benefits	2,366,912,230
															Total Benefits	2,623,908,995
-59,914,476	-60,696,827	-61,493,772	-62,308,689	-63,140,874	-63,990,528	-64,858,362	-65,744,651	-66,649,618	-67,573,889	-68,517,763	-69,481,714	-70,466,058	-71,471,008	-72,498,020	sum for NPV	
															net	-262,269,766
															NPV	(\$115,295,618.65)

Debt and Financing, Electricity, and O&M increase at an escalating rate each year (at 2.5, 4, and 2.5% respectively).

Status Quo

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Costs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benefits	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Losses to:															
SDCWA	0	0	0	0	0	-2,774,886	-2,774,886	-2,774,886	-2,774,886	-2,774,886	-15,062,179	-15,062,179	-15,062,179	-15,062,179	-15,062,179
Agriculture	0	0	0	0	0	-76,239,261	-76,239,261	-76,239,261	-76,239,261	-76,239,261	-413,829,324	-413,829,324	-413,829,324	-413,829,324	-413,829,324
Urban Users	0	0	0	0	0	17,675,000	17,675,000	17,675,000	17,675,000	17,675,000	18,519,120	18,519,120	18,519,120	18,519,120	18,519,120
sum for NPV	0	0	0	0	0	-61,339,147	-61,339,147	-61,339,147	-61,339,147	-61,339,147	-410,372,382	-410,372,382	-410,372,382	-410,372,382	-410,372,382

2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	Year	total
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Costs	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Benefits	0
																	Losses to:	0
-25,971,363																	SDCWA	-115,156,687
-713,556,234																	Agriculture	-3,163,899,158
19,350,000																	Urban Users	200,320,600
																	Net Benefits/losses	-3,078,735,245
-720,177,596	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	sum for NPV	
																	NPV at 2046	-6,780

Appendix 3: Calculations and Formulas

Loss Avoidance to SDCWA					
	2015	2020	2025	2030	
Shortage Urban no act ny	55,524	-15,160	-82,289	-141,889	negative means shortage
Shortage Urban dry yr	-149,715	-179,305	-202,325	-236,745	positive means loss not incurred
Urban alt 1 ny	55,524	27,869	70,798	106,476	
Urban alt 2 ny	72,326	21,805	-37,737	-45,811	
Urban alt 1 dy	-149,715	-151,436	-131,527	-130,269	
Urban alt 2 dy	-132,913	-142,340	-157,773	-140,667	
How many people will not get water (Shortage AF / average use AFY per capita)					
Cost of Shortage Urban no act ny	315,477	-86,136	-467,551	-806,188	
Cost of Shortage Urban dry yr	-26,350	-31,558	-1,149,574	-1,345,142	
CoS Urban alt 1 ny	9,772	4,905	402,261	604,977	
CoS Urban alt 2 ny	12,729	3,838	-214,415	-260,290	
CoS Urban alt 1 dy	-26,350	-26,653	-747,313	-740,165	
CoS Urban alt 2 dy	-23,393	-25,052	-896,438	-799,244	
avoided losses of those people not getting water (SDCWA loss) (number of people*average bill per year (\$1,040))					
Shortage Urban no act ny	321,786,818	-87,859,091	-476,902,159	-822,311,250	
Shortage Urban dry yr	-26,876,837	-32,188,834	-1,172,565,341	-1,372,044,886	
Urban alt 1 ny	9,967,668	5,003,043	410,306,591	617,076,818	
Urban alt 2 ny	12,983,964	3,914,434	-218,703,068	-265,495,568	
Urban alt 1 dy	-26,876,837	-27,185,791	-762,258,750	-754,968,068	
Urban alt 2 dy	-23,860,542	-25,552,877	-914,366,250	-815,229,205	

Water Conversions

1 million gallons= 3.07 Acre Feet

1 million gallons per day (MGD) = 1,120 acre feet per year