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San Diego's Options for Alternate Sources of Water: A comparative analysis of water recycling and desalination as alternative methods to importing water

Alana O. Pokorny
Scripps College

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By

Alana Pokorny

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Professor Char Miller

Professor Cindy Forster

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Table of Contents

Chapter 1: Introduction

Southern California has an abundance of redeeming qualities, with which it has seduced most who visit its breathtakingly diverse landscapes. The constant clear blue skies, the juxtaposition of ocean and desert, desert and mountain is appealing to anyone who enjoys the outdoors. Most of the time, these traits make the Golden State an ideal place to live. However, the clear blue skies that allow my family and me to surf on Christmas morning are also the skies that don't have clouds holding precipitation for a state that desperately needs it. This consistent lack of rain puts California in a constant state of 'drought'[1] because of the minimal annual precipitation rates. Currently, the United States is in what some scientists are calling a 'megadrought,'[2] referring to the consistent, elongated period of dryness, as opposed to the severity of dryness. So while rain may fall periodically, the annual rates of precipitation are not high enough to break out of the heading of 'drought', forcing California to consider methods of obtaining water other than importing, in order for its incredibly large population to survive.

My interest in the present-day megadrought, besides living in the state that is being arguably most effected, stems from my frustration with the lack of water conservation by some and the lack of water availability to others. This disturbance became clear to me after taking a variety of Environmental Analysis classes throughout my college career and attempting to find a solution, to almost no avail. It is not possible to conjure new fresh water, given all the water on this planet is finite. The only proof of opposition to this idea is what led me to seek an internship during the summer of 2014

[1] A relative term
[2] 100 Years of Drought

with a government sector that was making something (freshwater) out of nothing (wastewater).

I worked for the San Diego Public Utilities Department (SDPUD), which is a branch of the government that oversees all stages of water. From the collection of wastewater, grey water, and groundwater to storm water, the SDPUD monitors where water is, and determines where it will go and at what cost.

Within the SDPUD, I worked with the Pure Water San Diego (PWSD) public relations team. The project takes wastewater and cleans it until the water cannot be identified when compared to tap or bottled water.[3] The public relations department within Pure Water SD works incredibly hard every day, as it has had to do since the project's inception in 2006, to ease the concerns of a public that is weary of drinking "toilet" water. Since the system cleans wastewater to become drinking water, the alliteration "toilet-to-tap" became a common way to refer to recycled water, demeaning the process; while also leaving a negative connotation in the minds of those who did not know the whole purification progression. Though this issue may seem trivial, it is surprising how much information and demonstration it takes to change a public's perception, especially when they believe they are drinking toilet water. During one tour of the plant, the main tour guide[4] was obligated to spend an excessive amount of time answering the questions

[3] The water has been deemed "purified" or safe to drink, however, PWSD has not received official clearance from the EPA
[4] North City Water Reclamation Plant Employee

of a skeptic even after scientific and visual proof was given. It became clear that some individuals, no matter the scientific evidence, refuse to drink recycled water.[5]

Through my internship at Pure Water San Diego, I was able to see intimately how the project works and was able to interact with those who created it; talking with them about their initial ideas in 2004 and how they feel about where the project is a decade later. I was able to go on tours and interact with the public, which enabled me to witness a variety of different perspectives when listening to the reactions of individuals before and after the tour. Some were sold, as I was, on the technology and were very excited to drink recycled water, while others were hesitant, like the incessant skeptic, earlier, from one of my tours.

This cynicism and the power of social and community ideals to overpower scientific evidence is the main reason I chose to write this particular thesis in addition I was intrigued with water and all the drama and political controversies it causes. If even during one of the worst droughts California has seen on record, people cannot accept this method of alternative water sourcing, I am worried they never will. Many Pure Water nonbelievers claimed that desalination and importation are better options for obtaining water for Southern California. Since I have not worked with the agencies for these methods, I cannot definitively declare that Pure Water is a better option than desalination, however even in my preliminary research, both Pure Water and Desalination are better options than continuing to import water for a plethora of reasons.

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[5] Though in a few years, the projected plan will mix recycled water with imported water before being delivered to the rest of the city

Importing water from other regions does not only take water from the people in that region, but the pricing of imported water is much higher than if local sources were to be used. As the deputy director of water for San Diego stated, "the majority of water that we use in the city is imported. The price of that water has increased about 85 percent or more during the last eight years. So our customers are really feeling that."[6]

Aqueducts and dams are the primary means by which San Diego imports its water. While wondrous technological creations, are not always the most environmentally friendly as dams are built across rivers, hindering migrating fish from their destination, resulting in horrifically sad scenes of fish butting into dams until they die, attempting to reach their destination.[7] Furthermore, they are not the most reliable method of obtaining water due to the fact that they could break or crack during a natural disaster, or simply a malfunction in their construction. For example, Teton Dam located on the Teton River in Idaho was completed in November of 1975, only to rupture and collapse in June of 1976. The failure killed 11 people, 13,000 heads of cattle, and was projected to cost 2 billion dollars had the government chose to rebuild.[8] While this scenario is not always the case, if there are ways in which to avoid the chance of a dam or aqueduct catastrophe completely, while becoming a city that is sustainable due to local water sources, there seem to be no significant drawbacks to eliminating imported water.

In the chapters to follow, I will describe the processes, methods, backgrounds, and economic challenges, of Desalination and Water Recycling and provide current examples

[6] Brown and Caldwell Water News
[7] Damnation
[8] Teton Dam

of both. To create a baseline with which to compare the two methods, I will also delve into the history of California water policy. This complicated past is the reason water importation into Southern California remains the main method of obtaining water. Yet, as the current drought continues and technology advances, the need for imported water will become obsolete as the methods for recycling and desalinating water become less expensive, more convenient and more equitable. In the conclusion, all the methods will be compared and I will give suggestions on potential solutions for solving San Diego's water dependence.

Chapter 2: California Water History

The Background

California has a colorful, controversial, and complicated water history, which is one reason implementing changes or altering fundamental aspects of the current system have proven difficult. Far before European settlers arrived in the United States with their mindset of controlling the land, the Indians of California had successfully learned to live on the land that was the western pacific coast. A crucial difference between the Indians of California and the European settlers was that the Indians held a deep respect for nature, "yet it was a respect that permitted them to manipulate the environment, including the most precious of nature's resources, water, without doing harm," thus allowing them to live off of nature while simultaneously amongst it. As the Indians of California settled the west, they built their communities and villages around rivers, they did not divert them in order to bring them to a different settlement. The natives were able to do this because California was a much wetter region then, with marshland and lakes within the Great Central Valley continuing for hundreds of miles. The San Joaquin and Sacramento rivers wound through the valley connecting north to south, mixing salt water and freshwater, creating beautiful estuaries along their path. This once natural, connected flow of water throughout the state would soon be used up and remade but with concrete and steel, once again connecting the northern and southern parts of the state, in a much less positive manner.[9]

With the arrival of the Spanish to the lands of the natives, came their ideals of human supremacy over nature and the need to claim and alter the environment around them in order to "improve it." After exploring the region and deeming it drier than their homeland, the Spaniards realized that there was only one way to combat these periods of dryness and that was with an irrigation system. The Spaniards stumbled across San Diego and found it suitable for a presidio and appreciated the look of sustainability from the "large river" to the "good arable land." The Spaniards need to establish missionaries around the state, was brought over with their religion, thus after making San Diego a mission in 1769, Los Angeles was given its title as a "presidio" in 1781. With the establishment of these presidios and pueblos in order to create communities, extensive land grants were given to those who met specific requirements, however never were the rights to water ever given to those living on the land. The Spaniards controlling the towns announced

[9] The Great Thirst

that water would be a public entity, much like the "pastures and wood," but water was a communal resource passed down from the monarch.[10]

As the gold rush hit California in 1848,[11] spirits were high and the need for a centralized government controlling their actions was low. A spirit of laissez-faire was taking over the state, becoming a very different California than when under the hand of the Spaniards. As American's crowded into California to strike it rich, there was the issue of what water could be used in order to mine, due to the lack rivers. Due to a combination of the high regard for superior rights and the hook on Whig ideals, such as solving local issues locally, the answer to the miner's questions was solved by the phrase, "first in time, first in right." As long as the water was being used and others saw this, that water had an owner. Within this newly established appropriative right, there was a stipulation that the ownership was not of the river or body itself, just the man made divergent, bringing the water where it is need. Naturally, this method ran into problems when miners who didn't have appropriative rights to water still wanted to mine or those downriver from rights holders were no longer receiving water[12]. After complications arose amongst miners arose, Congress removed itself from a position of decision making in regards to this particular issue, consequently allowing states to regulate water rights. By doing this,

[10] The Great Thirst
[11] Water Transfers in the West
[12] Water Law in a Nutshell

not only did congress endorse appropriative rights for mining, but also for agriculture and manufacturing.[13]

As water rights became progressively less clear in California, the method of basing water rights off of land adjacency arose. Otherwise known as riparian rights, as long as the owner's land was adjacent to, or touching some part of, a body of water, the owner had the right to that water, and his or her lack of use would not change that. However, by acknowledging both types of rights holders, confusion ensued, and the Supreme Court did not help matters by switching their favor for different cases, and not setting a precedent. By 1865, the court ruled in favor of allowing riparian rights to pertain to agricultural land, where they had not been permitted prior to the verdict.[14] Court rulings like this would prove to be incredibly important in the decades to come, especially when establishing precedent in regards to environmental and social issues.

Throughout the state after the gold rush, populations began to rise prompting the expansion of roads and consequently the influx of people to new destinations. Los Angeles, San Francisco and San Diego, though each very different cities with history's all their own, have a linking thread that continues to hold them together to this day.

Los Angeles

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[13] The Great Thirst
[14] The Great Thirst

In 1904, the city of Los Angeles was being told that in order to support their growing population, the Los Angles River was not going to be a sufficient enough source of water. William Mulholland, the Superintendent of the municipal water system, stood facing the public of LA and delivered news that no one was expecting. “The time has come,” he proclaimed, “when we shall have to supplement its flow from some other source.” This statement marked the day that Mulholland and Eaton began planning and scheming behind the backs of two cities in order to turn Los Angeles into the metropolis they always wanted. The two men suggested the city seek alternatives in Owens Valley, for Mulholland believed that “could support the present number of Los Angeles residents, and also allow the city’s ‘boundaries…[to] be greatly extended.”

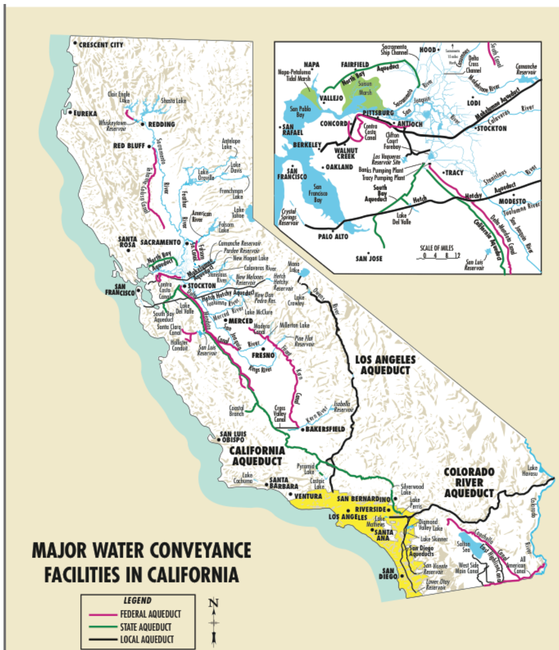

Figure 1: Current (2014) Major water conveyance facilities in California

Before official approval had taken place to begin the project, Eaton went behind the backs of his colleagues to buy land around the Owen’s River Valley, so that when the time came, and the votes were secured, the land around the valley could be used for building an aqueduct.[15] To build the aqueduct, the city needed to pass a bill granting 25 million dollars towards the project, pending government approval. The bill was passed,

15 Western Times and Water Wars

the citizens voted to allot 24.5 million towards the aqueduct. While this was occurring, Eaton and his colleague Joseph Lippincott, a supervising engineer for the reclamation department, were caught ‘snooping’ around Northern California to purchase the land for a reservoir, along with the construction of the planned aqueduct.[16]

As another voting day approached, planned for September of 1905, the weather was unseasonably warm, solidifying the city’s worries. In order to make sure they knew the pressure of the bill, Mulholland emphasizes to the LA crowd, “If Los Angeles runs out of water for one week… the city within a year will not have a population of 100,000 people.” In reality, the unseasonable dryness for the time was not due a drought and the city was not running out of water; but Mulholland and Eaton had dreamed of the city becoming a metropolis and with this new water, that dream could, and would, become a reality.

Northern California

Simultaneously, San Francisco was facing real water scarcity problems as its population increased due to the gold rush; and later, because the water that Los Angeles bought from them.

In order to secure fresh drinking water for the growing population, city officials scrambled in an attempt to buy Alameda County’s Calaveras Valley, only to have it purchased from under them. Nearly 40 years after the search began, in 1900, the city agreed to purchase the Tuolumne River. Connected to the Sierra Nevada’s, the Tuolumne

[16] Drowning the Dream

drained a large portion of the freshwater runoff, including Hetch Hetchy Valley. Much like in Los Angeles, San Francisco kept the plan a secret from the public until it was too late to do anything, causing the citizens of Los Angeles to become quite upset. Hetch Hetchy was a beautiful valley, which the city took away from the residents pretty much overnight.[17] After the draining of Hetch Hetchy, political turmoil and controversy took hold of San Francisco. Half of the citizens were angry due to the destruction of a beautiful landscape, while another group was angry about the water Los Angeles had taken, leaving their agriculture vulnerable.

Despite the fact that both cities were at odds with one another due to corrupt bureaucrats and untruthful deals, they have more in common with each other because of that; and due to those actions, they are connected by not only an aqueduct but through a larger system that also connects the two to San Diego. The State Water Project has been instrumental in connecting every part of California with water. From building dams, reservoirs and aqueducts to refilling groundwater basins and monitoring water levels, the State Water Project has attempted to recreate the once natural landscape that existed before European settlers came and completely changed the way nature worked. The SWP is how San Diego is tied to these two cities, and although their histories are interesting, staying reliant on them for San Diego's water is not the best idea.

San Diego History: From LA to SF to SD

[17] The Great Thirst

Southern California owes much of its success to Los Angeles' water, and by the transitive property, Northern California through the SWP. However, the smaller city has an earlier history all its own and unique geographical entities, that have prompted the decisions it has made today.

In 1850, California became part of the United States after the Mexican-American war. Part of the land that was annexed to the United States was the City of San Diego. Then the city would have been considered more of a pueblo, and its residents would soon realize the instability of water levels, since most of the year land that far south is dry with little rainfall.[18] However there were a few natural sources of water and citizens received the majority of their water from the San Diego River or from the few private wells that were in existence. With the growing population, and constant worry that the San Diego River would not be enough, San Diego began expanding its borders to bring in water and connect parts of the city. 23 years later, in 1873, the San Diego Water Company was established in order to create a delivery system to serve water to the 2,000 citizens living in San Diego. As the quality of water began to diminish due to the urbanization of the land surrounding the

Year	San Diego City	San Diego County	California
1850	650	798§	92,597
1860	731	4,324*	379,994
1870	2,300	4,951*	560,247
1880	2,637	8,618*	864,694
1887	30,000*	[the great boom]	
1890	16,159	34,987*	1,213,398
1900	17,700	35,090*	1,485,053
1910	39,578	61,665	2,377,549
1920	74,361	112,248	3,426,861
1930	147,995	209,659	5,677,251
1940	203,341	289,348	6,907,387
1950	333,865	556,808	10,586,223
1960	573,224	1,033,011	15,717,204
1970	696,769	1,357,854	19,971,069
1980	875,538	1,861,846	23,667,764
1990	1,110,549	2,498,016	29,760,021
2000	1,223,400	2,813,833	33,871,648

Figure 2: Population Chart for San Diego between the years of 1850 and 2000

18 San Diego County Water Authority: History

wells and pumps, the San Diego Water Company begins to drill into the San Diego River to pump more water out, to then be delivered to a newly created Reservoir in Old Town.

About a decade later, in 1889, San Diego began to build flumes to expand their water resources. Flumes are "artificial channels or troughs for conducting water… used to transport logs or provide water power,"[19] but not only was San Diego able to transport items along these channels, but they were used simply to obtain the water itself. Thus beginning San Diego's quest for water from sources around them in order to create a stable water level for the growing city. Along with the implementation of flumes for water transportation came the establishment of dams in order to control the newly obtained sources of water.

When these new implementations proved to be insubstantial for the growing need for water, in 1901, the City of San Diego voted to purchase the holdings of the San Diego Water Company and the Southern California Mountain Water Company, which were within the city's limits, but were in possession of much more water than the city had access to prior to 1901. Even after these purchases, between the years of 1914 and 1943, San Diego purchased the rights to many local small rivers in the region and continued building connections between these new sources and the center of the city. A plethora of reservoirs were built to preserve all the extra water the city then owned but was not always being used immediately. Other smaller dams and reservoirs that were built during this period of water expansion are shown in Figure 3. Then in 1947, all local water dependence was alleviated with the finished construction of the San Diego Aqueduct,

[19] Dictionary.com

which brought water from the Colorado River to a local San Diego reservoir, monitored by the newly founded Metropolitan Water District. In 1978, San Diego began to receive water from the State Water Project, securing the water the city would need for future development and population growth.

Year	Completed Projects in San Diego County
1897	Lower Otay Dam Lower Otay Reservoir
1918	Lake Hodges Dam San Dieguito Dam
1922	Barrett Dam Barrett Reservoir Morena Reservoir
1931	El Capitan Dam El Capitan Reservoir El Capitan Pipeline
1943	San Vicente Dam San Vicente Reservoir San Vicente Pipeline

Throughout this period of water expansion and municipal growth, the byproduct of water once it was used was not considered to be anything other than ‘waste’ and was funneled into sewages, never to be considered again as useful. In 1996, the process of separating and collecting wastewater began, creating the Metropolitan Wastewater Department. From here, the idea of recycling said wastewater for urban and agricultural use became a reality in 2002 with the South Bay Water Reclamation Plant.

Following the process the South Bay and Orange County plants set with water reclamation and recycling, and learning from their mistakes, San Diego began its Pure Water Demonstration Project in 2007 due to the external pressures the city was facing from importing instability, population growth and the current drought.

Chapter 3: Drought

North America: Prone to Droughts

Due to scientific advancements in technology, meteorologists have been able to track rainfall patterns to determine dry and wet periods throughout the past thousand years. The chart below demonstrates the percent of North America that has been in a drought since 814 and illustrates that the continent has been in a persistent drought for the last 15 years.[20]

This chart allows the different droughts to be compared in length and severity, which is especially helpful today when attempting to predict future weather patterns and projecting the end date for the current drought. Bioclimatologist Park Williams[21], states that the past 15 years in the

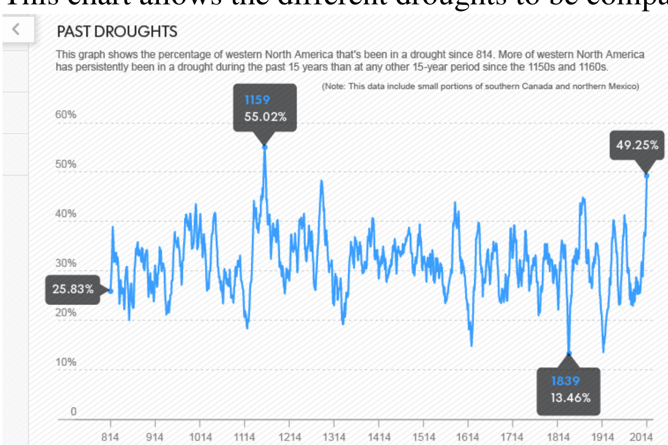

Figure 3: Percentage of North America in a drought since 814

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20 USA Today: Graph of Past

21 William is also a professor at the Lamon-Doherty Earth Observatory of Columbia University,

west have been the driest episode in more than 850 years. He goes on to add that “when considering the west as a whole, we are currently in the midst of a historically relevant megadrought”, referring to the duration of the current drought as opposed to the severity, which ebbs and flows between years.[22] To signify the way scholars view megadroughts, Cornell University scientist Toby Ault compares the likeness of these droughts to “great white sharks”, but for the climate. He describes them as “…powerful, dangerous and hard to detect before it's too late. They have happened in the past, and they are still out there, lurking in what is possible for the future, even without climate change."[23]

Not only have drought rates been higher in the entire continent for the past hundred years, records show that within California periods of incredible dryness have become a climatic pattern. About every ten to twenty years there are periods of drought surrounded by periods of flooding. A geological survey which chronicled floods and droughts, also calculated the amount of time it will take for a particular state of climate to repeat itself. This is of special concern currently and for the near future due to the fact that following ten years of statewide drought, predicted to reoccur every ten to forty years, the driest years recorded in the states history began in 1928 lasting until 1937. This level of dryness is predicted to

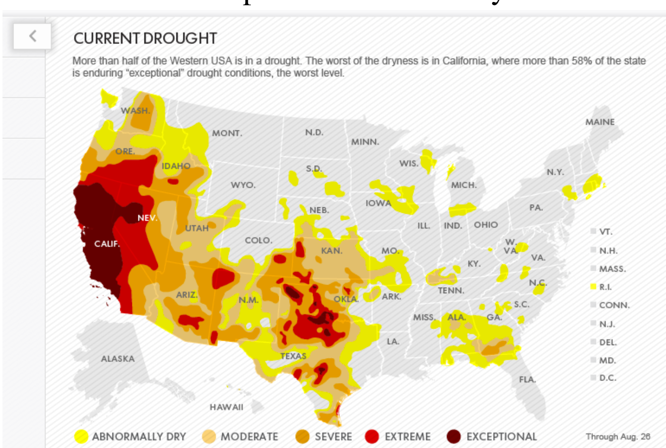

Figure 4: Current Drought Projection by Region

[22] *100 year Drought* by Doyle Rice
[23] *100 year Drought* by Doyle Rice

occur about every 100 years, therefore, if correct, California will experience another drought of this level around 2028. This projection is even more pressing given California's current state of dryness, as stated by Park Williams.[24]

USA Today's meteorologists compiled precipitation data from the past in order to project the state of drought the country is in currently, by region, on a scale from "abnormally dry" to "exceptionally dry". As shown in Figure ##, it is clear that the majority of California is in a state of exceptional, dryness. Due to this information combined, or not, with climate change, and the need for alternative methods of obtaining water other than importation, San Diego has begun to test various methods of doing so in order to combat the effects of the drought and made the Southernmost part of California hydraulically sustainable.

Chapter 4: The Alternatives

San Diego, with a population of 1.3 million, making it the 8th largest city in the United States, has begun researching and implementing new methods of developing local drinking supplies in order to "lessen dependence on imported water, keep up with population growth and combat water supply reliability challenges, including recurring drought conditions".[25] In doing so, the city will no longer be vulnerable to potential drastic losses of water due to natural disasters, or political turmoil regarding the use of water sources in other regions. In this chapter the two alternatives that are most suitable for the San Diego region, due to its geographic location, are examined and compared in

[24] National Water Summary
[25] Pure Water San Diego

order to determine the most efficient, reliable, and sustainable method for obtaining fresh water to implement moving forward.

Water Reclamation and Recycling

Recycled water, is a feasible alternative to water importation. The process of reclaiming and recycling water is incredibly advanced and reliable, and is currently being used in San Diego and Orange County. However, because of its recent past, in order to establish the process on a larger scale, both cities had to prove the safety, efficiency and reliability of water recycling.

Pure Water San Diego

The San Diego Public Utilities Department contains a branch which focuses on water distribution, wastewater, grey water, conservation efforts and much more. Within this Water Branch is a program called Pure Water San Diego and was created in order to look into the feasibility of water reclamation and recycling in order to "deliver clean, safe drinking water for the city of San Diego".[26] However, before the program could be initiated, years of research and practice trials were performed in order to prove the systems reliability.

In January of 2004, the San Diego City Council supported the comprehensive study and evaluation of recycled water. The study looked into health effects and reuse options, but also incorporated societal views and opinions on the idea of recycled wastewater. The reuse study established that the water would be reclaimed and sent to the

[26] Interview with Marsi Steirer

North City recycling plant, where the water would be purified and sent to the nearby San Vicente Reservoir. The process of purifying water and sending it to a reservoir is known as "reservoir augmentation", and after undergoing this process, the water is taken to an additional drinking water treatment facility. In 2007 after finalizing reports and holding countless forums, the study was deemed successful and by the City Council to begin the at that point Water Purification Demonstration Project began would instigate purifying water for potable reuse and recharging the reservoir.[27]

The Water Purification Demonstration Project was a implementation of the reuse study conducted between 2004 and 2007. The intention of those working on the study was to demonstrate the potential of recycled water and prove that the negative effects were far lesser than people believed. Some components of this project included testing, operating and monitoring a demonstration scale Advanced Water Purification Facility (AWP) that produced one million gallons of purified water per day. The project also performed an energy and cost benefit analysis, along with a pipeline alignment study to account for the water being sent to the San Vicente Reservoir. Because of some societal discontent regarding the idea of drinking wastewater that was recorded during the study, an education and outreach program was an appreciable part of the Purification Demonstration Project.[28]

The project's findings were as follows and were adopted by the City Council in April of 2013: the AWP Facility produces exceptional quality water that meets all federal

[27] Reuse Study
[28] Demonstration Project

and state drinking water standards and the energy needed to power the purification plant would be comparable to the amount of energy used for importing water, and the full scale plant would produce 15 million gallons a day at $2,000 per acre foot of water. Public support of the project rose from 26% in 2004 to 73% in 2012 due to the outreach and education program. "Ultimately, the Demonstration Project has proven that purified water can be produced and safely added to the San Vicente Reservoir as part of a full-scale potable reuse project" creating Pure Water San Diego within the water branch in the Public Utilities Department.[29]

Currently, the role of Pure Water San Diego is to "provide a safe, reliable and cost effective drinking water supply for San Diego"[30] using the proven purification technology from the Demonstration Project. PWSD's projected twenty-year plan incorporates a combination of structural and legislative initiatives in order to rely on recycled water plants to create 83 million gallons of purified water a day, about one third of San Diego's drinking water supply, by 2035. To accomplish this goal, PWSD plans to construct more purification facilities around the county using the AWP technology, while continuously running tests on this process in order to keep the system up to date and make it as efficient as possible. In addition, the continued regulation of all aspects of the system will fall under the program's supervision; along with any policy or legislative changes regarding the AWP's or water delivery. Lastly to continue raising support for,

[29] Demonstration Project
[30] Interview with Marsi Steirer- Official Motto of PWSD

and increasing knowledge of the system the education and community outreach program will continue.[31]

The facility currently recycling water through the Pure Water San Diego program is located in North City, very close to La Jolla. Daily tours are given of the AWP plant, and the process the water undergoes is clearly explained by the tour guides. In addition, a presentation is given before entering the plant itself, going over in detail the water purification process. The process, though incredibly advanced, is fairly straightforward, with a minimal number of steps, as the chart below will demonstrate; however when examining each step closely, the scientific basis will present itself.

This entire process takes place on a plot of land about half the size of a football field, with pipeline running beneath it, carrying the wastewater to the plant under the 1-805 freeway. Wastewater, or influent, is taken to the Influent Pump Station at the plant and pumped 90 feet above to the Headworks, where the rest of the process will begin, operating using gravity.[32]

The wastewater is first passed through “large rake-like” bars in order to remove large debris and floating material. Once through, the dried waste is taken to the landfill and the remaining water is passed through an aerated grit, where other heavier solids are removed, such as gravel and coffee and taken to the landfill as well. After this process, Primary Sedimentation occurs as solids sink to the bottom of the tank, and grease and oil

[31] Pure Water San Diego
[32] North City Water Reclamation Plant

float to the top. Both are removed, and taken away for disposal; this step takes about “90 minutes and removes 99% of the solid” debris in the water.[33]

The next step is aeration, which is found in two different zones. The anoxic zone, where oxygen is depleted and the aerobic zones, where oxygen is consumed; both zones contain bacteria that eat soluble organic material. The zone without oxygen is intended to control filaments while the zone with oxygen is to allow the bacteria to digest the organic solids. In order to reduce foul odors throughout the plant, a step is taken that removes the hydrogen sulfide gas from the flow of the water and forces it through a bleach solution spray which neutralizes the sulfide compounds. Secondary Clarification occurs when the mixed liquids settles to the bottom of the basin, after the bacteria has consumed the organic molecules, and is removed, along with some water in order to pump the sludge through to waste pumps. The leftover water, void of solid waste is then ready to be set to the Point Loma Wastewater Treatment Plant, which produces tap and bottled water, or the water can be sent to Tertiary Treatment for reclaimed water purposes, on the same site.[34]

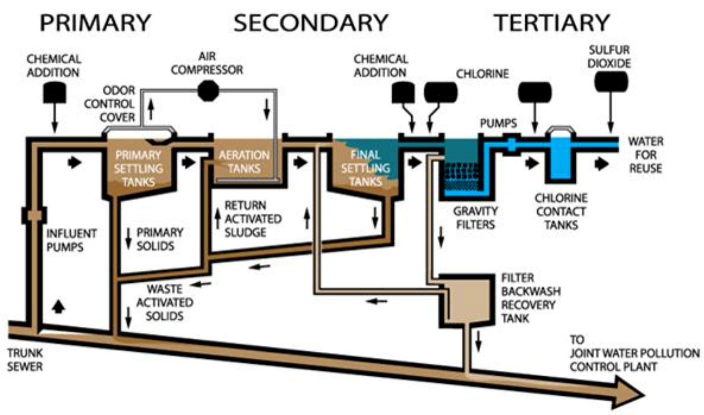

Figure 5: Illustrated process of wastewater treatment at the San Diego facility from PWSD Website

[33] North City Water Reclamation Plant
[34] North City Water Reclamation Plant

Tertiary Treatment consists of removing all effluent that may not have been removed after the previous steps. The remaining water is chlorinated for 90 minutes to insure disinfection. After this step, the water is clean enough for irrigation. A portion of the water is sent to a demineralization facility, where it is put through an electro dialysis reversal (EDR) process in order to reduce the salinity of reclaimed water. This EDR treated water is then blended with the treated effluent water, and chlorinated for ninety minutes, thus making it safe for industrial use or agriculture that require less salinity in the water.

An on site cogeneration facility provides all the power used on the plant through the entire purification process. Methane is piped from the Miramar Landfill and converted into energy, of which approximately 75% is used at the plant and the remaining power is sold back to the electrical grid.[35]

The intelligence and care put into this process to make it the efficient system it is currently, is due to a few prominent individuals who dedicated themselves to this program and the idea of a sustainable San Diego. One such individual, Marsi Steirer, the deputy director of the Water Department in San Diego was instrumental in the program's initiation in 2004, and has since continued to lead the city in a progressive direction for water reclamation and reuse.[36]

In an interview with Steirer, when asked about issues the department was facing in 2006 with the Demonstration Project, her reply was, the cost of materials. "Whether

[35] North City Water Reclamation Plant
[36] Brown and Caldwell

it's steel or plastic or availability of concrete…just the availability [of these items] or the cost increases we've experienced in the last two to three years have really added onto the costs of our capital projects."[37]

While this is still a current issue, as prices are high with the construction of any kind of plant like that of the AWP plant, when asked the same question in 2012, Steirer replied that the first issue is the Bay Delta. "I don't think we've been able to solve outstanding differences" and "on a statewide basis," she says, "our traditional water supplies are oversubscribed because of a growing population and continue to be impacted by drought, climate change, regulations and other restrictions."[38] Between 2006 and 2012, the drought had increased in severity and length for the entire state, forcing pressure on San Diego to become unreliant on Northern California and Colorado's water sources, since eventually, those will run dry as well; forcing the city to seek alternatives with even more desperation. Steirer's change in her response reflected what those within the water department were thinking about the future of San Diego's water. During those six years, the program had become a success, allowing for the confidence of promoting it as an efficient alternative.

When asked for her opinion on the future of recycled water and what role it may play in addressing future challenges, Steirer responded that she sees it playing a major role. She believes that California is a leader in using "recycled water in 'purple pipes,' for separate uses and for integrating recycled water into our drinking water supply. The

[37] The Daily Transcript
[38] Brown and Caldwell

Orange County Groundwater Replenishment Project has set the bar on the latter. I think that will help mainstream the whole indirect potable reuse question."[39]

Orange County's Recycled Water

The Groundwater Replenishment System (GWRS), established in 2008, was Orange County's first step towards creating a water reclamation and recycling plant. Joined by the Orange County Water District (OCWD) and the Orange County Sanitation District (OCSD), the GWRS became the largest water purification project of its kind. Similar to San Diego's beginnings, planning was slow and implementation was even slower; Orange County began planning for this system in 1994, although construction did not begin until 2003. The first implementation of the plant cost $480 million, with another $142.7 million added for construction in 2012.[40]

While these two systems are very different, though both are recycled water plants, some similarities that they share are: the climate of southern California, and the lack of precipitation year-round and the need to deliver water to over three million people county wide and considering the future population growth.

One of the differences between San Diego and Orange County treatment facilities, is that GWRS receives secondary treated sewer water for further treatment, whereas San Diego receives wastewater and performs preliminary treatments on it before sending it out to other facilities or keeping it within the plant to purify on the tertiary level.

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[39] Brown and Caldwell
[40] Water- Technology

However, the process Orange County uses for purification is very similar, and consists of microfiltration, reverse osmosis and ultraviolet light treatments.[41]

Due to the sheer size difference between the two southern California plants, GWRS is able to hold and treat much of their water underground through a Siemens MEMCOR, a “submerged membrane system” that is capable of supplying 86 million gallons a day per water. This membrane system is composed of 26 compact units, which “can treat water five times more than the formal purification system established in the same footprint.”[42]

San Diego’s efforts to recycle water paired with those of its northern neighbor up the coast, demonstrate how two cities with large populations, similar climate but different geographies can implement a recycled water program successfully.

Due to the geographic location of San Diego, and the abundant availability of salt water sourced from the ocean or from the bay, water desalination is the second potential alternative to aid San Diego in its quest for reliable, local sources of water.

Desalination

Overview

The practice of extracting salt from water is not a new idea. In the fourth century B.C. Aristotle and Hippocrates were in support of distillation, which is the process of

41 GWRS
42 GWRS

heating water to the point of evaporation and collecting the salt-free condensed water.[43] With time, the process has been advanced by technology, and by 2001 there were more than 15,000 desalination plants worldwide.

Desalination, also known as desalting, desalinization or distillation, is one of the most consistent fields in advancing the technology for the methods of converting non-fresh water to fresh water.[44] With constant advancements within the field, desalination is becoming increasingly affordable, and thus a viable option to consider in San Diego's future. The most popular desalting processes available are Thermal and Membrane desalination. Differing in the method to remove salt from water, thermal uses a heat process while membrane utilizes a reverse osmosis approach, using screens and pressure instead of heat.

Thermal Desalination

Thermal distillation encapsulates three different manners of desalinating water: multi-stage flash distillation (MSF), multiple-effect distillation (MED) and vapor compression (VP). The last method is not as widely used due to its inefficiency, therefore will not be included in the comparison.

Thermal distillation is used in half of the desalination plants worldwide and replicates part of the natural water cycle, evaporation and condensation, in a controlled setting. In order to extract freshwater, leaving the salt behind. "In order to boil, water

[43] Supply From the Sea
[44] IDA

needs two conditions: the proper water temperature relative to its ambient pressure and enough energy for vaporization."[45] This correlated combination allows for desalination plants to control the temperature at which the water will boil by lowering the pressure within the tank. Most plants practice multiple boiling techniques, lowering the pressure and temperature in each vessel. This process typically produces one ton of steam, which is equivalent to eight tons of distillate. A drawback to this method, however, is that controlling the temperature in order to allow all the compounds in salt water to either boil or freeze simultaneously is incredibly difficult, and when approached incorrectly, results in "scale." Scale is a hard calcium film that coats the tubes and surfaces with which it comes into contact. To avoid this, a very strict control temperature can be set, or chemicals can be added to seawater in order to reduce the occurrence of scale when boiling water.[46]

The multi-stage flash distillation (MSF) process, the most heavily used throughout the 1960's,[47] heats seawater in a brine heater, a vessel that can withstand great heat. Once heated, the seawater flows into another vessel, where the pressure is lowered, causing the water to boil immediately. This almost instantaneous conversion from water to steam produces a flash- effect, thus receiving its name. The result of this process is a small

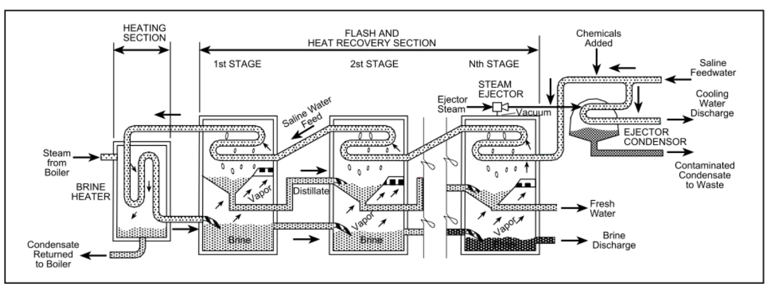

Figure 6: Illustrated process of MSF desalination

[46] ABCs of Desalting
[47] Multi-effect distillation plants

amount of vapor, however when conducted on a large plant, with thousands of vessels that are constantly "flashing", the condensed steam accumulates rapidly, making this method very popular in regions with open, flat plots of land.[48] The drawback to this method is the hazard of having constant incredible heat blasts around equipment that was not built to withstand such high temperatures (230 degrees F) consistently. Nonetheless with careful observation and regulation changes, within the last 10 years, the MSF plants have become more reliable.[49]

Multi-effect distillation is the oldest method of thermal distillation. Replaced for some time by the more efficient MSF process, in 1980, interest in the older method was reestablished due to the use of lower temperatures, therefore minimizing the negative side effects of MSF.[50] MED is the thermal process that takes seawater and boils it at lower temperatures directly correlated with lower pressure. The reason this method is favored by energy conservationists is due to the fact that only the initial vessel needs to be heated; the decrease in pressure throughout the following stages accounts for the lack of a heat source.[51] Due to recent conservation movements and heightened Green House Gas[52] awareness, this method has become more frequently utilized for its ability to create freshwater, while using the least amount of energy, when compared to MFS.

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[48] Article References Saudi Arabia as Success Story
[49] Thermal Analysis of Multi-Stage Flash
[50] Multi-effect Distillation Plants
[51] SIDEMVEOLIA
[52] Green House Gas

Both of the methods under thermal desalination discharge salt, saltwater, brine, and/or pollution into the ocean, creating a harmful effect on the marine life nearby.[53] When comparing these methods with the membrane desalination methods, the amount of heat energy used and steam produced must be compared to the process and results of membrane desalting.

Membrane Desalination

Electrodialysis (ED) and reverse osmosis (RO) are both processes of desalting seawater that use membrane filtration to selectively separate salts and water.[54] ED, introduced in the 1960's, uses a series of "anion- and cation-exchange membranes arranged in an alternating pattern between an anode and a cathode to form individual cells."[55] Due to this make up of positively and negatively charged ions in contact with the charged barriers, a permeable membrane is made, allowing certain molecules through. This chemically charged fence draws the salt to one side and the freshwater to the other creating two completely different solutions on either side of the membrane.[56]

The other method of membrane desalting, reverse osmosis, implemented in 1970, is relatively new. RO consists of four major components: "(1) Pretreatment, (2) pressurization, (3) membrane separation, and (4) post treatment stabilization."[57] Overall, these steps demonstrate how the water is cleaned before entering the treatment pump,

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[53] Environmental Impact/ Impact Assessment
[54] ABCs of Desalting
[55] Assessment of Electrodialysis
[56] Assessment of Electrodialysis
[57] Organization of American States

how the pressure within the pump is elevated so that when it is dense enough, the salt and water separate, allowing the water to pass through the membrane, while deterring the salt molecules. The final step in the process treats the water with pH adjustments before sending it elsewhere.[58] A drawback to reverse osmosis, pointed out by Robert Service, a proponent of the method in general, is that RO requires high pressure, and therefore energy, to push the water through, however the membranes are prone to "biofouling, in which thin films of organic material coat the surface of the membrane and block water from going through." He mentions that chlorine could remedy this organic issue, except chlorine destroys the polymer, giving researchers a new goal to reach.[59]

Case studies conducted on the different methods of desalting water express opinions, concerns, observations and suggestions in regards to the method of producing fresh water for the present day and for the future.

When comparing the different methods of desalination, Robert Service,[60] explains that thermal methods of desalting use much more energy than reverse osmosis, and the example of the Saudi Arabia plant as a successful method was not a reasonable one due to the amount of oil they consume to power their machines. Service goes on to encourage the use of desalination plants, however since pricing has been going down quickly due to new technology. In Ashkelon, Israel, isobaric chambers have helped lower the cost of desalinated water down to $0.527 cents per m^3. "At that rate, a seawater desalination plant could supply a typical U.S. household with fresh water for the amount of power

[58] Organization of American States
[59] Desalination Freshens Up
[60]Desalination Freshens Up

needed to light an 80 watt light bulb," MacHarg[61] says. Both Service, and authors of *Ocean Desalination Part of a Larger Plan*[62] agree that the membrane desalination and even thermal MED, are the same price as importing water, making the sources local and incredibly reliable.[63]

A very strong counterargument of desalination in general comes from Sabine Letterman and Thomas Hopner, authors of *Environmental Impact and Impact Assessment of Seawater Desalination.* The authors argue that due to the make up of most desalination plants, as shown below the tubes that extend from the plant into the ocean to collect seawater aren't very long, thus disrupting shallow aquatic habitats when water is removed and when discharge is replaced. Since these habitats are so close to the surface, their environments become disrupted much easier by the pull of water or the injection of chemicals. If the water was taken from open ocean, the result might be different, but where the tubes are placed currently, organisms become caught in screens (impingement) or are brought into the plant, past the screen (entrainment).The authors also reason, which can be supported by Robert Services' statement regarding biofouling, that if plants do decide to combat the organic organisms within the system, those chemicals will eventually be redistributed into the ocean, killing the organisms nearby, since that was the original purpose of the chemical within the plant.

Lastly, in *Supply from the Sea: Exploring Ocean Desalination,* Jeff Szytel argues for an economic approach to the idea of desalting water. He begins with the idea and

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[61] CEO of the Affordable Desalination Coalition
[62] James Williams and Jeffery Szytel
[63] Desalination Freshens Up

reality of "reliability" and the lack thereof in local freshwater sources, the unpredictability of weather patterns, the drought, environmental regulations, infrastructure condition, natural disasters and variability in water quality, as supportive of argument of finding an alternative water source. He attempts to analyze the worth of desalination by using a high risk, high reward model. In this case, the cost for reliability are high, however, so is the rate of return; meaning putting a lot of money into a reliable source of water, will guarantee that source of water. Szytel concedes that currently, prices for desalination plants and the water desalted there is very high, however with subsidies and natural energy sources, these prices can be lowered and mitigated. Closing his argument, and relating it back to his economic comparison, he suggests "diversification." Why would anyone put all of his or her money into just one investment? Szytel says they would not, so California should not do so with their water sourcing.[64]

Currently in the United States, the Bureau of Reclamation is funding sixteen desalination projects, with each research group focusing on different aspects of the process in the hopes to improve and build upon the current methods and practices. This action by the government not only shows their support of the idea of alternatives to water importation but also demonstrates how research is much more manageable when subsidized by the government.[65]

Currently, the City of Carlsbad's proposal to create a desalinization plant has been accepted by the public, and the San Diego County Water Authority is working with

64 Supply from the Sea
65 Bureau of reclamation Helps fun 16 Desal Projects

Poseidon, a desalting construction company, in order to have the plant up and running by 2016.

Chapter 5: Conclusion

Attempting to place blame for Southern California's current need for alternative water sources would be futile. Those who lived through the history of the city, of the region, and even of the state up until today could easily be partially to blame. However, with that logic, the decisions we make today, or made yesterday for that matter, are affecting not only our futures but those of our decedents and so on. Unless there is no longer any water on this planet, in which case, pinpointing our lifetime give or take 50 years, would be quite simple. No civilization wants to be the one that brought the entire human race down; because desalination plants blocked the views of their homes or the idea of recycled water was too gross to handle or that having a brown lawn for a few months or a few years was worse than running out of water forever. This analysis is incredibly dramatic, but for a reason. It is sometimes hard for humans to be able to grasp the bigger picture, and though the one just delivered was pessimistic at best, it demonstrates what "can be" in the future if the problems at hand are not addressed and alternatives are not implemented.

Comparing alternatives point by point would be ideal, however, these alternatives seem to have benefits in very specific ways, making it very hard to directly compare aspects of them.

Pure Water San Diego and their water recycling plant does not exceed the energy use of importing water to San Diego, making it economically feasible. The program also does not take up very much space, thus disrupting very little around them upon construction. The program recharges a reservoir that was dried up years ago due to human consumption and prevents wastewater from going into the ocean or landfills. A drawback to PWSD, is the small, but existent, public dislike of drinking purified wastewater.

The two sources of desalination that were the most reasonable to implement in San Diego would be reverse osmosis under the membrane method and multiple effect distillation (MED) under the thermal method. These two are the most efficient for the amount of energy they use and do not have any, save the land the plant is built on, negative effects on the environment. Their drawbacks however, would be in terms of size and the quantity of water being desalted every day. As Robert Service pointed out, the membranes are effected organic compounds, and there hasn't been a new discovery to fix this on a large enough scale to be implemented right away. However even with their drawbacks, all the alternatives listed here, and even the other methods of desalting, are excellent alternatives to importing water. Though hard to compare to each other due to the vast fundamental differences, PWSD recycles wastewater while MED desalts seawater, comparing and determining that these alternatives are more efficient, cost effective and environmentally sound than importing water is simple.

Chapter 6: Suggestions moving forward

Primarily, no matter the method of obtaining water San Diego is using, conservation must always be a priority. During dry years and wet, all Americans, but Californian's especially, must be conscientious of water use so when another drought does hit, the amount of drastic changes made previously will not need to be made again. The goal would be to hardly notice there is a drought at all, besides the grasses looking less green and the sands feeling warmer.

After working for PWSD I was convinced that if given the opportunity to determine San Diego's next water source, I would nominate PWSD to produce 100% of the city's water. I am still in support of this idea, however perhaps on a lesser scale. The idea of treating our water sources like an economic investment is incredibly realistic and achievable.

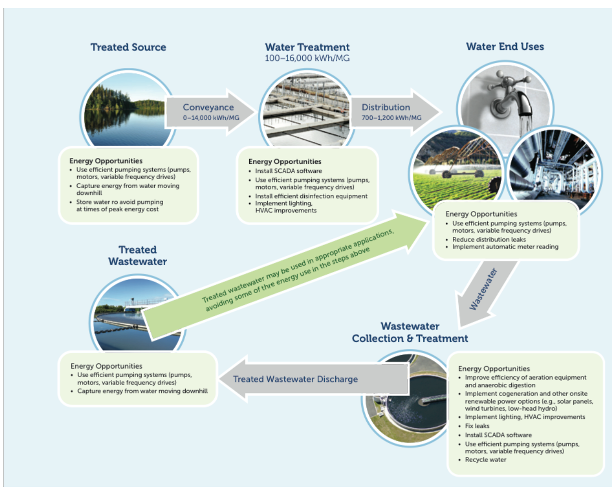

Figure 7: The steps of the municipal water cycle, and ways to conserve water within each one (from the PWSD website)

The diversification of our water assets would mean to distribute the burden but also the achievement on multiple sources of water so in case one failed, there would still be plenty of water for the city in the meantime. That being said, my ideal solution for San Diego moving forward with new water sourcing would be: a fusion. The implementation of a MED desalinization plant on the coast with more scattered throughout the inlands of San

Diego to allow them to desalt brackish water. Multiple water reclamation and recycling plants, with the extra purified water recharging ground basins and reservoirs. In addition to those, the construction of a small reverse osmosis plant on the coast, but another one on the San Diego Bay, in order to sustain every region of San Diego. These alternatives would help make every part of San Diego independent and sustainable as well, so if one technology malfunctions there will be plenty of water to have as an emergency fund.

In order to mitigate any future societal unrest with the decisions that have been made in regards to placement of constructed plants or length of desalination tubes, a brief EIS, unless a real one is required through the state or federal government, should be written out so that there is always a stakeholder protecting the environment.

Many authors writing about desalinization pointed out that in many places, constructing natural energy sources near desalting plants or even recycled water plants, would establish an even greater level of independence, while simultaneously lessening the amount of GHG in the air.

As for the role of the government in my plan, I would like to see more government funding and/or subsidies for research into advancements of current water sources or even research into brand new water sources. If the government did this, scholars and researchers could focus solely on advancing technology and creating new ways to go green and make it a lifestyle not a trend.

> "I think the future answer for our water supply isn't one answer; it's not imported water, it's not desalination, it's -- we like to say -- a diversified water portfolio. It

comes from a variety of sources. That's what will help the region have a safe and reliable and locally controlled water supply in the future, and that's really important for all of us."

-Marsi Steirer

Deputy Director of Water in San Diego

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