2005

Water resources on the Monterey Peninsula : how the efficient use of water through increased conservation, water reuse, and aquifer storage and recovery can help to meet water demands in the urban sector : a capstone project ...

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To the ESSP faculty of CSUMB:

Throughout the world, water quality and quantity are being diminished. As the population along our nation's coastline continues to increase, greater demands are placed on potable water supplies. In response to this and the contamination of groundwater and surface water due to pollution, communities across the country are looking for alternatives to alleviate problems associated with water supplies. The Monterey Peninsula is no exception and has been considering several options including desalination and aquifer storage and recovery to augment and lessen demands placed on freshwater supplies.

With the current state of water resources throughout the world, this project is one of great interest and timely significance. Water is essential to life and is an inherent right to all species on the planet. Therefore, it is of the utmost importance to reach a solution to the present water crisis that will provide for the long-term water needs of the community and be the least destructive to the fragile coastal environment.

This project was done with the general public in mind. People can use this report to become better informed about water resources in their local community. The ultimate goal was to present options for meeting current water demands without the development on new water sources. Through an extensive literature review and communication with officials in the field, I have formed opinions and made recommendations for the Monterey Peninsula. In the beginning, it seemed I could come up with a simple answer as to which option would be better. As I continued to dig deeper, it became apparent the simple question of whether or not Monterey should endorse the idea of building a desalination plant as an alternative water source seemed to skirt the real issue of water resources management. Through the process of trying to synthesize a coherent picture of what is taking place and what is really at stake, I discovered that a fundamental shift in our thinking about water is necessary to achieve a long-term sustainable water supply.

After working in the laboratory at the Monterey Regional Water Pollution Control Agency, I discovered water quality was something of great interest to me. It was here I first learned about the recycling of wastewater and its subsequent reuse. Through the recycling of water we can maximize water supplies. Technological advances are essential to providing safe and reliable water. However, in areas were other options exist, desalination of our oceans waters may be going to far. Despite my own preconceived notions of what is right and wrong and what should or should not be done, this topic is of great interest to us all. I encourage future students and the general public to become more involved and better informed about what is taking place in their local communities concerning their water supplies.

I feel this capstone should be assessed in the ML0 # 3 and # 4.Thank you for your time and consideration. I hope you find this paper and topic as interesting as I do.

Sincerely,

Jessica Sharkey

Water Resources on the Monterey Peninsula:

How the efficient use of water through increased conservation, water reuse, and Aquifer Storage and Recovery can help to meet water demands in the urban sector

A Capstone Project

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Abstract

As the population along our nation's coastline continues to increase, greater demands are placed on potable water supplies. In response to this and the contamination of groundwater and surface water due to pollution, communities such as the Monterey Peninsula are looking for alternatives to alleviate water supply problems. However, the development of new water supplies can be costly and have adverse environmental impacts. Through an extensive literature review and communication with experts in their respective fields, recommendations are made as to the best options available to meet current water demands without the development of new water supplies. An emphasis is placed on the use of recycled water to supplement freshwater. Increased conservation of water supplies through ordinances, taxes, and public education can provide significant reductions in water usage. Aquifer storage and recovery projects can serve to decrease groundwater withdrawals and surface diversions during dry periods. With further improvements in treatment technology and continued research on the health effects, recycled water can provide a significant source of urban water supply in the future. Through rethinking watershed management we can have a safe sustainable water supply and a viable economy.

Introduction

Only about 1% of the water on Earth is available as potable freshwater, with most of it occurring in the form of groundwater. Water is used to serve many needs including crop irrigation, industrial uses, and urban supplies (Anderson 2003). Accessing and delivering freshwater to consumers presents a challenge to water suppliers. Water management projects have disrupted the natural cycle of water through groundwater extractions and surface water diversions (Bouwer 2000). These practices have significantly altered water supplies by lowering water levels in aquifers and reducing stream flows.

The demand for freshwater will continue to rise due to population growth, increased urbanization, and higher general standards of living. Additional water resources are often not logistically feasible or even legally available. Since the most practical supplies are exploited first, each additional source of water will come at a greater price economically and environmentally (Okun 2000, Gleik al. 2003). Finding and developing new sources of water is an extremely arduous task that takes large investments of time and money to accomplish.

Since supplies of freshwater are limited, the reuse of wastewater for specific purposes increases overall supplies without the development of additional sources. Use of recycled water for non-potable purposes has become a widespread practice throughout arid regions of the world (OCWD 2004). Reuse to augment potable aquifers has received more opposition, but is becoming more accepted with increased treatment technologies.

The Monterey Peninsula (Figure 1) is a medium-sized mostly residential community located on the central coast of California (MPCC 2005).

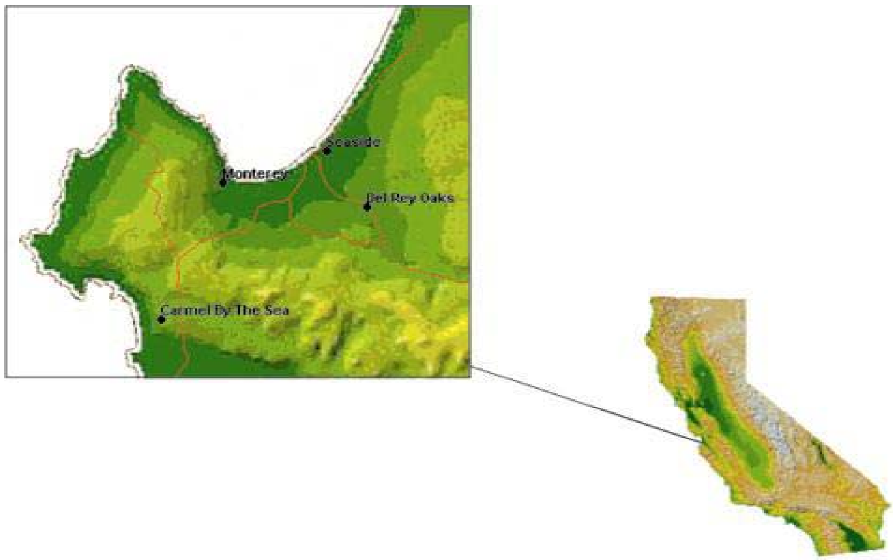


Figure 1. Location of the Monterey Peninsula on the central coast of California
Map made by ICE MAPS

The Monterey Peninsula Water Management District (MPWMD) oversees water supplies for cities located on the Monterey Peninsula as shown in Figure 2. The cities falling within the jurisdiction of the MPWMD include Monterey, Pacific Grove, Sand City, Seaside, Carmel-by-the-Sea, and unincorporated parts of Monterey County. California American Water Company (Cal-Am), a private enterprise, acts as the water purveyor for these areas. Cal-Am manages the collection, storage, and distribution of water supplies to these central coast communities.

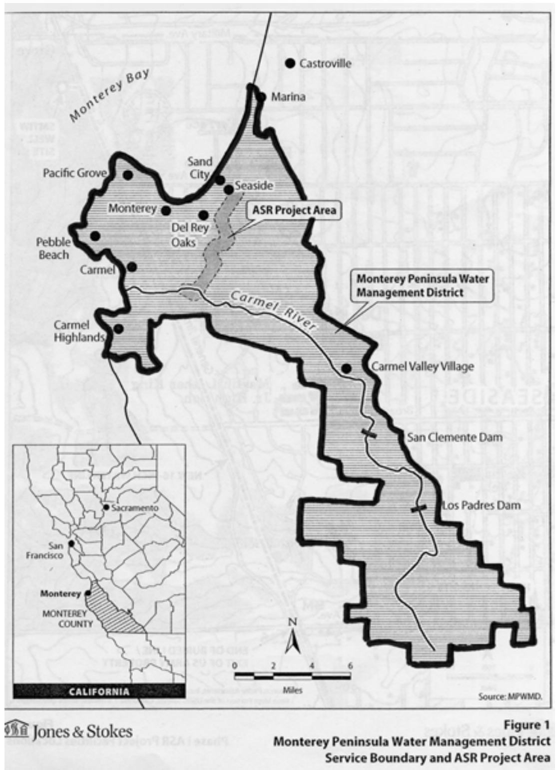


Figure 2. MPWMD and Cal-Am service area. (Map taken from MPWMD 2005)

The Carmel River watershed, as shown outlined in Figure 3, supplies most of this water. A small portion also comes from the Seaside groundwater basin (Denise Duffy 2001, DWR 2003, MPWMD 2004b). Increased growth and development along the central coast of California has depleted local water supplies. Over 15,012 acre-feet (af) were supplied to customers on the Monterey Peninsula in the 2004 water year. The Carmel River Watershed supplied 11,000 af, while the Seaside Groundwater Basin supplies 3,918 af to the Cal-Am service area (MPWMD 2005). The Carmel Area Wastewater District (CAWD) treatment plant located at the mouth of Carmel Valley supplied 791 af of recycled water to irrigate turf at several Monterey Peninsula golf courses and at one local school (MPWMD 2005).

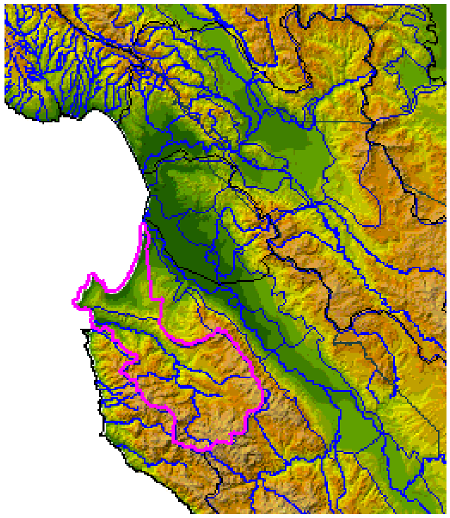


Figure 3. Outlines of Carmel Valley watershed
Map made using ICE MAPS

The Carmel River is a coastal stream that encompasses a 255 square mile drainage area (NMFS 2003). The Carmel alluvial aquifer is drawn down by pumping in the spring and summer months and reduces water flows enough to seasonally dry the lower reaches of the Carmel River. The over-allocation of water in the Carmel River Watershed has degraded the natural habitats of two federally threatened species: the Steelhead trout (*Oncorhynchus mykiss*) and the California red-legged frog (*Rana aurora draytonii*) (MPWMD 2005). Because of this, in 1995 the State Water Resources Control Board (SWRCB) handed down Order WR 95-10. This mandate requires Cal Am to make one-for one reductions with alternate water supplies and reduce its annual take of the Carmel River to less than 4,000-acre feet year (afy). This is a significant difference from the amount historically used by Cal-Am and in to order meet this requirement 10,730 afy must be supplied by other sources. Due to the need to decrease pumping from the Carmel River, groundwater withdrawals from the Seaside Aquifer have subsequently increased (MPWMD 2004).

The need for additional sources of water has become an issue of intense debate on the Monterey Peninsula. Excess use of the Carmel River continues and studies show withdrawals from the Seaside Groundwater Basin are unsustainable. Steps are actively being taken for the long-term development of water supply alternatives (Yates et al.2005 and MPWMD 2005). This paper makes recommendations for strategies to address the problem of water supply shortages on the Monterey Peninsula based on each strategy’s ability to minimize the need for new sources. Topics discussed in this paper include aquifer storage and recovery, recycled water use, and conservation. The recycling of water to augment water supplies is examined and the health concerns associated with reuse for indirect potable use are addressed. Information was collected through an extensive literature review. Documents containing information on proposed projects were used to assist in proposal analysis. Additional information was gathered through interviews with members of local agencies as well as through attendance at regular meetings of key organizations involved

There has been increased controversy on the central coast between the different stakeholders described in Figure 4. Numerous organizations have an interest in the outcome of proposed alternative water supplies. Both government and non-government organizations play a key role in water management. Water purveyors such as Cal-Am manage the water supply and are responsible for providing water to the consumer. Water management agencies, such as the MPWMD oversee local water supplies and are tasked with ensuring that a safe and reliable supply of water exists. The Department of Health Services (DHS) protects the public by establishing guidelines to ensure the water delivered is safe for the consumer. Regulatory agencies, such as the Environmental Protection Agency (EPA) and the Regional Water Quality Control Board (RWQCB) set standards, regulations, and issue permits concerning water use in ordinance with federal and state legislation. The California Public Utilities Commission (CPUC) regulates and sets rates for investor-owned water systems. Organizations such as the Carmel River Watershed Conservancy (CRWC), National Marie Fisheries Service (NMFS) along with the California Department of Fish and Game (DFG) and the Monterey Bay National Marine Sanctuary (MBNMS) work to protect environmentally sensitive areas such as the spawning habitat of the Steelhead Trout along the Carmel River. Citizens are the driving-force behind water demands and influence decisions concerning water supplies based on public opinion and acceptance.

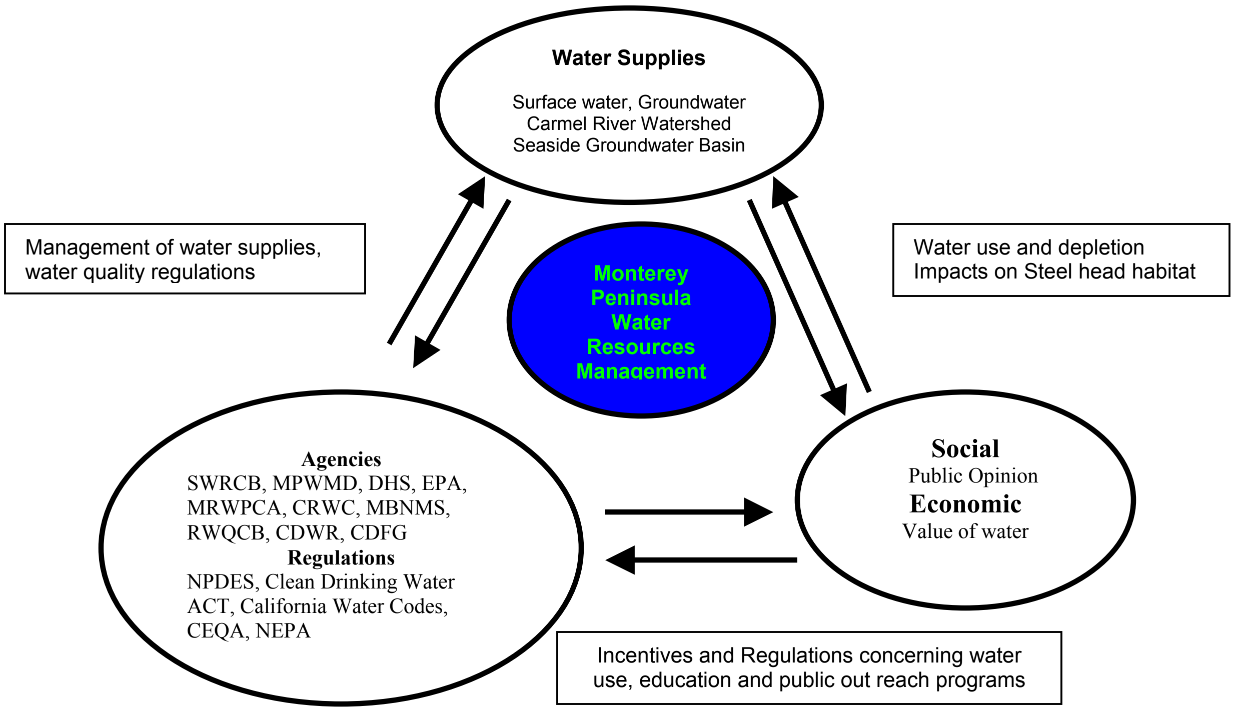


Figure 4. Systems diagram showing the different stakeholders and roles they play

The overarching goal is to provide a reliable source of water with the least amount of adverse environmental impact. There are many ways to deliver additional sources of water to the consumer and everyone involved has a different idea as to how this should or shouldn't be done. The easiest way to obtain more water is to conserve what you already have.

Conservation

According to a statement made in a conservation report by the Pacific Institute for Development, Environment, and Security, "The potential for conservation and improved efficiency [in California] is so large that no new dams or reservoirs will be needed for the foreseeable future, even with expected growth in population and the state's economy. Moreover, capturing this water will be cheaper and more environmentally beneficial than any other alternative available (Gleik et al. 2003)." Conservation can be considered a management tool and should not only be employed in times of water shortage. The amount of water used per capita has risen in both developed and less developed countries and is attributed to the increased use of water consuming amenities (Gleik et. al 2003).

Unaccounted for water is the amount lost in the distribution process. Much of this comes from leaks within the systems. Updating infrastructure can be time consuming and costly, but the results of not doing so can be significantly greater in the long term. Fixing leaks and replacing out-of-date pipelines could potentially increase supplies up to 25% (Vikers 2002). In a comprehensive conservation report by Gleik et al. 2003, it was shown that water savings from leak reduction on the consumer side also has the potential to save water. Audits and regular maintenance can reduce residential water leaks to nearly zero. An average reduction in leak rates to less than 5 gallons per minute (gpm) would reduce the amount of water lost due to leaks to approximately 240,000 afy for all of California (Gleik et al. 2003). Reducing leaks in the home will save the consumer usage costs and the distributor a reduction in delivery costs.

A large potential for water savings exists in the areas of landscaping and urban use. According to the California Department of Water Resources (CDWR) reducing outdoor water use in new and existing developments could decrease usage by as much as 13,000 afy for the entire central coast region (CDWR 2003). Efficient outdoor water use can be accomplished through landscaping techniques and the use of native drought-tolerant plants. Over-watering can occur even when efficient landscaping is utilized (Gleik et al 2003). Irrigation based on site-specific water budgets is a simple way to increase water savings. One type of water saving technology is an evapotranspiration sensor. This piece of equipment determines when plants need to be water based on the actual amount used (Vikers 2002).

Although water consumption per capita has increased, advanced technologies maximize the efficiency of water use. Many opportunities exist for easily employing additional water saving strategies (Vikers 2002). Low-flow toilets and showerheads are easy to install and readily available (Gleik et al. 2003). Through local ordinances, cities are able to reduce demand by encouraging more efficient use. Restricting flows and usage encourages the public begins to see water as a limited resource and in turn the consumer may begin to use water more wisely (Okun 1996, 2000).

One way in which regulations may influence conservation are through local landscape ordinances. Assembly Bill 325, passed in 1990 by the California Legislature, requires local agencies to adopt and enforce a Local Water Efficient Landscape Ordinance. On March 8, 2005 the Technical Advisory Committee (TAC) of the Monterey Peninsula Water Management District (MPWMD) met to discuss baseline outdoor water use concepts. The goal of the meeting was to create an ordinance that would provide incentives for reductions in outdoor water use.

Uniform enforcement is necessary to establish consistency and compliance. The MPWMD has left enforcement of landscape ordinances to local jurisdictions. Fifteen years after the passage of the bill, only three areas within the MPWMD's jurisdiction have established regulations. In order to ensure consistent levels of water conservation across the district, the TAC is now tasked with developing a comprehensive landscape ordinance for indoor and outdoor water use. Currently, outdoor water conservation practices are limited to new developments and large lots. One of the proposed local additions to the state ordinance is to provide water bill credits and incentives to individuals and organizations that replace lawns with drought-tolerant landscaping. At present no other action has been taken to adopt regulations for baseline conservation requirements (MPWMD Technical Advisory Meeting 2005).

The Water Awareness Committee (WAC) committee is a collaborative group of local water agencies in Monterey County that work to promote education and public outreach within the community. The WAC sponsors a program called 'retire your turf' to encourage the public to use native drought-tolerant plants. In a meeting with Karen Harris, and active member of WAC and the education and outreach coordinator for the Monterey Regional Water Pollution Control Agency (MRWPCA), she explained that if people were to 'retire' or convert to drought-tolerant landscaping just 25% of their lawns, enough water could potentially be conserved to meet SWRCB Order WR 95-10 (Harris, personal communication 2005).

Felicia Marcus, a former EPA Regional Administrator explains that, "Through water conservation and recycling, we can meet environmental needs and still have sustainable development and a viable economy (EPA 1998)." According to the CDWR, additional use of water conservation practices and expansion of water recycling facilities could potentially supply the entire central coast region from southern San Mateo County to Santa Barbara County, with more than 30,000 afy (CDWR 2003). As reported in Gleik et al. (2003), approximately one-third, which amounts to 2.3 million afy of California's current urban water-use, could be saved with existing technology. In addition, much of this can be accomplished at costs lower than developing new sources. Overall the potential for additional conservation in the urban sector is significant. According to some estimates made, indoor residential use can be reduced a further 40% and anywhere from 25% to 50% additional water savings can be achieved in outdoor urban use (Gleik et al 2003).

Conservation of agricultural water usage does not directly apply to this paper but should be looked at if a holistic approach towards regional water management is to be taken. In the California Water Plan Update, a bulletin put out by the DWR, water management options for the different regions of the state are discussed. For the central coast region, where over five hundred thousand total acres of crops are irrigated and agricultural uses make up the largest portion of the water budget, the DWR deemed reductions in irrigation water uses were unnecessary because "no significant depletion reductions would be achieved." And, "Excess applied irrigation water recharges aquifers in the major agricultural areas (CDWR 2005)."

Wastewater Treatment

The CDWR defines water recycling as "the treating and managing of municipal, industrial, or agricultural wastewater to produce water that can be productively reused (CDWR 2004)." The EPA expands this to include the idea of "… reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing, and replenishing ground water basins."

Under the Clean Water Act of 1972, wastewater must be treated to meet certain standards before it can be legally discharged into receiving waters. All entities discharging wastewater must have a permit issued under the National Pollution Discharge Elimination System (NPDES). Minimum treatment for most wastewater involves physical and biological processes (Okun 1996, 2000). In more environmentally sensitive habitats, such as the Monterey Bay National Marine Sanctuary, additional treatment maybe required. Increased regulations have in some cases made it more costly to discharge wastewater than to treat it for non-potable uses (Okun 1996, Bouwer 2000).

The Monterey Regional Water Pollution Control Agency (MRWPCA) operates a sewage treatment system permitted under NPDES (permit No. CA0048551) for communities on the Monterey Peninsula (RWQCB 2002). During the summer months when demands for water are high, the MRWPCA delivers tertiary treated wastewater to farmers as part of the Monterey County Water Recycling Projects (MCWRP). The Salinas Valley Reclamation Program (SVRP), the treatment component of the MCWRP is used for distribution to farmers as part of the Castroville Seawater Intrusion Project (CSIP) to minimize seawater intrusion in the Salinas Valley.

In the winter months, secondary treated water is discharged into the Monterey Bay. The maximum wet weather discharge is 75 million gallons per day (RWQCB 2002). This water has the potential to serve the needs of users on the Monterey Peninsula. The current facilities at the MRWPCA are designed to deliver around 30 million gallons of treated wastewater per day, which amounts to a little over 33,000afy. Of this amount about two-thirds of it is used to irrigate 12,000 acres of food crops during the summer months. A portion of the remaining amount along with winter productions could potentially be used to serve the needs of the Monterey Peninsula (MPWMD 2004 and Harris personal communication 2005).

The MRWPCA is proposing a two phase Regional Urban Water Recycling Project (RUWRP) to serve non-potable water needs, such as outdoor uses, in the urban sector. The first phase, which could potentially be completed by 2008, would require no additional seasonal storage facility and deliver approximately 1,700 af of water. The second phase would provide for a total yield of 3,100 afy. Providing additional recycled water in the long run would require a seasonal storage facility (Holden, personal communication 2005, CPUC 2002, MPWMD 2005).

The Carmel Area Wastewater District/Pebble Beach Community Services District also operates a smaller reclamation plant on the Monterey Peninsula. The plant has a capacity of two million gallons per day. Approximately 700 AF of treated wastewater from this facility was used for golf course irrigation in the 2004 water year (MPWMD 2005). Expansion of this facility can serve other large irrigation users in the Pacific

Grove area. Infrastructure needed to do this would require a seasonal storage facility. An increase in storage capacity would allow for irrigation water to be delivered on demand during peak usage (CPUC 2002 and MPWMD 2005).

Cities along the Monterey Bay National Marine Sanctuary have been ordered to eliminate stormwater runoff into areas of biological significance (MPWMD 2005). Runoff from these urban areas may have the potential for reuse. Different treatment options may be required depending on the contaminants most prevalent in the runoff. If this water is diverted to the sewage treatment plant, it can provide an additional source of water to be recycled and would decrease the amount of pollutants and sediment entering the sanctuary (CPUC 2002). Preliminary tests have been conducted to determine the feasibility of stormwater diversions. Dry-weather diversions have proven to be successful thus far and plans are in the process to expand the coverage area. Diversions from storm drains are not conducted during the rainy season because the treatment plant is not capable of handling the excess rainwater (Hoover, personal communication 2005).

Treatment plants can differ slightly in their operations and may utilize different technologies. The main function of any water treatment plant is to reduce the amount of organic matter, solids, nutrients, disease-causing organisms and other pollutants from wastewater (Mancl n.d.). The following description is of the treatment plant, as shown in Figure 5, owned and operated by the MRWPCA. Before water ever reaches the plant, ferric chloride ($FeCl_3$) is added at pump stations located within the community to induce coagulation. $FeCl_3$ has the ability to bind to colloidal matter and is therefore important for removing total organic carbon (TOC). $FeCl_3$ also precipitates with hydrogen sulfide (H_2S), an extremely corrosive chemical (Mancl n.d.). The wastewater then enters the treatment plant at the head works, labeled number one in the figure below, where the treatment process begins. Preliminary treatment involves removing large inorganic debris through a physical screening process. A mechanical bar-grate with a rake separates such things as rags and other trash from the water. Sand and grit are also screened out of the water. The trash is taken to the landfill, while the water continues through the process (MRWPCA n.d.). Hydrogen peroxide (H_2O_2) is added to control the amount of H_2S in the water. The H_2O_2 reacts with the H_2S to form sulfur and water. Both H_2S and large debris can be damaging to the equipment used in the treatment process if not removed in preliminary treatment (Wikipedia 2005).

The next step, called primary treatment, utilizes gravity and density differences to remove grease and suspended solids from the water. The water moves from the headworks into the primary clarifiers (labeled number two), where it is allowed to sit for a few hours. Small particles and grease float to the top of the holding tanks and are skimmed off and sent to the landfill. The solids that settle to the bottom of the clarifier are sent to the thickeners and then to the digesters, where they eventually are turned into bio-solids. The water then moves from the settling tanks into several large domed structures called trickling filters, pictured in the diagram by the number three. This step utilizes biological processes to remove organic contaminants in the water. Wastewater is sprayed from a rotating arm at the top of the dome onto suspended plastic sheets, which act as a substrate for the growth of microorganisms. A thin film of microorganisms on the substrate breaks down the dissolved organic matter and nutrients present in the wastewater. These organisms continue to grow and form large aggregates on the sheets as they feed. After about a day the coagulate slumps off at the bottom and is replaced by new growth (MRWPCA treatment plant operators, Personal communication 2003, 2005).

The water, including some of the microorganism from the trickling filters, now flows to the biofloccultaion basin (labeled number four). Here air is mixed with the water to provide oxygen for the microorganisms as they continue to coagulate dissolved materials in the water. The remaining bacteria and coagulants, termed activated sludge, are sent to the thickeners and then the drying beds. This material is eventually sent to the landfill where it is used to help facilitate biodegradation of wastes. Finally, the water makes it way to the secondary clarifiers (labeled number 5), which act to increase water detention time. These holding tanks allow for the microorganisms used in the previous steps to settle out on the bottom. The water left on top can legally be discharged into the bay under the treatment plant's NPDES permit. This entire treatment process as depicted in Figure 5 takes around seven hours. Water is tested at each point along the treatment path (MRWPCA treatment plant operators 2005).

Tertiary treatment, as shown by number six through eight in the figure below, is employed to ensure high quality water is available for crop irrigation. This process begins in the flocculation basins, where Hyper Ion 835, a coagulant, is added to cause the coalescing of remaining organic materials. The water then flows through sand filters to remove the solids that are formed in the flocculation basins. After filtration, the water is disinfected with chlorine for no less than two hours in a contact basin. This step increases the retention time of the water and effectively kills any remaining microorganisms and disease causing pathogens in the water. This water is then pumped to a holding pond where it awaits distribution (Holden personal communication 2005, Mancl n.d., MRWPCA n.d.).

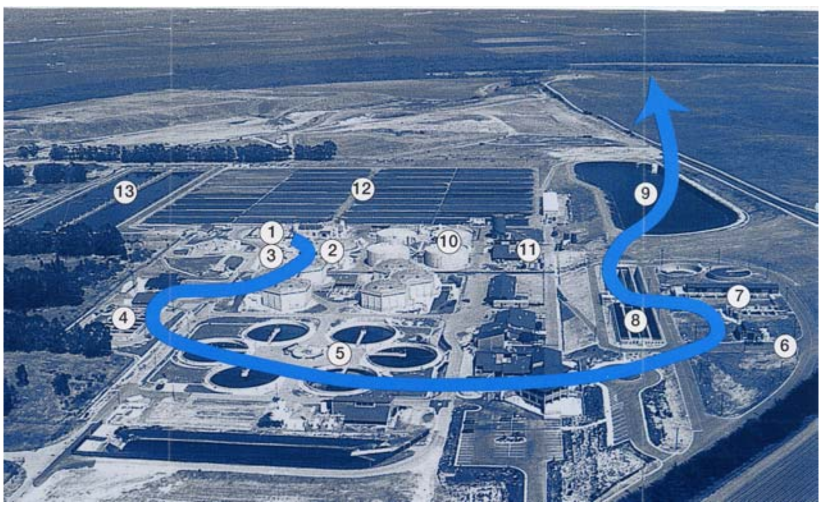


Figure 5. The flow of water through the MRWPCA treatment plant. Graphic taken from MRWPCA educational literature.

To ensure the reliability of all wastewater treatment plants, several steps must be taken to increase efficiency. These steps may include backup systems, standby power supplies, continuous monitoring, and multiple treatment barriers (Okun 1996). Different treatment options may be employed depending on the contaminants desired for removal. Multiple treatment barriers, including reverse osmosis (RO), micro filtration (MF), activated sludge, ultraviolet disinfection (UV), chlorination, and ozonation can be exploited to ensure that the treatment process covers a wide-range of contaminants. These treatment technologies have been widely used and accepted. Continual advancements in the field of wastewater treatment are being made to identify and reduced pollutants (OCWD 2004).

Title 22 of the California Administrative Code (Water Codes) sets regulations regarding the treatment of the wastewater and how it may be used. The water codes set guidelines, which must be strictly adhered to before recycled water can be applied for any purpose (Water Code 2001). Potable reuse of the recycled water requires advanced treatment for the removal of nitrogen, phosphorous, additional inorganic and organic carbon compounds and further pathogens (Bouwer 2000). In order to make the recycled water now produced at the MRWPCA suitable for indirect potable use, further advanced treatment such as ozonation would be needed (Holden, personal communication 2005).

Water Reuse

Public health concerns and opinions must be addressed before the implementation of reuse projects. The public usually has little knowledge of its water supply and wastewater treatment systems. Policies are often made based on overall public acceptance of a water management project. Reuse can be classified in different categories: non-body contact, body contact with no ingestion, and ingestion. The public is less accepting of uses that involve body contact or drinking (Stone 1976).

Different types of water reuse projects exist. Unplanned water recycling occurs when cities draw on surface water supplies used and discharged further upstream. Before the water reaches the last downstream user it has been treated (because it is surface water), used, treated, discharged, treated and used again (Anderson 2003). Mankind has unintentionally been using recycled water for generations. For example, in Virginia, the Upper Occoquan Reclamation plant discharges highly treated water into a stream located above the Occoquan Reservoir, which serves as the local public water supply. Recycled water represents around one-tenth of the input into the reservoir (EPA 1998). Intended water recycling projects plan to use recycled water as an alternate water source. The most well known example is Water Factory 21, a treatment plant operated in Orange County California since the 1970’s, where highly treated wastewater is used for groundwater recharge. In some areas where water is scarce, wastewater is considered too valuable to be discharged. This was the case for a small village near the Grand Canyon, which had no water source of its own. Water was brought in by truck and subsequently recycled for non-potable uses. Even after other sources of water were developed, the village continued to utilize its wastewater (Anderson 2003).

Studies have shown when individuals are more aware of water supply problems they became more receptive to the use of reclaimed water. Areas with limited water sources or polluted water supplies are more likely to have increased public acceptance of reuse. A way to gain additional support for reuse projects may be to emphasis the need for reuse based on issues of supply and demand (Stone 1976).

Increased population growth and additional development not only means more water use, it also means more wastewater (Bouwer 2000). Water recycling minimizes adverse environmental impacts and maximizes efficient use by allowing for significant reductions in freshwater diversions and the amount of wastewater discharged (Anderson 2003). Since the amount of wastewater discharged is decreased pollutant loads entering receiving waters are reduced, thus improving the quality of water. Because reuse also minimizes the amount of surface water diverted, greater stream flows are available to maintain river ecosystems. By reducing the amount of groundwater withdrawn, reuse can also act to prevent or slow the progression of saltwater intrusion into freshwater aquifers (EPA 1998).

Recycled water serves as a form of drought protection by providing a reliable source of water. The most logical uses for recycled water are those requiring a non-potable use of the water. Activities that utilize non-potable water such as landscaping, firefighting and golf course irrigation often require large amounts of water. Landscape irrigation can include the use of recycled water to maintain parks, playgrounds, golf courses, commercial areas, office buildings, as well as private residential areas. Other non-potable beneficial uses for recycled water include toilet flushing, dust control, cooling systems, in addition to industrial and recreational purposes. Recycled water has also been used for artificial groundwater recharge (EPA 1998).

Studies have shown public acceptance for wastewater reuse varies depending on education level, age, and location. In most cases people oppose wastewater reuse due to lack of information and education as well as psychological factors (Olsen and Bruvold 1982). Psychological factors affecting acceptance could be lack of faith in science and technology. Disagreement between organizations can lead to public confusion and distrust (Dishman et al. 1989).

Direct potable use of recycled water is illegal in the United States. However, due to such severe drought and lack of access to water, other parts of the world have been forced to supplement supplies with reclaimed water. Recycled water has been directly augmenting drinking water supplies in Namibia for over a generation. In this scenario highly treated wastewater is blended with drinking water before entering the storage reservoirs. The average ratio of reclaimed water to freshwater is around 1:4; therefore a 25% maximum proportion of recycled water exists in the supply at any one time (Anderson 2003). Increased non-potable uses may lead to potable acceptance. If people become aware of how recycled water is being used in other parts of the country, they may be more willing to acknowledge the possibility of indirect reuse (Stone 1976).

Approximately 525,000 afy of recycled water is used in California. As seen in Figure 6, almost half of this is used for agricultural purposes. The use of recycled water for landscape irrigation has doubled to around 100,000 afy in the last 15 years and is projected to increase. In 2002 almost 15% of recycled water in California was used for artificial recharge of aquifers. The amount of recycled water used for developing and maintaining environmental areas such as recreational lakes, marshes, and increasing stream flow has grown over the past decade and a half by a little more than 5% (DWR 2004). These numbers will continue to increase with better technologies, greater public acceptance, and increased need due to water shortages.

Figure 1
Municipal Recyled Water Use in California in 2002

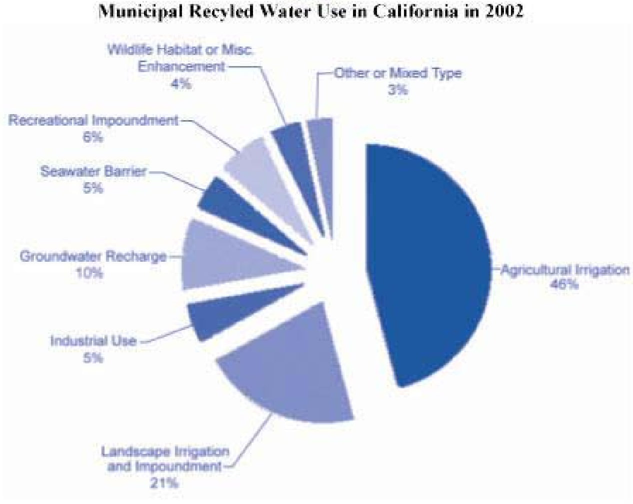


Figure 6. Percentage of uses for recycled water in California. Pie chart taken from Gleik et al.

Aquifer Storage and Recovery (ASR)

Due to the limited amount of surface water supplies available, growing demands have placed increase pressures on groundwater reserves. Groundwater recharge occurs naturally through excess rainfall. The amount percolating down into the aquifer is the total amount of precipitation minus surface runoff and evapotranspiration. The rate at which this occurs determines the sustainable amount of water that can be withdrawn from the aquifer (Bouwer 2000). Important considerations regarding groundwater flow and aquifer storage are based on the aquifer's ability to transmit and store water. Permeable substrates allow for greater percolation and an unconfined aquifer is necessary for water to move freely through the groundwater table (Yates et. al 2005).

Land use type also has an impact on the amount of groundwater recharge. Development can reduce both the quantity and quality of water supplies. By building homes, shopping centers, businesses, etc., communities have reduced the amount of natural recharge area. The increased amount of impermeable surfaces caused by developments limits the amount of water able to percolate down to reach the aquifer.

When the amount withdrawn from an aquifer exceeds the recharge rate, a deficit is created. If the imbalance persists over long periods, eventually the aquifer becomes over-drafted. If coastal aquifers become over-drafted, saltwater intrusion occurs by the landward flow of seawater through submarine outcrops and the aquifer becomes unusable (Bouwer 2002 and CDWR 2003). Saltwater intrusion due to severe overdraft has become a problem for many coastal communities including Castroville in Monterey County.

Artificial recharge (AR) helps to restore a balance and establish sustainability in overused groundwater systems. This can occur by either direct injection of the water into the aquifer, or by infiltration basins. If an aquifer exists between confined layers, direct injection of the water is necessary. This type of recharge project is often costly, due to the infrastructure required and pretreatment of the water needed to prevent clogging (Bouwer 2000). Wetlands and wildlife habitats can also act as storage areas for gradual release into recharge systems or in areas where large amounts of land are needed for recharge (EPA 1998).

Aquifer storage and recovery (ASR) is the process of applying excess water in an aquifer when supplies are plentiful for later withdrawal during times of shortage or high demand (CPUC 2002). The DHS in conjunction with the RWQCB sets standards and requirements for aquifer storage and recovery programs. The amount of time the water must be retained in the aquifer is no less than six months. The distance between injection and extraction wells is considered in the health codes, along with a minimum the depth to the groundwater table (Asano 2004). All water entering an aquifer through artificial means must meet drinking water standards as defined in the administrative codes before injection and additional removal through soil treatment should act only as an additional barrier (Brissand 2001).

If reclaimed water is used for artificial recharge, the percentage of recycled water entering and exiting the aquifer is also regulated (Water Code 2001). The use of recycled water should not necessitate further treatment after initial withdrawal. Therefore, the quality of the recycled water entering an aquifer should be treated for the highest intended use so as not to risk contaminating the overall water quality. Toxicological and epidemiological studies should be evaluated when utilizing recycled water for aquifer recharge (Angelakis 2001).

Potential problems have hindered some recharge operations. Clogging of injection wells or spreading basins due to the build up of organic matter reduces infiltration rates and presents technical challenges (Bouwer 2000). Chlorine, added during the disinfection process, is very effective in killing microorganisms whose growth, if present, would cause clogging. By-products produced by the addition of chlorine during treatment pose questions of public health concern (Bouwer 2000). The free chlorine available in the water after treatment interacts with the dissolved organic matter (DOC) still present to form other compounds. The amount of these disinfection by-products in the water varies greatly depending on the type and amount of organic matter present. Two by-products commonly associated with the disinfection of water are trihalomethanes (THM) and total organic halides (TOX) (Ronstad 2002). Once disinfection by-products are present in the aquifer, they can be diluted, volatilized, or absorbed into the sediment. Studies show with increased depth and distance from injection site less THM are present (Ronstad 2002). Much information is already known about their formation, but further studies must be done on their fate in the environment before ASR with recycled water can become a widely accepted practice.

When recharge occurs through infiltration basins, water quality can be improved as the water percolates through the unsaturated zone (Brissand 2001). Underground formations act as natural filters for the water in a process known as soil aquifer treatment (SAT) or geo-purification. This can be used as an inexpensive means to further treat the water as it moves through the soil. During its passage through the vadose zone, the water is re-mineralized, and pollutants are removed thus "polishing" the water and making it suitable for potable purposes (Jimenez 2001).

Some types of bacteria are able to grow and thrive under the right temperature, salinity, pH, and dissolved oxygen conditions. The process of water movement through the recharge zone can provide additional microbiological treatment. Fairly small flow rates are needed for bacteria to be eliminated from the water (Aertgeerts and Angelakis 2001).

As pointed out by (Salgot et al. 2003) the effects of exposure to pathogens, namely bacterial, often occur in a relatively short amount of time. However, the potential long-term health effects of exposure from various contaminants continue to raise doubts as to the suitability of using reclaimed water. Various strains of bacteria are found in the feces of infected individuals. High concentrations of bacterial pathogens may be present in wastewater depending on the time of year. Common types of bacterial pathogens found in municipal wastewater include *Salmonella, Shigella, and E. coli*. Enteric diseases are caused by many of these pathogens and can produce symptoms of cramping, vomiting, dysentery, and gastroenteritis if organisms are not removed during treatment. Certain strains of bacteria are more harmful to humans and animals than others and can be especially dangerous to children and the elderly (Aertgeerts and Angelakis 2001).

Chlorine is an effective agent for removing microbial contamination and preventing bacterial growth from clogging the aquifer**.** Inidcator organisms can be used to determine if the recharge zone of the aquifer is being affected by viable microorganisms from the recycled water (Griffen 2002). Organisms, such as coliform and enterrococcus, are also used to determine the average probable levels of bacteria in the treated effluent before injection (Nelson 2003).

Other microorganisms of concern include viruses and protozoa. Unlike bacteria, pathogenic viruses are not able to reproduce outside a host. Viruses are more resistant to the disinfection process than bacteria. Viruses are also difficult to isolate and identify in wastewater. More research must be done to determine the effects of SAT on virus attenuation (Dishman et al 1989). Like viruses, protozoa are not able to reproduce outside a host. However, protozoa are sometimes able to survive and remain active depending on environmental conditions (Bausum et al. 1983). Protozoa are transmitted through water and contaminated food, but are not usually present in treated wastewater. According to a report conducted by the MRWPCA, *Giardia* and *Cryptosporidium* cysts were detected in the effluent in low concentrations on several occasions. These low concentrations are not thought to be threat to human health and further tests proved the cysts to be non-viable and not a cause for concern (Nelson 2003).

Inorganic pollutants such as metals and chemicals are often present in drinking water supplies. Metals can sometimes accumulate in animals and the environment and can pose chronic health problems over long exposure period. Metals are not commonly found in treated domestic wastewater, but when present they may limit the use of the recycled water (Jimenez 2001). Many endocrine disrupting chemicals exist and are found in pharmaceuticals and personal care products such as birth control pills, hormone replacement drugs, cosmetics, and detergents. These chemicals are often present in low concentration in wastewaters. Adverse health effects on growth and reproduction in certain individuals have been shown to be the result of exposure to endocrine disrupting contaminants. Pharmaceutically active compounds (PAC) may also have subtle health effects (Sedlak et al. 2000).

Reliable methods for quantifying certain compunds is difficult due to such low concentrations present in wastewater and intereference from other constituents (Salgot et. al 2003). Increased advancements in technolgy have allowed for the detection and quantification of low concentrations of potentially harmful consituents (Sedlak et al. 2000). “Emerging pathogens” are also a cause for concern. These pathogens are not new, but have recently been associated with diseases related to water consumption (Jimenez 2001). Unregulated contaminant monitoring is an important tool in helping to determine acceptable levels of contaminants for which no standard exists in drinking water (Cal-Am

2004). This same concept can be applied to recycled water. The present standards for drinking water do not account for contaminants that may be unique to wastewater (Asano and Cotruvo 2001). The need for this type of monitoring is exemplified in a quote received in an email from Bob Holden the Water Recycling Projects Coordinator at the MRWPC, "…there are hundreds of thousands of chemicals in wastewater, many of which are in such low concentrations that they can barely be observed. However, we only know the health risks of a small percentage."

Risk assessment can be used to quantify the hazards posed by water reuse. This can be beneficial tool to guide management decisions and policies. Since a limited amount of parameters are used to test for water quality, many opponents argue the ability to accurately determine the risk associated with the reuse of reclaimed water is severely lacking. Water quality tests often exclude viruses, parasites, certain pathogens and other toxins that may be present in the recycled water at varying concentrations (Salgot et al 2003).

The EPA along with the DHS regulates the concentrations for various pollutants commonly found in water supplies. These standards are based on an accepted exposure level. The maximum acceptable amount of a contaminant present is established based on the technical and economic feasibility of regulating a contaminant (DHS 2002). When concentrations exceed these levels they are considered to be dangerous. Various pollutants are found in water supplies, but are below the acceptable maximum contaminant levels and are not thought to pose a health threat. A statement made by the World Health Organization (WHO) states that, " There are certain hazardous chemicals for which the analysis are costly and time consuming, therefore drinking water standards are a compromise between the scientific health risk and the feasibility of water analysis. Standards are based on the assumption that natural water is used as the water source."

Water quality concerns for recycled water are similar to those for potable water supplies. According to the California American Water Annual Water Quality Report, microbial contaminants, inorganic chemicals, organic chemicals, pesticides, and radioactive contaminants are substances commonly found in drinking water (Cal-Am 2004). Table 1 and Table 2 show the common constituents in drinking water and recycled water respectively.

Water Quality Results — Monterey

Regulated Substances (Measured on the Water Leaving the Pumping/Treatment Facilities or within the Distribution System)							
Substance (units)	Year Sampled	MCL	PHG (MCLG)	Average Amount Detected	Range Low-High	Violation	Major Sources in Drinking Water
Gross Alpha Particle Activity (pCi/L)	2003	15	NA	3.44	2.18 – 5.76	No	Erosion of natural deposits
Combined Radium (pCi/L)	2003	5	NA	1.53	ND – 3.27	No	Erosion of natural deposits
Arsenic (ppb) [1]	2004	50	NA	ND	ND – 18	No	Erosion of natural deposits; Runoff from orchards; Runoff from glass and electronics production wastes
Fluoride (ppm)	2004	2	1	0.23	0.1 – 0.6	No	Erosion of natural deposits; Water additive which promotes strong teeth; Discharge from fertilizer and aluminum factories
Nitrate as NO_3 (ppm) [3]	2004	45	45	4.8	ND – 36.6	No	Runoff and leaching from fertilizer use; leaching from septic tanks and sewage; erosion of natural deposits
Selenium (ppb)	2004	50	(50)	5	ND – 30	No	Discharge from petroleum, glass, and metal refineries; erosion of natural deposits; discharge from mines and chemical manufacturers; runoff from livestock lots (feed additive)
Tertachloroethylene (PCE) (ppb)	2004	5	0.06	ND	ND – 0.7	No	Discharge from factories, dry cleaners, and auto shops (metal degreaser)
Xylenes (ppm)	2004	1.750	1.8	ND	ND – 0.001	No	Discharge from petroleum and chemical factories; fuel solvent
Total Trihalomethanes (TTHM) (ppb)	2004	100	NA	31.5	6.9 – 55.9	No	Byproduct of drinking water chlorination
Haloacetic Acids (ppb)	2004	60	NA	14.4	1.9 – 26.6	No	Byproduct of drinking water chlorination
Chlorine (ppm)	2004	MRDL = 4.0 (as Cl_2)	MRDL = 4.0 (as Cl_2)	1.45	0.48 – 2.54	No	Drinking water disinfectant added for treatment

Secondary Substances (Measured on the Water Leaving the Pumping/Treatment Facilities or within the Distribution System)							
Substance (units)	Year Sampled	SMCL	PHG (MCLG)	Results	Range Low-High	Violation	Typical Source
Chloride (ppm)	2004	500	NS	63	7 – 212	No	Runoff/leaching from natural deposits; seawater influence
Iron (ppm)	2004	0.3	NS	ND	ND – 0.2	No	Leaching from natural deposits; industrial wastes
MTBE (ppb)	2004	5	NS	ND	0 – 6.7	No	Leaking underground storage tanks; discharge from petroleum and chemical factories
Odor (units)	2004	3	NS	1	1 – 1	No	Naturally-occurring organic materials
Specific Conductance (µmhos/cm)	2004	1,600	NS	756	290 – 930	No	Substances that form ions when in water; seawater influence
Sulfate (ppm)	2004	500	NS	72	22 – 101	No	Runoff/leaching from natural deposits; industrial wastes
Total Dissolved Solids (ppm)	2004	1,000	NS	443	210 – 610	No	Runoff/leaching from natural deposits
Turbidity (NTU)	2004	5	NS	0.18	ND – 1.3	No	Soil runoff
Zinc (ppm)	2004	5.0	NS	0.12	ND – 0.30	No	Runoff/leaching from natural deposits; industrial wastes

. Table 1. Drinking water quality results. Taken from Cal-Am Consumer Confidence Report

RECYCLED WATER - AGRONOMIC CHEMICAL ANALYSIS

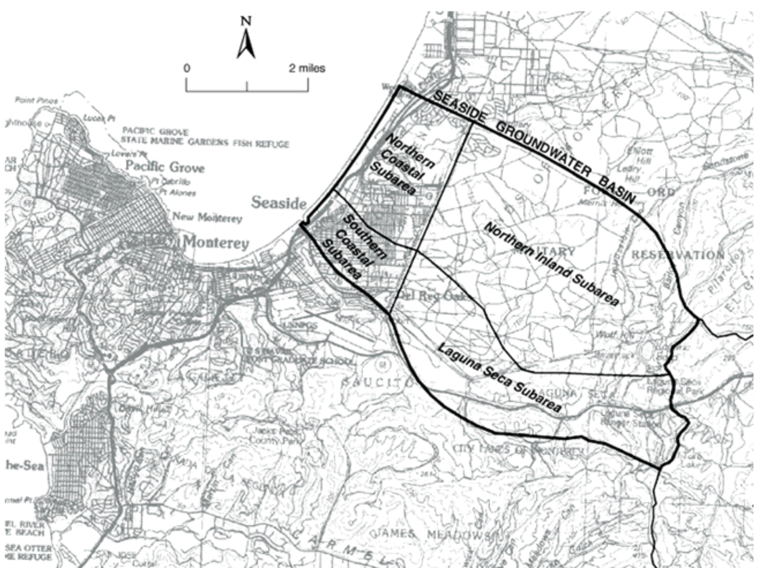
Date	Alkalinity (ppm) ($CaCO_3$)	Bicarbonate (ppm	Boron	Calcium (ppm)	Carbonate (ppm)	Chloride (ppm)	Conductivity dS/m	Hardness (ppm) (as $CaCO_3$	Magnesium (ppm)	Nitrate (ppm) (as N)	Nitrate (ppm) (as NO_3	Nitrite (ppm) (as N)	Nitrite (ppm) (as NO_2)	Total Kjeldahl nitrogen	Total Nitrogen (ppm)*	pH (units)	Potassium (ppm)	Sodium (ppm)	Sulfate (ppm)	Total Dissolved Solids (ppm)	Total Phosphorous	SAR (equation)	SAR (adj) (equation)**
7/25/2005	289	353		53		224	1.6	210	19	2.1	9.3	0.61	2			7	18	173	86	787	3	5.2	6.2
7/18/2005	279	340		51		228	1.6	201	18	2	8.9	0.44	1.45	28	30.4	7	16	175	87	826	2.7	5.3	6.5
7/11/2005	286	349		57		223	1.5	233	22	2.8	12.4	<0.43	<0.43	29.7	32.5	7.1	21	171	90	794	2.8	4.9	5.9
7/6/2005	317	387		61		260	1.8	247	23	4.9	21.7	0.63	3.04	42	47.6	7.1	25	189	106	890	3.8	5.2	6.4
6/27/2005	269	328		63		217	1.5	238	19	4.1	18.2	0.49	1.61	25.2	29.8	7.1	20	180	90	812	2.8	5	6.3
6/20/2005	289	352		56		205	1.5	226	21	0.9	3.98	0.43	1.41	29.6	30.9	7	20	169	94	792	3.4	4.9	5.9
6/13/2005	272	332		49		203	1.5	192	17	3.5	15.5	0.5	1.64	31.4	35.4	7	16	161	89	793	3.4	5	6
6/6/2005	265	323		58		220	1.5	236	22	3.1	13.7	0.5	1.64	26.3	29.9	7.1	21	172	90	796	3	4.9	5.9
6/2/2005	308	376	0.61	56		256	1.8	222	20	4	17.7	0.8	2.63	47.6	52.4	7.1	20	181	96	876	1.04	5.3	6.5

Table 2. Recycled water quality results. Taken from the lab results at the MRWPCA

Aquifer storage and recovery on the central coast has been shown to be a viable option for augmenting water supplies (Stern, personal communication 2005). The MPWMD has been operating a small-scale test injection wells located near General Jim Moore Boulevard near the city of Seaside. These wells directly inject water into the Santa Margarita and Paso Robles Aquifers (Yates et al, 2005). Excess Carmel River flows are diverted and used to recharge the Seaside basin in the winter months when surplus flows are available. The amount available to be used for injection can vary greatly from year to year (MPWMD 2005).

The MPWMD is currently preparing an Environmental Impact Report (EIR) to initiate Phase I, of a three-phase project to expand existing aquifer storage and recovery facilities on the Monterey Peninsula. Implementation of the initial phase will require minimal new infrastructure and would allow for up to 2,000 af to be diverted annually from the Carmel River. The entire project proposal could provide up to 7,000 afy to be used for aquifer recharge. The water would be injected to a depth of approximately 800ft into the Santa Margarita formation, since this portion of the aquifer has highly desirable hydrological properties for recharge (MPWMD 2005, Stern personal communication 2005).

As illustrated in Figure 7, the Seaside Basin is composed of four sub-basins and encompasses a 24 sq mile area along the Monterey Bay [MPWMD 2004].



Base: USGS Monterey 1:100000 topographic map, 1983 metric edition, contour interval = 50 meters
Original projection: UTM Zone 10, 1927 North American Datum (NAD), meters, Current projection: State Plane, California Zone 4, 1983 NAD, feet
Subarea boundaries from SGD (1990, 1991) and J.W. Oliver, MPWMD (written commun., 2002)

Figure 7. Seaside Groundwater Basin and Sub-areas. Map taken from MPWMD Contingency plan

Rainfall serves to naturally recharge the Seaside groundwater Basin by direct infiltration and subsurface flows. Soils in the Seaside basin are sandy which allow for high infiltration rates. The sustainable yield from the Seaside Groundwater Basin has been estimated to be around 2,800 afy (CDWR 2003 and Yates et al). As seen previously, withdrawals have been much greater than this in recent years (3,918 af for 2004). Most of the water extracted comes from the Northern Coastal Sub-area. Declining water levels and increased deficits in the groundwater budget put aquifers in the basin at risk for seawater intrusion (Yates et al. 2005). North of the Seaside Basin boundary in the Salinas Valley Aquifer near the city of Castroville, the 180ft as well as the 400ft aquifers have already been contaminated with saltwater. The recycled water from the MRWPCA is used for irrigation purposes to reduce demands on groundwater supplies and to help slow the spread of seawater intrusion in the Castroville area (CDWR 2003).

The geology of the Seaside basin is composed of water-bearing sedimentary layers overlying granite bedrock. The Monterey Formation, composed of siliceous shale, sits above the bedrock and is not considered to be a sufficient water-bearing unit. The next younger geological unit in the bedding sequence is the Santa Margarita Formation. This layer is made up of loosely consolidated marine sandstone and is associated with the Santa Margarita Aquifer. The Paso Robles Formation is made up of interbedded sand, gravel, clay, and calcareous beds and can reach 600ft in thickness in certain parts of the basin. The Paso Robles Aquifer represents the shallow water supply. The next higher unit, termed the Aromas Formation, is composed of quaternary old sand deposits (CDWR 2004, Yates et al 2005). According to Bob Curry, a well-respected local hydrologist, a substantial amount of storage volume is available in the aquifers of the Seaside basin for water storage (Curry personal communication 2005). According to some estimates, the storage capacity of the Seaside aquifer sub-basin is around 100,000 AF (CDWR 2003)

Recycled water can serve as a potential source of water for use in artificial recharge. For over 25 years, treated wastewater in Orange County, California has been used in order to prevent saltwater intrusion as well as to augment potable groundwater supplies (Anderson 2003, EPA 1998, OCWD 2004). In this scenario, wastewater treated to drinking water standards is blended with deep well water and used for recharge of potable water supplies (Durham 2002).

An initial feasibility study is currently underway to determine if recycled water can be used in conjunction with the ASR project proposed by the MPWMD. (MPWMD

2005) The Seaside Groundwater Replenishment Project (SGWRP) would involve blending purified recycled water with Carmel River flows of water from the Seaside basin and injecting it into the aquifer (MPWMD 2005).

Recycled water produced at the SVRP would undergo further advanced treatment, such as MF and RO and, to remove salts microorganisms and other constituents prior to injection. UV disinfection is an additional form of treatment that would be employed to disable microorganisms present in the water (MPWMD 2005).

Economics

Water is usually considered a cheap, non-hazardous, readily available resource (Mann 2003). Because of this, it is often taken for granted or wasted. Demand for a product or service can be thought of as the desire to posses something combined with the ability to purchase it. When a demand for something exists, not enough is necessarily available to the consumer. This concept of supply and demand drives the free market economy.

Economists often ask the question, "Can the economics of supply and demand be applied to water resources?" The difference between water and other commodities is that no substitute for water exists. The answer might be to reduce the quantity available or raise the price of water to help balance consumer demand with available resources. Reducing the quantity of water delivered can increase consumer appreciation for it. Full-cost pricing factors in all costs required to deliver water to the consumer and the long-term value of the resource. Increasing the price charged for water will aid in limiting usage for unessential activities (EPA 1998). Rising block rates is a pricing scheme which charges an increasing rate for water used above a minimum amount determined to be life sustaining. This type of rate structure can help to decrease water use outside the home. Installing meters and adopting rising block rates are effective in reducing water use, especially in dry months when supplies are short. These strategies have impacted per capita water usage, but have not significantly affected demand placed on freshwater supplies by urban growth (Okun 2000).

Surcharges, taxes and usage fees can act to decrease water usage and create revenues for water projects. The MPWMD is proposing to increase the existing usage fee from 7.125% to 8.125% through the adoption of Ordinance 123. The revenue generated from this increase in fees will be used to fund the proposed ASR project by the MPWMD (MPWMD 2005).

Recycled water, if made readily available to the urban sector, could be used at a cost less than that of other options including desal (MPWMD 2004). However, the cost of recycled water can be highly variable compared to potable water supplies depending on location and intended use (Okun 2000). Lower rates charged for recycled water can serve as an incentive for commercial businesses and industries. The price charged for recycled water could then be at a flat rate or a block rate similar to that of freshwater.

The cost of installing new water saving technology and applying efficient landscaping concepts can save money as well as over all water in the long-run. The costs to discover and develop as well as the energy requirements to produce and deliver new water should be taken into consideration when developing long-term water management strategies (CPUC 2002).

The objective of a water-recycling project should include cost reduction and long-term sustainability. It should also focus on more than implementation costs and ensure plant reliability and product quality (Mann 2003). Initial costs can be minimized, since much of the necessary infrastructure for water recycling already exists in Monterey.

Distribution is an inherent cost of supplying water to the consumer. Adequate infrastructure would be necessary in order for water of different qualities to be delivered to different destinations (Bouwer 2000). In some cities retrofitting of old water lines to serve recycled water has proved economically viable (Okun 1996).

Energy usage is an important consideration when evaluating alternative supply options. At the MRWPCA water reclamation plant, all of the plant's energy needs is derived from a co-generation plant. Water recycling and aquifer storage and recovery projects are more energy efficient than importing water or utilizing desalination (Durham et. al 2002).

The use of reclaimed water creates huge savings in diversion costs and resource development. Consumers may also be willing to pay more if the availability of reclaimed water can provide assurance that water service will not be interrupted in times of drought.

The costs for controlling water pollution control may also be avoided through water reclamation (Okun 1996).

Using less water is often associated with less prosperity. Gleik et al(2003) points out that a decrease in non-essential water will not necessarily reduce overall productivity and states it is merely a question of whether a service can be provided with a reduced amount of water (Gleik et. al 2003). The externality of a commodity is the benefit outside the market transaction. This is an inherent value placed upon an object by an individual. This is the willingness of the consumer to pay in order to ensure the availability of freshwater for future use.

Cal-Am uses rising block rates for residents on the Monterey Peninsula. Customers pay \$1.58 for the first unit (750 gallons) of water used. Each additional unit continues to increase until all water after the fourth block is charge at a rate of \$12.54 per unit. When calculated out, this comes to approximately \$2000 per acre-foot for urban consumers. Currently, Cal-Am is petitioning the CPUC to increase water rates for the Monterey Peninsula. The cost for recycled water supplied to farmers is a flat fee based on the number of af used. The cost per af to growers in the CSIP service area is \$ 241.58/af, with an additional \$16.87/af use charge (Harris, personal communication 2005). This amounts to approximately \$1000 per acre foot, an amount significantly less than that supplied to customers on the Monterey Peninsula. Note: the water delivered to Cal-Am customers is of potable water quality while the water supplied by the MRWPCA is not.

Discussion and Recommendations

A balance must somehow be maintained between supply and demand of local water resources. Long-term sustainability should be the objective of any water management project. Using a variety of approaches to solving water supply issues ensures that a safe and reliable water source exists. In order to meet the SWRBC Order WR 95-10 requirements, reductions must be made to diversions in the Carmel River. The following recommendations can be used in to meet this requirement in lieu of developing new sources.

Ordinance 123, which would increase the usage fees, should be enacted. Fees based on actual water usage help to decrease water usage. Revenues generated from usage fees can be used to help offset costs for other water projects, maintenance, and public outreach programs.

The debate about whether water is a need or a basic human right ensues. A need is defined as a necessary requirement. Water is essential to all life, therefore it is a need. A right is something that is automatically afforded to everyone. Everyone has the right to live and in order to live one needs water. Therefore, it can be logically concluded that water is a necessary right. If water is indeed an inherent right, then how much is one entitled to? If people had to pay the actual cost of the water, water use would decrease. Citizens must be held accountable for their water use. More accurate water pricing is necessary to increase appreciation for water resources. However, consumers must still be able to afford at least a life-sustaining amount of water. The CPUC should allow water rates charged to consumers on the Monterey Peninsula to be marginally increased with the stipulation that a certain portion of the revenue generated will go to fund educational programs. Water users may not like to see their rates increased, but with further educational programs and increased rates, the public may begin to regard water as a valuable commodity to be conserved.

The TAC committee should develop and adopt guidelines for a comprehensive model landscape ordinance under AB 325. The use of drought tolerant and native landscaping along with site-specific water budgets will reduce the demands placed on freshwater for outdoor uses, thus acting to conserve potable supplies for uses requiring higher quality water. The MPWMD should actively pursue a joint project with the MRWPCA to implement the Urban Recycled Water Project (URWP), which could supply up to 3,100afy of recycled water to consumers on the Monterey Peninsula. Recycled water use in conjunction with model landscape ordinances, can conserve significant amounts of freshwater.

Currently no new developments, unless prior water rights exist, can be built on the Monterey Peninsula until a new source of water has been implemented. Despite this, developments along the central coast seem inevitable. With the possibility of large developments on the former Fort Ord Military Base the opportunity exists to install a long-term innovative and collaborative water management plan. A dual pipe ordinance should be established for all new developments on the Monterey Peninsula. New developments offer an excellent opportunity to install dual pipe systems and provide easy access to non-potable water for outdoor use. These new communities can utilize the recycled water to reduced demands placed on freshwater supplies.

Reductions in indoor use can continue to be expanded through increased use of water-efficient amenities. Old appliances can be replaced with new more efficient models after their life expectancy has run out. In order to ensure efficient technology is utilized, an ordinance should be developed and adopted requiring the sale of only new water saving appliances. The consumer may see this as limiting their choices, but old models are naturally being fazed-out and increased technology in the future may make water-saving appliance more affordable. The Pacific Institute for Studies in Development, Environment, and Security reports that a significant amount of additional water can be conserved in the urban sector. If we use this to make a rough estimate of potential water savings through urban conservation to be 30% of the total 15,012 af of water supplied to consumers in WY 2004 we can conclude that an additional 4,500afy can be conserved on the Monterey Peninsula.

The first phase of the MPWMD aquifer storage and recovery program should be utilized to the full extent of 2,100 afy when Carmel River flow permits. Artificial recharge will enhance the Seaside groundwater basin and protect it from being over-drafted. Aquifer storage and recovery provides the benefit of being able to store excess water underground until it is needed again.

The SGRP should undergo a public comment period. Public perceptions regarding water supplies may have the most influence over what happens in the local community. Increased education concerning water supplies may lead to increased acceptance of water-saving strategies, including use of recycled water. This can be done through community events, which bring people together to discuss options. Instead of taking an "us versus them mentality", a cooperative environment should be encourage where everyone is working toward the goal of sustainable water use. Regardless if recycled water is used, aquifer storage and recovery can and should become a vital part of water resource management on the central coast

The above recommendations can be achieved through the use of an integrated water management plan. The purpose of using integrated water resources management

(IWRM) is to maximize the overall benefits while minimizing costs and damage to the environment. Planning for the future water needs of a community requires communication between the various stakeholders involved. Increased communication between the water district and the purveyor and the public can ease tensions and work toward the goal of achieving a safe, sustainable and affordable water supply. Collaboration between local water management groups such as the MPWMD and the Monterey County Water Resources Agency (MCWRA), which oversees water supplies for the Salinas Valley, and the Marina Coast Water District (MCWD), which supplies water to Marina and parts of the former Fort Ord, can work toward achieving a regional water budget. This can bring about unifying strategies and sustainable water use. Agencies and operations must remain flexible in order to adjust to the changing supplies and demands of the system. Aquifer storage and recovery on the Monterey Peninsula is based on the availability of excess flow in the Carmel River. If these flows are not available, back up alternatives such as the use of recycled water can be employed.

Desalination, although not specifically covered in this report, is another option under consideration to provide a new water source. A bitter fight has ensued on the Monterey Peninsula as to who should own and operate a proposed desalination plant. Meanwhile the Carmel River and Seaside groundwater basins continue to be over pumped. Some water scientists and environmentalists fear tampering with the oceans through widespread desalination could have unknown implications. The oceans act as the moderators of our climate and slight increases in salinity could have disastrous effects for certain aquatic species (Rothfeder 2001). While talking with Jason Nachamkin, a research meteorologist with the Naval Research Laboratory, I asked him why there were so many more hurricanes now than in the past. He explained to me it is thought that changes in the global thermo-haline circulation in the oceans have altered the climate in such a way that is conducive to storm formation. What will be the outcome if large-scale desalination projects become the trend in water resources?

When I asked Mr. Marc del Piero of the Pajaro Valley Water Management Agency (one of the parties involved in the desal debate), if he thought desalination would give people a false sense of security concerning water supplies, he had no real response. Though it may not be a viable option for places located further inland, the idea of desalination should not be completely discarded as a water management tool. In some situations it maybe necessary to supplement water supplies in arid regions of the world. Monterey is not one of those areas and Jean-Michel Costeau agrees. “Monterey doesn’t need a desal plant. Look at Santa Barbara, they have a desal plant and don’t even use it,” he told me when he came to speak on a separate topic last year. When taking into consideration all the other options that can be employed, a few of them are listed above, the building of a large desalination plant to supply water to Monterey Peninsula users seems unnecessary and unlikely.

It is critical for communities to take the initiative to employ strategies to lessen demands on freshwater supplies. Ecologically and economically it makes more sense to use a resource as many times as possible. Instead of simply looking for new water sources or ways to increase what little amount is left, more attention should be given to the end use. The use of reclaimed water, where appropriate, will help to alleviate demands placed on current water resources. Recycled water can be thought of in terms of virtual water, because water is used, but the water supply is not depleted and thus act as a conservation tool. The benefits of using recycled water are numerous and may outweigh initial health concerns. However, the public may not be ready for indirect potable use at this point.

Since the time of the industrial revolution, we have been continually exposing ourselves to a variety of different toxins from various sources. A certain level of inherent risk exists in our society and exposure to harmful chemicals may not be avoidable in all situations. Therefore, it is important to minimize this risk wherever possible. More research and long-term studies must be done to fully understand the potential risks associated with using recycled water for potable uses such as recharge. Consideration for the various combinations of contaminants present should be given the highest priority. Certain chemicals have not previously been cause for concern because techniques have not been sensitive enough to measure them effectively in drinking water. As methods continue to improve we may find more and more chemicals present. If possible, interception of pollutants at their source may be effective in reducing potential heath threats.

The use of recycled water for certain beneficial purposes can be done incrementally. Overcoming the initial hurdle of gaining public acceptance takes the biggest effort. Opportunities exist for groups with an interest in the future of water resources to play a role in initiating public support. One group that could play a significant role in influencing the public through education and outreach is the Monterey Bay National Marine Sanctuary. Issues discussed in this paper should be of concern to the Sanctuary. Increased use of recycled water means less water is being discharged into the bay. More efficient landscaping means less water use, which reduces urban runoff and pollution entering the bay. More water in the river means lagoons can serve as protection for maturing steelhead. Agencies such as the NMFS and the CRWC would like to see this happen, since it would increase overall steelhead populations.

The reuse of water can work towards decreasing the need for worldwide water transfers. In many places where sources are over allocated, water reuse can serve to bridge the gap between supply and demand. The first human settlements were located near water sources. In today's culture, people often do not live in close proximity to freshwater supplies, but still depend on its availability. Canada, which has a significant amount of the worlds freshwater, has been under pressure to open up its water supply for water transfers to regions of the world with water shortages. Water supplies often cross many government jurisdictions and are the cause for conflict. Such is the case in the water poor region of the Middle East. Competition over water supplies will continue to increase as the amount available decreases. Using recycled water to alleviate demands can act to ease political tensions.

Conclusion

Many options exist to enhance and increase water supplies without the development of new sources. Conservation can be used as a management tool to reduce the overall amount of water used in urban communities. Efficient landscaping and irrigation can decrease outside water use. The MPWMD should enact and enforce a district wide landscape ordinance. New development may increase overall consumption of the water but serves as an opportunity to use water efficiently and provides as an additional source and use for recycled water. A dual pipe ordinance should be enacted on the Monterey Peninsula and used in conjunction with the use of recycled water.

An additional 4,500 afy can be conserved through use of existing technology. If implemented, much of these savings could occur in a relatively short amount of time.
It may be assumed much of this additional conservation will not occur without incentives, regulations, and enforcement. Adoption of a district-wide landscape ordinance is essential to reduce outdoor water use. Educational programs can be sponsored through an increase in rates, and water supply projects can be funded by an increase in usage fees.
Use of water efficient technologies can be encouraged through incentive programs and ordinances that require the sale of new water efficient technologies.

The expansion of ASR could initially provide an additional 2,000 afy per year through the diversion of excess winter Carmel River flows. This water could later be used when supplies are limited or demand is high. If we assume that Phase I and II of the MPWMD ASR project are built, 3,200 afy of water could be supplied to consumers. ASR will maximize use of the Carmel River flows in wet months and provide for the sustainable use of water from the Seaside Groundwater Basin. Since less water would be diverted from the Carmel River during dry months natural habitats will be enhanced. The potential to use recycled water for ASR should be explored and commented on by the public.

The Urban Recycled Water Project (URWP) if implemented can provide recycled water to users on the Monterey Peninsula for non-potable uses. This project can provide approximately 3,100 afy to consumers.

The total acre-feet potentially supplied from these three components totals 10,800. The combination of these yields in savings per year would be enough to meet the SWRCB WR 95-10 mandate of 10,730afy in reduced pumping on the Carmel River. These projects should be employed before new sources of water are developed. Additional water needed for future development may be supplied from the expansion of all of these components.

Endnote:

This capstone was completed in a relatively short amount of time. Because of this, some information relating to the Monterey Peninsula may be out of date due to the constantly changing nature of the subject. This paper was prepared to the best of my ability and I believe all information to be factual based on current sources at the time. The basic principles presented regarding, ASR, conservation, and reuse still apply, but due to financial and political reasons some of the proposed projects may have changed. This makes it hard to present a coherent picture of what is happening on the central coast regarding water supplies. This document was intended to provide some clarification as to the state of water resources and in addition present alternatives, to desalination to augment water supplies. Students and other interested parties can use this paper as a basis to better understand the complex problem of water resources. It may also serve as a reminder to the public how serious of an issue this is.

After completing this project, I discovered I was misinformed. Unfortunately, I assumed much of the water form the Urban Water Recycling Project could be potentially used for customers in the MPWMD and Cal-Am service area. It turns out this most of this water has been earmarked for the Marina Coast Water District, a separate water entity which supplies water to Marina and the former Fort Ord, also located on the Monterey Peninsula and only about 300 af is designated for Cal-Am users. However, this does not change my overall conclusions. In lieu of the UWRP, the Seaside Groundwater Replenishment Project could be implemented. As described in this paper, the SGWRP would utilize recycled water for aquifer storage and recovery in the Seaside Basin and could potentially supply 2,800af. Since many factors must be taken into consideration, simply doing one over the other is not that easy. For instance, this project might come under more resistance, since it involves using recycled water for recharge of a potable aquifer. I am also unsure at this time if this would have any affect on the MPWMD program that uses excess Carmel River flows for ASR in the Seaside Basin. Perhaps an alternative storage system could be used for recycled water in the winter months when there is less of a demand from farmers. There are many possibilities in the area of water resources. Many projects and strategies exist, but the main take home point I wanted to make was that there are other ways to provide water, even if it is done in smaller increments, than a new water supply projects (i.e. desal). I also wanted to point out the influence consumer attitude toward plays in the demand for water. Perhaps if more efficient water use is increased and demand is reduced, a balance can be achieved without the development on new water supplies. Thank you for taking the time to read this capstone project since it is topic that directly affects us all.

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