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Water Conservation and Reutilization on the Monterey Peninsula: Strategies to Reduce Residential Water Demand

CSUMB Class ENVS 660:

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Disclaimer:

This report primarily represents student work completed within the constraints of a fixed-duration (four week), limited-verification, college class setting.

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Executive Summary

This document was created as part of a class project in the Advanced Watershed Science and Policy course at California State University, Monterey Bay. The goal of the project was to provide an initial assessment of the potential of water conservation and reutilization strategies to reduce water demand in the Monterey Peninsula. We compiled and analyzed regional water-distribution and water-regulation data and generated new information from Geographic Information Systems (GIS) analyses. This information was used to estimate the potential of five strategies for reducing residential water demand: reductions in indoor use, rainwater harvesting, residential gray-water recycling, outdoor water conservation, and large-scale wastewater recycling.

In the past twenty years, the search for alternative water supplies has intensified in the Monterey Peninsula due to regulatory changes that limit the amount of water that can be extracted from the two potable water sources in the region: the Carmel River basin, and the Seaside basin. The California American (Cal Am) Water Company currently extracts and distributes between 70% and 80% of the water supplied to the Monterey Peninsula. The Monterey Peninsula Water Management District (MPWMD) estimates that by 2021 the water supply deficit will be between 6,500 and 8,000 acre-feet. Water conservation and reutilization strategies reduce the demand for water from large-scale distribution systems by maximizing the use of the resource and can help alleviate water supply shortages.

We estimated that reducing residential water use, by installing ultra-low flow devices and addressing leaks, could save up to 2,584 acre-feet a year in the Monterey Peninsula. The rainwater harvesting analysis found that up to 2,971 acre-feet could be collected and stored for non-potable water uses. Under the current water usage, we estimated that residential gray-water recycling can produce between 2,007 to 3,011 acre-feet of water each year to be used for non-potable water uses. On a larger-scale, the Monterey Regional Water Pollution Control Agency (MRWPCA) estimates that up to 5,700 acre-feet of water could be recycled for potable-use in the Monterey Peninsula. Finally, we found that reducing the amount of water used for residential landscaping could reduce water demand by up to 1,956 acre-feet.

Although uniform and total implementation of any of these measures is unlikely, the findings of this report suggest that conservation and reutilization measures can significantly reduce the water supply gap in the Monterey Peninsula. Recommendations were made to assess the alternatives proposed here, to evaluate their feasibility and to calculate their water reduction potential with a greater precision to better inform regional water management policies.

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List of Definitions and Acronyms

- AFY – Acre Feet a Year
- ASR – Aquifer Storage and Recovery
- Cal Am – California American Water
- CV – Carmel Valley
- GIS – Geographic Information System
- IRWMP – Integrated Regional Water Management Program
- MCWD – Marina Coast Water District
- MCWRA – Monterey County Water Resources Agency
- MPWMD –Monterey Peninsula Water Management District
- MRWPCA – Monterey Regional Water Pollution Control Agency
- NAIP – National Agriculture Imagery Program
- NCDC – National Climatic Data Center
- RUAP – Regional Urban Augmentation Project
- SWRCB – State Water Resources Control Board
- USGS – United States Geological Survey
- WY – Water Year

1 Introduction

Population growth and declining trends in water quality have intensified competition for water resources around the world (Jury and Vaux 2005), making reliable sources of potable water increasingly challenging to secure. Water scarcity has driven governments and public utilities to explore alternative water supply strategies to improve water security (Makki et al. 2011), but the range of available alternatives is inextricably linked to the climate and resources within each region.

In the past 20 years, costal California's Monterey Peninsula has intensified its search for alternative water supply sources, but the alternatives are limited by the fact that, currently, the supply of potable water is entirely dependent on local rainfall (WMG 2007). Unlike other areas in California, the Monterey Peninsula does not obtain water from sources outside the region, such as snow melt or diverted water from large rivers of the Central Valley.

The Monterey Peninsula Water Management District (MPWMD) (Fig. 1) is the local agency that manages the production of water from the two sources in the area: the surface water from the Carmel River and the ground water from wells in Carmel Valley and Seaside (MPWMD [date unknown]). The MPWMD comprises the cities of Monterey, Pacific Grove, Seaside, Sand City, Carmel-by-the-Sea, Del-Rey Oaks, the Monterey Peninsula Airport District, and portions of the unincorporated towns of Pebble Beach and Carmel Valley (MPWMD [date unknown]). For the purpose of this report we will use the term Monterey Peninsula to refer to the area managed by the MPWMD.

The MPWMD covers an area of 442.63 Km^2, and has a population of approximately 90,000. The climate in the region is semi-arid, with average temperatures of 65 °F in the summer and 52 °F in the winter. The average annual rainfall is 19.7 inches. Several federal, state, and local agencies regulate different aspects of water supply within Monterey County, and most of the potable water for human consumption is extracted and distributed by the California American Water (Cal Am) company (MPWMD 2011).

Orders from the State Water Resources Control Board (SWRCB) and the Monterey County Superior Court have limited the amount of water that Cal Am is allowed to extract from the Carmel and Seaside basins, making it a priority to examine alternatives for water supply in the region. The main goal of this document is to assess the potential of water conservation and reutilization strategies in reducing the demand for water on the Monterey Peninsula. Our purpose is to make this information accessible to the residents of the Monterey Peninsula to aid in the understanding of local water management issues.

Figure 1. The Monterey Peninsula Water Management District (MPWMD) service area, in Monterey County, CA, comprises the cities of Monterey, Pacific Grove, Seaside, Sand City, Carmel-by-the-Sea, Del-Rey Oaks, the Monterey Peninsula Airport District, and portions of unincorporated Pebble Beach and Carmel Valley. Map prepared by Ashbach 2011 with data from the MPWMD and the USGS.

2 Background

2.1 Water supply and water usage on the Monterey Peninsula

The Carmel River basin and the Seaside groundwater basin (Fig. 2) provide fresh water for most of the Monterey Peninsula's residential, commercial, and municipal uses. The main water supplier in the area, Cal Am, is a private company that extracts, processes, and distributes over 80% of the water supplied to the Monterey Peninsula (MPWMD 2011). Cal Am obtains between 70% and 80% of the water needed for the Monterey Peninsula from the Carmel basin and obtains the rest from the Seaside basin (Order WR 09-60).

Figure 2. The two sources of water for the Monterey Peninsula: the Carmel basin and the Seaside basin. Map by Ashbach 2011 with data from the MPWMD, the USGS and Yates et al. 2005.

The amount of water consumed in the Monterey Peninsula varies slightly every year. The main use of water in the region is for residential and multi residential purposes, accounting for approximately 62% of the water consumption on the Monterey Peninsula (Table 1, Fig. 3). In the period between the years 2000 and 2007, the annual water consumption was, on average, 13,350 acre-feet (MPWMD 2008a). In the past ten years, the population of Monterey Peninsula cities has decreased by 4.9% (Table 2) (U.S. Census Bureau 2011) and this change, along with other factors, such as precipitation variability, changes in behavior, economic growth rates, and advances in water-efficiency technology may be affecting annual water usage in the region.

Table 1. Water usage per sector on the Monterey Peninsula (MPWMD 2008a). All values are in acre-feet.

Sector	2001	2003	2004	2005	2006	2007	Average	Percentage
Residential	6,906.77	7,449.69	7,288.61	6,588.66	6,841.19	6,493.30	6,928.04	52.26%
Multi-Resid.	1,462.28	1,392.65	1,393.54	1,275.95	1,275.35	1,301.96	1,350.29	10.19%
Commercial	3,388.66	3,329.61	3,369.96	3,141.02	3,129.50	3,169.23	3,254.66	24.55%
Industrial	99.03	80.25	86.85	80.21	70.92	92.54	84.97	0.64%
Golf Course	615.42	457.44	656.16	368.1	247.31	421.48	460.99	3.48%
Pub. Authority	1,174.91	1,004.50	1,286.17	1,068.28	992.8	964.82	1,081.91	8.16%
Other	39.84	44.72	57	31.46	30.72	62.32	44.34	0.33%
Non-Rev.	26.56	0.14	32.02	20.89	55.32	174.27	51.53	0.39%
Total Billed	13,713.47	13,759.00	14,170.31	12,574.57	12,643.11	12,679.92	13,256.73	100%

Table 2. Population per city, in the Monterey Peninsula for the years 2000, 2005-2008, and 2010. Compiled from data from the U.S. Census Bureau 2011.

City	2000	2005	2006	2007	2008	2010
Pacific Grove	15,528	14,907	14,637	14,559	14,601	15,041
Monterey	29,730	28,936	28,397	28,275	27,763	27,810
Carmel-by-the-sea	4,090	3,945	3,867	3,863	3,886	3,722
Carmel Valley	6,281	6,281	5,933	5,933	5,933	4,407
Del Rey Oaks	1,650	1,564	1,534	1,525	1,529	1,624
Seaside	33,111	33,821	33,572	33,356	33,797	33,025
Sand City	263	300	297	360	361	334
Pebble Beach	4,531	4,514	4,514	4,514	4,514	4,514
Total	95,184	94,268	92,751	92,385	92,384	90,477

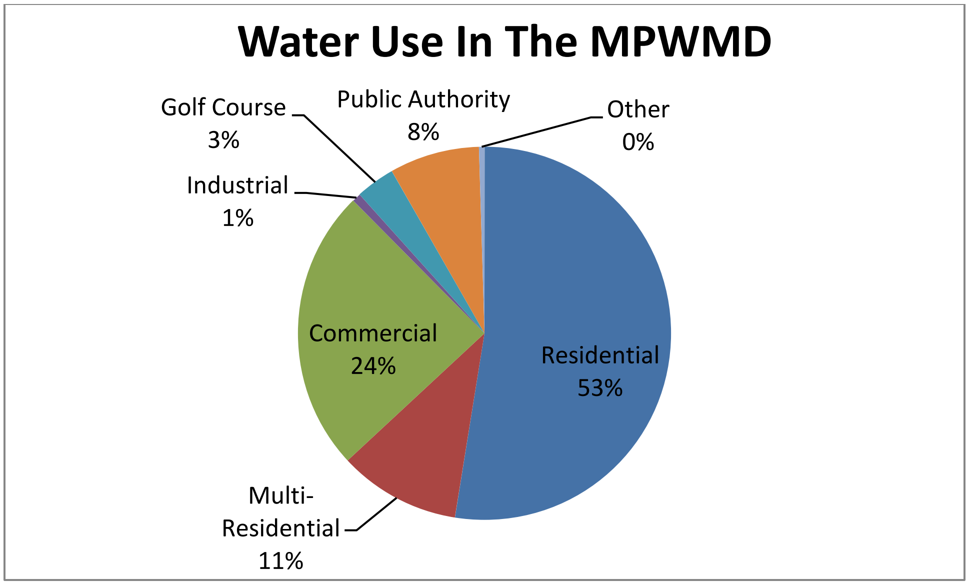

Figure 3. Cal Am water use per sector on the Monterey Peninsula for the years 2000 to 2007. MPWMD 2008a.

The amount of water that Cal Am extracts from sources in the Carmel River basin and in the Seaside Groundwater basin varies each year. In the period between 1996 and 2007, Cal Am extracted, on average, 10,967 acre-feet from the Carmel basin, and 3,689 acre-feet from the Seaside Basin (Table 3). The amount of water that Cal Am extracts from both sources, however, seems to be decreasing over the years (Fig. 4); in the period between 1996 and 2007 the total amount of water extracted decreased significantly ($p < 0.05$), from 16,020 acre-feet to 14,068 acre-feet.

In 1995 the State Water Resources Control Board (SWRCB) determined that Cal Am was extracting too much water out of the Carmel Basin (SWRCB 1995), and, in 2009, issued a Cease and Desist Order mandating Cal Am to reduce their extraction by approximately 70% by 2016 (MBRDP 2011). In 2006, the Monterey County Superior Court adjudicated the Seaside basin (Cal Am vs. City of Seaside et al. 2006), resulting in Cal Am having to reduce their extraction from the Seaside wells by approximately 50% by 2021 (MBRDP 2011). Both mandates responded to sustainability concerns; overdraft from the Carmel was adversely affecting fish and wildlife (SWRCB 1995), while overdraft from the Seaside basin had been identified as a potential cause for seawater intrusion (Yates et al. 2005).

Table 3. Water extraction by Cal Am from sources in the Carmel and Seaside Basins (MPWMD 2008b). CV stands for Carmel Valley. Although the amount of water extracted changes every year, the total amount seems to be decreasing over the years. All values are in acre-feet.

Water Year	San Clemente Reservoir	Upper CV Wells	Lower CV Wells	TOTAL CARMEL BASIN	Seaside Coastal Wells	SYSTEM TOTAL
1996	3,527	197	7,977	11,701	4,319	16,020
1997	3,159	357	9,331	12,847	4,025	16,872
1998	1,557	490	8,086	10,133	3,910	14,043
1999	1,385	836	8,163	10,384	3,982	14,366
2000	258	1,106	9,815	11,179	3,754	14,933
2001	98	835	9,788	10,721	3,444	14,165
2002	175	619	9,965	10,759	3,521	14,280
2003	242	629	10,259	11,130	3,507	14,637
2004	0	536	10,558	11,094	3,918	15,012
2005	0	634	10,041	10,675	3,003	13,678
2006	0	904	9,638	10,542	3,263	13,805
2007	0	460	9,983	10,443	3,625	14,068

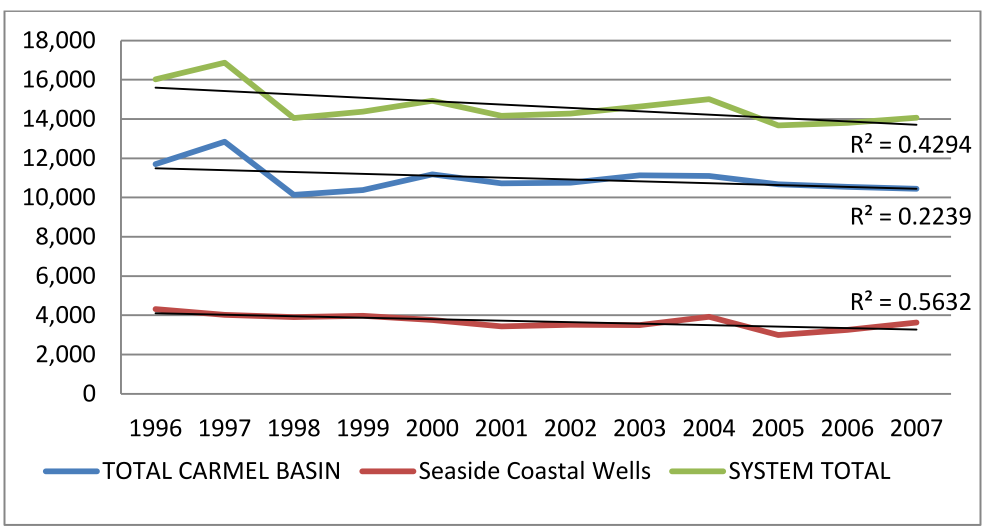

Figure 4. Cal Am extraction by source, showing an overall decrease in water extracted for supply of the Monterey Peninsula (MPWMD 2008b).

2.2 Water Budget for the Monterey Peninsula

A water budget is a way to assess the balance of inputs and outputs of a watershed or of a water management area. Assessing the sustainability of the local water budget is crucial for the management of water resources; if withdrawals exceed the inflow of water to the system, the demand load is unsustainable over time. A simplified water budget, the sum of the changes in groundwater storage (ΔG), can be thought of as precipitation (P) minus runoff (R), evapo-transpiration (ET), and demand (D), or

$$P - R - ET - D = \Delta G.$$

Urbanization and development can introduce additional components to a water budget (Hydrometrics 2009). Impervious areas can decrease the amount of precipitation that percolates into the ground, causing more water to leave the system as runoff, while irrigation, pipe leaks, and septic systems can be indirect additions to the amount of water that percolates into the ground. In addition to increased runoff, wastewater is often exported for treatment. The use of gray-water systems and reclaimed water for irrigation could increase the amount of water that percolates back into groundwater storage.

This Monterey Peninsula water budget has many components typical of a developed area as well as a few unique components (Fig. 5). Surface (Los Padres Dam) and underground storage reservoirs (Seaside aquifer) are typical sources of water extraction for potable water supply. Due to the close proximity to the coast, any surface flow that is not captured from impervious surfaces or rivers becomes runoff to the ocean. Several golf courses in the region utilize wastewater reclamation facilities to decrease the amount of potable water used for irrigation. One unique component to the Monterey Peninsula water budget is the export of winter surface flow from the Carmel River into the Seaside basin. This Aquifer Storage and Recovery, denoted as “ASR” in Figure 5, exemplifies artificial exchange from one watershed basin to another.

A detailed analysis of the Seaside groundwater basin by Yates et al. in 2005 found that the inputs to the system are less than the amount of water extracted annually for human consumption (Table 4). It is estimated that each year 7340 acre-feet enter the Seaside basin, from precipitation and groundwater flow into the system. In comparison, 8880 acre-feet exit the system, due predominantly to well pumping and groundwater flow out of the basin (Yates et al. 2005). This equates to 1540 acre-feet that are not naturally replenished, thus implying that the current system is unsustainable.

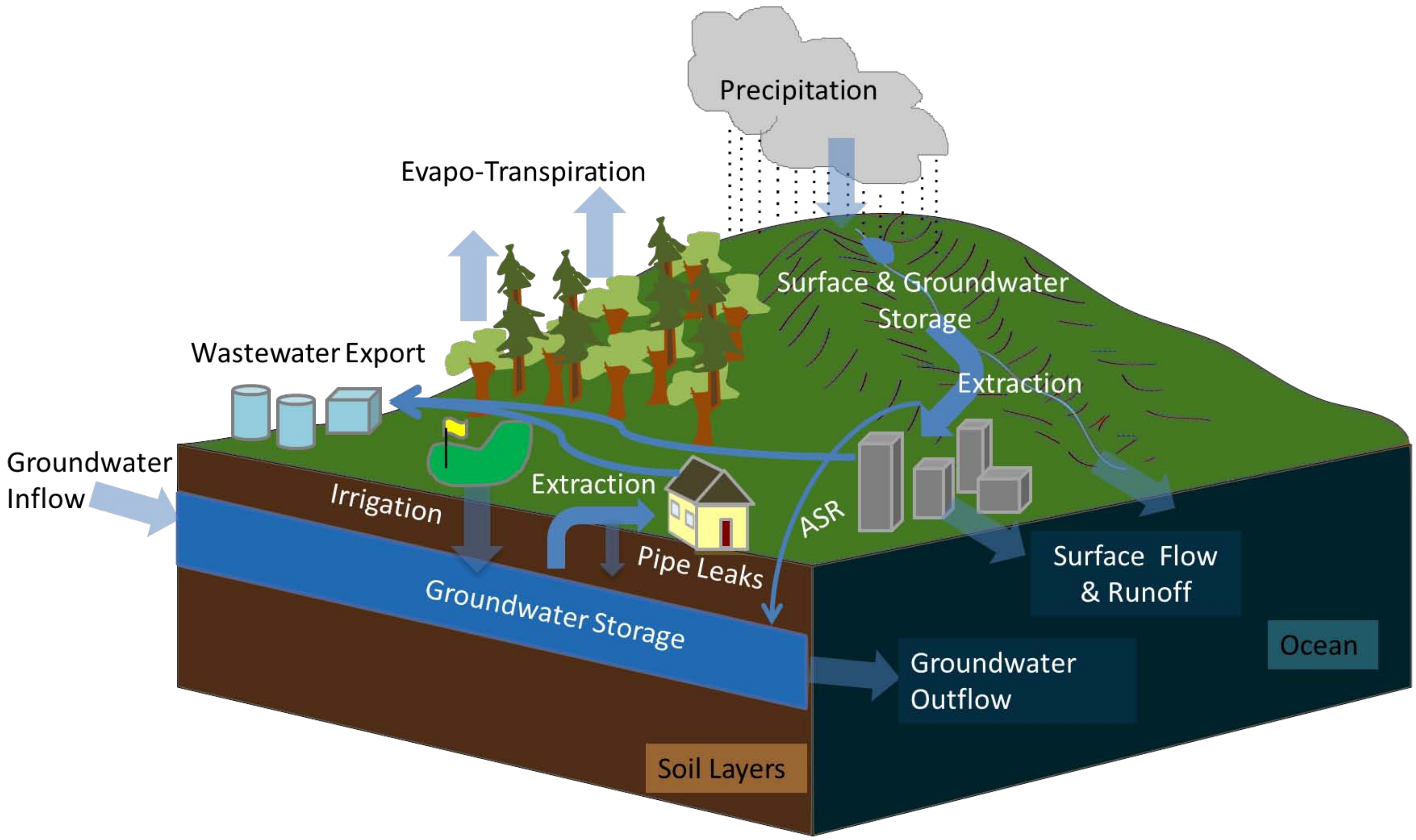

Figure 5. Simplification of the water budget of the Monterey Peninsula demonstrating the balance between hydrologic inputs and outputs. Illustration by Lanctot 2011, based on data from Tables 4 and 5.

Table 4: **Water Budget for the Seaside Basin (Adapted from Yates et al. 2005).**

	Recharge Source	Laguna Seca (acre-feet)	Northern Coastal Subarea (acre-feet)	Northern Inland (acre-feet)	Southern Coastal Subarea (acre-feet)	Seaside Basin Total (acre-feet)
Inflows	Percolation from streams	0	0	0	0	0
	Rainfall and irrigation deep percolation					
	Impervious areas	40	190	10	140	380
	Irrigated areas	130	470	20	150	770
	Nonirrigated areas	530	250	1050	100	1930
	Pipe leaks					
	Water pipes	80	160	10	120	370
	Sewer pipes	10	50	0	40	100
	Septic systems	20	0	0	0	20
	Injection wells	0	180	0	0	180
	Groundwater inflow					
	From onshore subareas	180	1820	0	510	2510
	From offshore area	0	1080	0	0	1080
	Total inflows	990	4200	1090	1060	7340
Outflows	Wells	1000	4420	0	160	5580
	Groundwater outflow					
	To onshore subareas	510	0	1370	450	2330
	To offshore area	0	520	0	450	970
	Total outflows	1510	4940	1370	1060	8880
	Storage change (inflows - outflows)	-520	-740	-280	0	-1540

A comparable study has not been conducted for the Carmel River alluvial basin, but inputs and outputs can be estimated based on average annual data (MPWMD - *pers. comm.*). The Carmel River runs atop a shallow aquifer made up of alluvial floodplain material, which is quickly recharged by percolation and surface flow and therefore the two are hydrologically connected. The Carmel River drains a watershed size of 656 km^2. The shallow nature of the basin makes it highly vulnerable to annual fluctuations in rainfall. Table 5 illustrates the susceptibility of the basin to drought. In a normal water year the precipitation can be above 300,000 acre-feet and the total outputs of 293,648 acre-feet leave an excess of 18,093 acre-feet. However, in a critically dry year the precipitation of 176,825 acre-feet is less than the outputs. The MPWMD categorizes each water year based on exceedance frequency values; for example, a normal year of about 20 inches of rain happens 50% of the time. A drought is defined as two or more consecutive critically dry years (13 inches of rain or less).

We compiled data from external sources to provide a simplified water budget for the Carmel River alluvial basin (Table 5). Surface flow values for Water Years (WY) 1902-2005 were reconstructed by the Monterey Peninsula Water Management District based on records provided by the United States Geological Survey (USGS) and California American Water (Cal Am). The runoff values for WY 2006 through WY 2010 were computed by the Monterey Peninsula Water Management District based on records provided by Cal Am. Precipitation and evapo-transpiration were computed based on records from the San Clemente Dam gauging station provided by MPWMD.

Table 5 Estimated budget for the Carmel River alluvial basin based on precipitation, flow and Evapo-Transpiration data from MPWMD. In normal years, there is a surplus of water that recharges the basin, but if the extraction levels are not reduced in critically dry years there will be a storage deficit. Source: MPWMD unpublished data.

		Normal water year		Critically Dry year	
		Acre-feet	Total	Acre-feet	Total
Inputs	Precipitation	311741	311741	176825	176825
Outputs	Evapo-transpiration	205193		159143	
	Surface Flow	77477		8608	
	Extraction	10978	293648	10978	178729
	Storage Change		18093		-1903

2.3 Water supply alternatives on the Monterey Peninsula

The Cal Am water company and different local agencies have been exploring options and collaborating in projects to increase the water supply for the Monterey Peninsula. Three main options have been considered: taking excess water from the Carmel River during the winter, when it rains, to inject it into the Seaside Basin for later use in a process called Aquifer Storage and Recovery (ASR); recycling waste water so it can be re-used; and taking water from the ocean and making it potable through a process called desalination.

The ASR project, a collaboration between the MPWMD and Cal Am, is already in place, producing an estimated 920 acre-feet each year (PWR 2011). The MPWMD is currently working on the expansion of the ASR project so it can produce up to 1,920 acre-feet a year. Waste water recycling, the second option, has been done, on a large scale, by the Monterey Regional Water Pollution Control Agency (MRWPCA) since 1997 (MRWPCA [date unknown]). Although, currently, the MRWPCA recycled water is used for summer irrigation in the city of Salinas, the MRWPCA, in collaboration with other agencies, is exploring options for using the recycled water to increase the water supply on the Monterey Peninsula. For the third option, water desalination, several projects have been proposed. Cal Am, in collaboration with the Marina Coast Water District (MCWD) and the Monterey County Water Resources Agency (MCWRA), has developed a project called The Regional Water Plan. The main component of the Regional Water Plan is a desalination plant that would produce 10,500 acre-feet of water each year. The Regional Water Plan is currently, as of the writing of this report, in the permitting process, but delays are expected as the interested parties have entered mediation to resolve conflicts that have arisen in the process. The MPWMD is also exploring the option of a smaller desalination plant.

The MPWMD estimates that the difference between the demand of water and the amount that they will be able to extract after 2021 will be between 6,500 to 8,000 acre-feet (*Stoldt 2011 - pers. comm*). The options presented above intend to bridge the gap between supply and demand by increasing the supply of water, but how much could be accomplished by approaching the issue from a different perspective, by reducing the demand of water instead?

3 Reducing water demand: conservation and reutilization strategies in the Monterey Peninsula

Water conservation strategies focus on reducing the amount of water used, while reutilization measures focus on maximizing the use of water that has already been made available to the users. Both types of strategies reduce the amount of water demanded from large-scale distribution systems. Water conservation and reutilization measures differ vastly from water rationing measures, which usually only come in effect during water shortages. Although water conservation strategies have been implemented on the Monterey Peninsula since the 1970's, the development of new technologies and the reassessment of old techniques constantly provide opportunities for further reducing water demand. The following sections present a brief history of water conservation and reutilization strategies on the Monterey Peninsula and detail the potential yield of several strategies for bridging the water supply gap in the region.

3.1 History of regional water conservation strategies

Despite numerous droughts and water shortages around the country, it was not until 1992 when the first national standard for water conservation and use efficiency for plumbing fixtures was adopted. By that time, many states had already implemented their own conservation measures. In 1977, a severe drought was the impetus for California to develop state-wide efficiency standards (CUWCC 2005). Additionally, county-wide conservation measures have been implemented to address more localized water supply shortages.

During the drought of 1977, residents of the Monterey Peninsula were required to ration their water to 1/8th of their normal usage, to 50 gallons per day per person. Water rationing continued through the 1980's, while water conservation practices, such as the following, continued to be adopted:

- the creation and implementation of water allocation and conservation plans
- the distribution of water conservation kits to the public
- support for waste water to irrigate golf courses
- recommendations for drought tolerant plant use
- education programs
- retrofit requirements (low-flow showerheads and toilets) for properties upon change of ownership and new constructions

Although water rationing ended in the early 1990's, many of the conservation programs continued (MPWMD 2008c). Following the MPWMD water ordinance No. 92 (MPWMD 1999), the Monterey Peninsula established a seven-stage community water conservation plan in 1999 that continues to this day and includes watering schedules and fines for excessive water use. Cal Am, the MPWMD, and other regulatory agencies have partnered in programs to provide rebates for installing high efficiency appliances, and distribute free low-flow equipment intermittently in the past two decades to continue to promote water conservation.

3.2 Conservation measures and how they work

Water conservation refers to the reduction in water loss, use, or waste due to improved water management policies or practices. It implies efficiency in sustainability (not diminishing the resource over time), energy conservation (less energy use due to a reduction of pumping, and less water going to treatment), and habitat and wildlife conservation (limited modification of natural systems). Additionally, water conservation has been called the largest, least expensive and most environmentally sound way to meet California's current and future water needs (Gleick et al. 2003).

Water conservation can result from structural and behavioral changes (Table 6). Structural changes include changes to plumbing fixtures that reduce the amount of water consumed per use, do not impose any kind of change in behavior, and therefore, permanently reduce per capita consumption. Behavioral changes in water usage have the potential to increase water savings, but are less permanent and require active lifestyle modifications. For this report, we will focus on conservation measures that reduce water consumption through structural modifications.

Table 6. Examples of structural and behavioral water conservation strategies.

Structural	Behavioral
Installing shower aerators	Taking shorter showers
Installing faucet aerators	Wet-and-rinse for dishwashing and teeth brushing
Installing low-flow toilets	Flushing the toilet only when necessary

3.3 Current Status of water conservation on the Monterey Peninsula

Estimating the current status of water conservation on the Monterey Peninsula poses many challenges. We found no source of information for current levels of conservation being practiced, or current usage of low flow infrastructures on the Monterey Peninsula. In this report we focus most of the water conservation strategies in the sector with the largest demand for water, the residential sector (Cal Am 2007) (Table 1).

We calculated per capita water use to be 65 gallons daily, based on residential and multi-residential water consumption (MPWMD 2008a) (Table 1) and a population estimation of 112,000 (MPWMD 2007). To calculate outdoor water use, we compared water use data in wet months (Nov – April) and dry months (May –Oct) from 2003 to 2010 (MPWMD 2010) (Table 7). Due to limitations in data availability, our analysis was based on monthly water use data that was not separated by sector (Fig. 6). It is possible that our estimated outdoor water use was influenced by other factors outside of the residential sector. We found that water use varied between years, probably due to variations in rainfall. We calculated the average difference in wet and dry month water use to be 37% (Table 7). To standardize the difference in summer to winter (outdoor) water use, we divided by 2 and assumed that Monterey Peninsula residents allocate 18.5% of their water consumption for outdoor water uses.

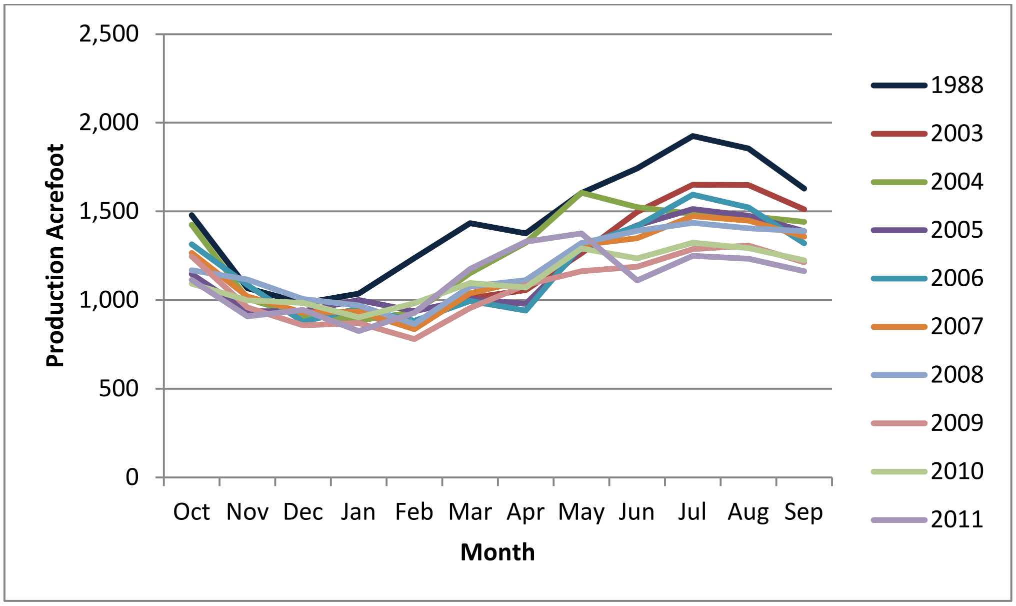

Figure 6: Monthly water production illustrating increased water usage in the spring and summer months, potentially showing the amount that could be conserved by reducing irrigation demands in the summer. Data compiled from MPWMD 2010 board meeting packets; available from: http://www.mpwmd.dst.ca.us/asd/board/boardpacket/2011/2011.htm

Table 7. Seasonal water use on the Monterey Peninsula. Outdoor water use varies annually, but has an average of approximately 37% of the dry month water use or 18.5% standardized annual average.

Year	Average Water Used Winter	Average Water Used Summer	Percent Difference
2003	1102	1437	0.30
2004	1036	1493	0.44
2005	966	1372	0.42
2006	957	1413	0.48
2007	952	1331	0.40
2008	1025	1352	0.32
2009	918	1235	0.34
2010	1007	1243	0.24
Average	995	1360	0.37

3.4 Potential conservation strategies

The California Central Coast is already notably water wise, as compared to the national US average water usage per day of 100 gallons per residence per day (WWC 2010). However, according to the World Water Council, European residences use 50 gallons each day and Sub-Saharan Africans use a mere 2-5 gallons daily. Although the Monterey Peninsula has a history of implementing water conservation and reutilization strategies, techniques that are not yet widely used in the region have the potential of further reducing regional water demand. The following sections explore five water conservation strategies and their potential to reduce water demand in the region: reductions in indoor use, rain water harvesting, residential gray-water recycling, outdoor water conservation, and large-scale waste-water recycling.

3.4.1 Reductions in indoor use through high-efficiency water appliances and behavioral changes

Calculating current level of indoor water conservation poses many challenges. Although the MPWMD estimated 93% compliance with the low-flow implementation of conservation kits in the 1980's and 1990's (MPWMD 2008c), adjustments to California's plumbing code, retrofit requirements, and many local water conservation programs have led to both mandatory and voluntary changes of water usage within the home.

We used an estimation of water allocation per household (Gleick et al. 2003) along with outdoor use (MPWMD 2010) (Table 7) to estimate the typical residential water use per capita on the Monterey Peninsula (Table 8). To identify potential savings in indoor water use, we multiplied the daily gallons used by the low-flow water use per fixture (Appendix A, Conservation Table) with an estimated usage rate (Table 9). We estimated that an additional 20.6 gallons per capita per day could be saved by installing ultra-low flow devices and if leaks were reduced to half of the current rate. That would represent a 31.7% savings, and if implemented throughout the Monterey Peninsula, a reduction in annual water demand by 2,584.4 acre feet per year.

Table 8. Estimated water allocation in the Monterey Peninsula for typical water usages

Activity	A) Total use per capita (G) [1]	B) Percent of total use[2]	C) Gallons used (total use x percent total use)
Shower	65	18%	11.65
Dishwashers	65	0.82%	0.53
Faucets	65	15.49%	10.07
Other uses, leaks	65	9.78%	6.36
Washing machine	65	11.41%	7.42
Toilets	65	26.08%	16.95
Outdoor uses[3]	65	18.50%[3]	12.03
Gallons per capita	65	100%	65

1. Personal calculation from water use data (Cal Am 2007) and population estimates (MPWMD 2007)
2. Estimates of residential indoor water use in California (Gleick et al. 2003)
3. See table 7.

Table 9. Potential water use reduction through conservation on the Monterey Peninsula

Activity	D) Rates under Ultra Low Flow & conservation behavior[4]	E) Assumed typical usage[5]	F) Daily Gallons used (column D x column E)	Potential Savings (G) (column C – column F)
Shower	1.5 G/min	7 min daily	10.5	1.15
Dishwashers	5.8 G/use	1 load/ 4 days	1.45	-0.92
Faucets	0.5 G/min	12 minutes daily	6	4.07
Other uses, leaks	0	NA	0	3.18
Washing machine	20G/use	1 load /7days	2.86	4.56
Toilets	1.2 G/flush	7 flushes daily	8.4	8.55
Outdoor uses[6]	NA	NA	12.03	0
Gallons per capita	NA	NA	41.24	20.59

4. See appendix A Conservation Table.
5. Assumed typical usage based off of personal observance, rates may change based on individual
6. See table 7

3.4.2 Rainwater harvesting

Although collecting rainwater from impervious surfaces and storing it for later use has been used for millennia, it is in recent decades that the United States has started to reassess its potential (Kloss 2008). Rainwater harvesting programs for residential users have been implemented in nearby cities such as San Francisco and Berkeley (Kloss 2008; City of Berkeley [date unknown]) for some time. Currently, within the MPWMD, the cities of Pacific Grove and Monterey are starting to offer incentives for the implementation of rainwater harvesting and collection systems. Additionally, collecting rainwater provides a secondary benefit of diminishing stormwater runoff.

For a rapid assessment of the rainwater harvesting potential, we chose a simplified analysis that only considered the catchment area and the amount of rain for each region. Evapotranspiration rate, absorption rate of the catching and storing materials, and actual storing capability are three important parameters that need to be considered for a more precise assessment. To calculate the total catchment area we multiplied the average roof size by the number of reported Cal Am customers in each city. We chose to base our calculations on the number of Cal Am customers in each city and not on the absolute number of housing units because we wanted to ensure the exclusion of non-Cal Am customers. We assumed that each customer represented one house, which may lead to an underestimation of the rainwater harvesting potential where one billed customer represents more than one housing unit with an average size roof.

To calculate the average roof size, we used Geographic Information Systems (GIS) software (ESRI 2010) to measure the size of twenty randomly chosen roofs in each city. We determined that the sample size of 20 was reasonable for all the cities after observing, using the running mean technique, that the mean stopped changing after increasing the sample size. We made our measurements on 2009 aerial images from the National Aerial Imagery Program (NAIP) that had a three meter resolution.

We found that a total of 2,971.45 acre-feet per year could be potentially collected and stored for use by residential and multi-residential Cal Am customers on the Monterey Peninsula (Table 9).

Table 9. Rainwater harvesting potential for residential customers within the MPWMD. Data on 2007 housing units was unavailable. Sources: housing data from the US Census Bureau; Cal Am customers and usage from MPWMD.

						Rainwater Harvesting Potential	
City	Housing Units (in 2010)	Cal Am Customers (in 2007)	2007 Water Usage by Cal Am Customers (acre-feet)	2007 Average roof size (in ft2)	Average yearly rain (inches)	Per Customer (ft3/year)	Per Service Area (AFY)
Pacific Grove	7,020	6,206	1,079.87	1,847.76	19.7	3,033.40	432.17
Monterey	12,184	8,696	1,851.95	2,530.50	19.7	4,154.23	829.32
Carmel-by-the-sea	2,095	2,932	511.27	2,311.95	17.5	3,371.59	226.94
Carmel Valley	1,895	6,136	1,765.50	2,311.95	17.5	3,371.59	474.93
Del Rey Oaks	701	730	136.15	1,854.19	19.7	3,043.97	51.01
Seaside	10,093	5,823	1,388.02	2,340.54	19.7	3,842.39	513.64
Sand City	128	96	13.77	1,529.06	19.7	2,510.21	5.53
Pebble Beach	1,925	2,707	901.33	4,292.31	19.7	7,046.54	437.90
Total	36,041	33,326	7,647.86			30,373.91	2,971.45

3.4.3 Residential gray-water recycling

Gray-water is wastewater from household fixtures that has not come into contact with sewage, or black-water (WHO-ROEM 2006). Because gray-water has lower levels of contamination, if separated, gray-water can be used in place of potable water for applications such as toilet flushing, outdoor landscaping, and other non-potable water requirements. Gray-water systems can range from do-it-yourself, low cost devices that divert gray-water for direct outdoor water use, to more costly, commercial devices that treat water for uses such as laundry.

Our current water distribution infrastructure consists of one pipe that brings water into our homes, and one pipe that takes the waste out (Figure 7). The high quality water that comes into our homes for us to drink is also used to flush toilets, water lawns, etc. If water of different grades was matched with uses based on quality, there would be a large reduction in water consumed. Benefits of gray-water reuse include the reduction of the demand for potable water and a reduction in the amount of water that needs to be transported and treated. In a gray-water system, gray-water is filtered and reused in non-potable applications such as toilet flushing and landscaping (Figure 8).

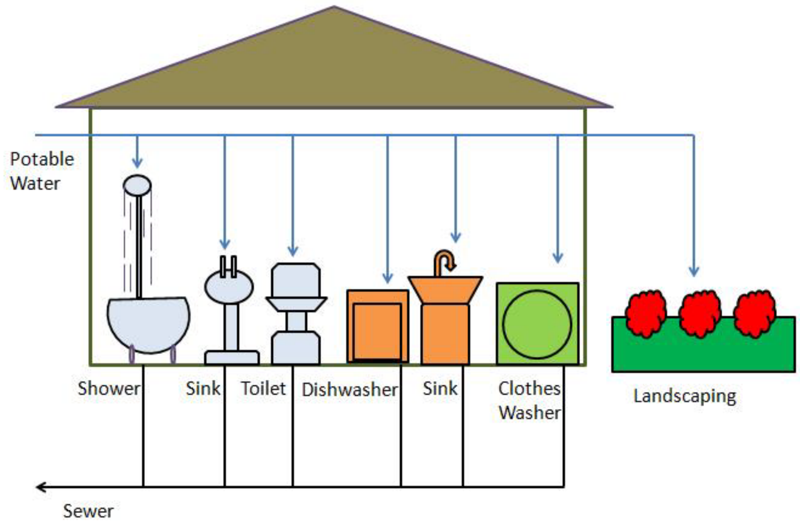

Figure 7. A typical utility system in which potable water sources all fixtures and a common sewage systems carry both gray-water and black-water away. Illustration by Ashbach 2011, adapted from Allen et al. 2010.

On the Monterey Peninsula it is estimated that of the 65 gallons of water used per person per day, 36 gallons go to non-potable applications (toilet flushing, outdoor water use, washing machines) (Table 10), and 29 gallons to potable applications (Table 11). Installation of a gray-water system has the potential to reduce water consumed for all non-potable water needs. Although our potable water needs range from 18-29 gallons per day (table 11), only 16 and 24 gallons of gray-water are created daily (Table 12). In other words, only 16 to 24 gallons of water could be allocated for reuse. Therefore, because non-potable water use is greater than gray-water created, additional potable water would be allocated to those applications. Other conservation measures, such as rainwater harvesting are available to fulfill additional non-potable water needs. Potential savings from installing a gray-water system is equal to the amount of gray-water created and re-used, 16 and 24 gallons per person per day (Table 12), a savings of 2,007 to 3,011 acre feet per year, if gray-water was implemented by all Monterey Peninsula residents.

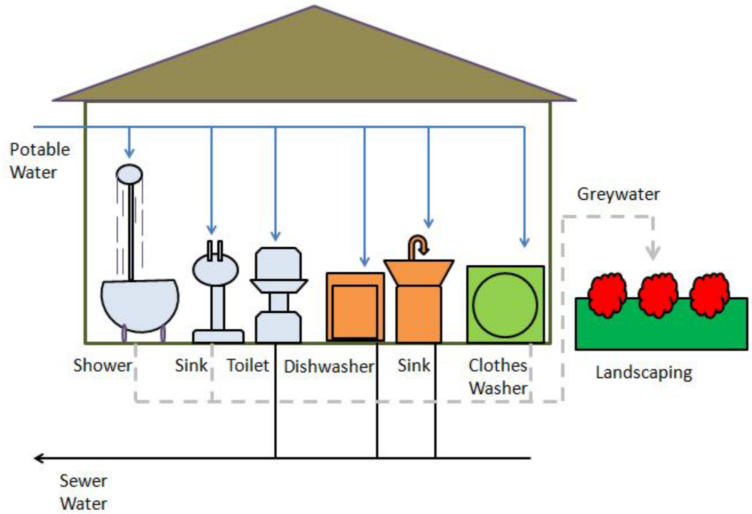

Figure 8. Basic gray-water system in which gray-water from non-food sinks, baths and washing machine is used to irrigate outdoor landscaping, , adapted from Allen et al. 2010).

Table 10. Non-potable water use (allocation per capita)

Activity	Gallons used[1]	% of total use[2]	Potential Savings[3]	Gallons used under low flow Senarios[4]
Washing machine	7.42	11.41%	7.42	2.42
Toilets	16.95	26.08%	16.9	8.40
Outdoor uses[5]	12.03	18.50%	12.03	12.03
Subtotal	36.39	55.99%	36.34	23.39

1. See table 8
2. Estimates of residential indoor water use in California (Gleick et al. 2003)
3. Potential potable water savings if gray-water was used for non-potable water applications
4. See table 9
5. See table 7

Table 11. Potable water use (allocation per capita)

Activity	Gallons used[6]	% of total use[7]	Potential Savings[8]	Gallons used under low flow Senarios[9]
Shower	11.6545	17.93%	1.5 G/min	10.50
Dishwashers[10]	0.533	0.82%	5.8 G/use	1.45
Faucets	10.0685	15.49%	0.5 G/min	6.00
Other uses, leaks	6.357	9.78%	NA	3.18 [11]
Subtotal	28.613	44.02%	NA	17.95

6. See table 8
7. Estimates of residential indoor water use in California (Gleick et al. 2003)
8. See appendix A
9. See table 9
10. Dishwashers are considered dark gray-water, due to high levels of organic matter. Some gray-water systems are capable of treating dark gray-water. However, some regulations prohibit re-use of dark gray-water.
11. Leaks reduced to half of current flow rate

Table 12. Amount of gray-water that is produced (per capita production from gray-water and potable water sources)

Activity	Gallons used[12]	% of total use[13]	Potential Savings[14]	Gallons used under low flow Senarios[15]
Shower	11.65	17.93%	1.5 G/min	10.5
Faucets[16]	5.04	7.25%	0.5 G/min	3
Washing machine	7.42	11.41%	7.42	2.42
Subtotal	24.11	36.59%	NA	15.92

12. See table 8
13. Estimates of residential indoor water use in California (Gleick et al. 2003)
14. See appendix A
15. See table 9
16. We cut the gallons used and % of total use in half, because in basic gray-water systems, faucets from the kitchen would not be re-used.

3.4.4 Outdoor water conservation: water-wise landscaping

Using native or drought-tolerant plants can reduce residential water consumption by decreasing the water used for irrigation during the dry summer months of our Mediterranean climate. Lawns and exotic plants require a large amount of water and can be replaced by similarly aesthetic varieties of plants that require much less water. For every 1000 square feet of turf it takes approximately 30,000 gallons (0.092 acre-feet) of water a year to maintain (WAC 2011). There are many ways to maintain a beautiful lawn with less water such as aerating, switching to drip irrigation, using drought-tolerant grasses, installing evapotranspiration controllers, enhancing the quality of roots with compost tea or installing artificial turf. Other alternatives include native bunch grasses, xeriscaping, or replacing the majority of the yard with hardscaping materials such as pavers, patios, or decks.

In order to calculate the regionally-specific potential of outdoor water conservation, we need to know how many residences currently irrigate lawn on their property. Lawn areas were estimated for each city using high-resolution (6 in) aerial imagery obtained from the MPWMD GIS specialist. The cities within the MPWMD include Seaside, Monterey, Pacific Grove, and the unincorporated areas of Del Monte Forest, Carmel-by the-sea and Carmel Valley Village. For each of these places, 5 points were randomly selected within residential areas only. A 10,000 square meter sampling area was created around each point using a circle with radius of 56.42 meters. Polygons were then drawn around any area of land that was irrigated lawn. For each sampling cirlce, the area of each polygon was recorded, as well as the number of residences with and without lawns. If houses had multiple sections of lawn that were separated, the areas were added together to maintain that areas were recorded as per residence. If the buffer covered an area with no lawns, the number of residences was still recorded. The data were then analyzed to determine the average size of lawns and total area of irrigated turf for the Monterey Peninsula (Table 13). The extrapolated area of irrigated turf was then used to calculate the total acre-feet of water typically used, and therefore the potential savings that could occur (figure 9).

Table 13. Summary table of residential lawn size analysis. For each city and the whole district the average area of irrigated lawn was calculated per 10,000 m^2. The second column shows the percent of houses that had an irrigated lawn, out of the total number of houses in every 10,000 m^2.

Location	Average Lawn Area in 10,000 m^2	Houses with Lawns (%)
Carmel Valley	288.50	41.4%
Seaside	279.55	23.5%
Pacific Grove	275.78	12.6%
Monterey	245.36	25.7%
Del Monte Forest	627.99	36.1%
Carmel-by-the-sea	102.85	12.6%
MPWMD	303.34	25.3%

From table 13 you can see that there is an average of 303 m^2 of irrigated lawn area per 10,000 m^2 of residential area. This equates to about 3% of land, or approximately 1,973,991 m^2 within the MPWMD. Using conventional irrigation and maintenance techniques (noted earlier as 30,000 gallons per 1000 ft^2) this amount of irrigated turf could require 1956 acre-feet of water annually. Figure 9 illustrates the range of water savings that can occur depending on the percent of residences that exchange their irrigated lawns for drought-tolerant native plants or synthetic turf. Because the MPWMD is so variable in climate, lot size, and affluence, a more detailed analysis is necessary to make any recommendations. For example, the average area of irrigated lawns per 10,000 m^2 was higher in Del Monte Forest at 628 m^2, and lower in Carmel-by-the-sea at 103 m^2. The percentage of houses with irrigated lawns was included to demonstrate the variability in landscaping choices throughout the district. These numbers can also help to focus on the areas that could contribute the most to water savings by decreasing the amount of irrigated land, for example Carmel Valley and Del Monte Forest.

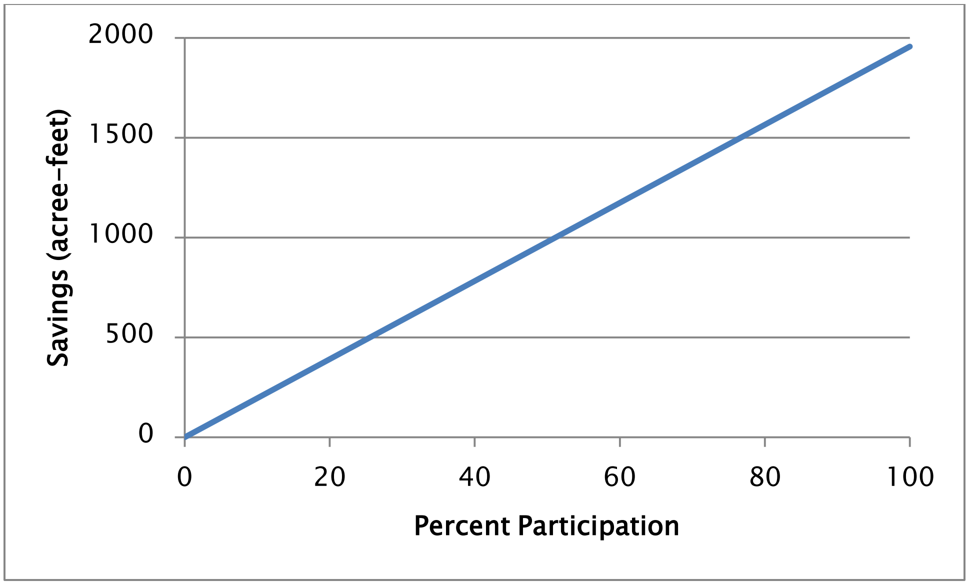

Figure 9. Potential water savings from increased amount of residences using water wise landscaping.

3.4.5 Large-scale wastewater recycling

Wastewater reclamation has been found to be a safe source of water, even for the irrigation of crops consumed without cooking (Sheikh 1990). Although Monterey County has been using recycled water since 1997 (MRWPCA [date unknown]) there is still potential for increasing the amount of water being recycled and for increasing its uses. The MRWPCA treats approximately 23,000 acre-feet of wastewater from the cities and unincorporated areas of Northern Monterey County, about 6,100 acre-feet of that comes from the Monterey Peninsula (MRWPCA 2010). The wastewater reclamation facility at the Regional Treatment Plant typically supplies 13,000 acre-feet of reclaimed water to farmland in the Northern Salinas Valley. In a typical year, 8,000 acre-feet of treated wastewater is discharged to the ocean. There is potential to utilize all of the treated water instead of discharging any water to the ocean, but certain uses require approval and construction of additional infrastructure. Table 14 illustrates the amount of water entering and exiting the treatment plant.

Currently, the Regional Urban Augmentation Project is in process to provide reclaimed water for irrigation to city parks, roadway landscaping and golf courses. This project will produce approximately 1,000 acre-feet in its initial stages, but The MRWPCA is currently exploring options for storing the reclaimed water during winter to increase the supply to 3,000 acre-feet annually. Additionally, 2,700 acre-feet of recycled water are proposed to be used for recharging the Seaside Basin, in a project called Groundwater Replenishment (MRWPCA 2010). Due to stricter regulations for groundwater quality the infrastructure required for the advanced treatment of the water makes the project more expensive. In addition, there is an unknown amount that may be used to dilute brine from the Regional Desalination Project (Cal Am 2009)

Table 13. Summary of wastewater treatment and reclamation by the MRWPCA in a typical year. Of the 23,000 acre-feet of wastewater only 13,000 acre-feet is recycled for irrigation. Currently 8,000 acre-feet are being discharged into the ocean. There are two in progress projects in place, but there are approximately 2,300 acre-feet left that could be utilized (MRWPCA 2010).

Wastewater entering treatment plant from:	Acre-feet
Monterey Peninsula	+ 6100
Other areas	+ 16900
Reclaimed water leaving treatment plant to:	
Northern Salinas Valley (irrigation)	-13000
Currently discharged to Ocean	-8000
Net remaining	0
Proposed and in-progress uses for the discharged 8000 acre feet:	
Regional Urban Augment Project	1000 (up to 3000)
Groundwater Replenishment	2700
Other (possibly de-salination brine dilution)	2300

Smaller recycled-water projects have also been successfully implemented in the Monterey Peninsula. The Carmel Area Wastewater District and the Pebble Beach Community Services District have collaborated on the CAWD/PBCSD Reclamation Project which provides 800 acre-feet of treated wastewater annually for the irrigation of the Pebble Beach golf courses.

4 Conclusion

Under different use scenarios, most of the daily water usage could come from alternative sources such as gray-water or rainwater harvesting. Total indoor potable water use under current estimations and low-flow scenarios for designated residential water use amounts to between 53 and 34 gallons per day, and outdoor water use equal to 12 gallons per day (Table 14).

The analysis of aerial imagery concluded that on average in the residential areas of the MPWMD there is about 3% coverage of irrigated lawn. In the best-case scenario the 1,956 acre-feet used to irrigate annually would be diminished through the increased adoption of water-wise landscaping and use of native plants. However, residents that appreciate an irrigated lawn in the summer can alternatively use harvested rain-water or gray-water to decrease potable water demand. Coupled with the completion of MRWPCA's RUAP program to use reclaimed water to irrigate non-residential sectors, there can be a substantial reduction in the demand of water during the summer months and annually.

Table 14. Potential reduction in indoor water usage in the Monterey Peninsula

	Allocation of Water	Gallons used[1]	% of total use[2]	Low Flow Fixture use[3]	G under ultra-low flow scenari[o]	G under ULF, and graywater[5]	G under ULF, graywater, and rain barrel [6]
Indoor water use	Shower	11.65	18%	1.5 G/min	10.5	10.5	10.5
	Dishwashers	0.53	0.82%	5.8 G/use	1.45	1.45	1.45
	Faucets	10.07	15.48%	.5 G/min	6	6	6
	other uses, leaks[7]	6.36	9.78%	NA	3.18	3.18	3.18
	clothes washers	7.41	11.41%	20G/use	2.86	2.86	2.86
	toilets	16.95	26.08%	1.2 G/flush	8.4	8.4	0
	Total indoor uses	52.98	81.50%	NA	32.39	32.39	23.99
	Outdoor uses[8]	12.03	18.50%	NA	12.03	0	0
	Total	65	100.00%	NA	44.42	32.39	23.99

1. See table 8
2. Estimates of residential indoor water use in California (Gleick et al. 2003)
3. See appendix B

4. See table 9
5. Because not enough gray-water is produced inside each residence to cover all non-potable water requirements, in this scenario, gray-water only covers outdoor water use
6. Rain water re-use for outdoor water use and gray-water re-use for toilet flushing
7. Leaks reduced to half of current flow rate
8. See table 7

If nothing but ultra low flow (ULF) appliances were used in the home, water consumption per capita would be reduced to 44 G per day. Under this scenario, a district wide savings of 2223 acre-feet per year would be achieved. When ULF implementation is combined with gray-water systems water demand is further decreased to 32.39 gallons per day. Under this scenario, we only reduce outdoor use, because only 17 gallons of gray-water are produced per day, not covering indoor non-potable and outside use requirements. Under ULF and gray-water scenarios, a district wide savings of 3731 acre-feet could be achieved annually. Under ULF, gray-water and rain-barrel harvesting, water consumption per capita is reduced to 24. gallons per day, totaling a district wide water savings of 4784 acre feet per year.

Table 15: Summary of savings under different conservation scenarios. Residential water conservation has the potential to reduce the supply deficit to approximately 5,316 acre-feet. All values in acre-feet.

Current supply deficit*	10,100
Residential Conservation	
Non-irrigation	1,956
ULF appliances only	2,223
ULF + gray-water	3,731
ULF+gray water +rain harvesting	4,784
Potential deficit with residential conservation (Supply deficit - ULF+gray water +rain harvesting)	5,316

*As estimated by Cal Am

Relying on conservation methods alone can substantially reduce the water supply gap to 5,316 acre-feet, but it cannot eliminate the gap completely. However, implementing the proposed Regional Urban Augmentation Project, which would increase the supply by 3,000 acre-feet, could potentially decrease the supply gap further to 2,316 acre-feet.

The findings of this report suggest that conservation and reutilization measures in the Monterey Peninsula can potentially reduce by a considerable amount the demand for water for residential uses. Given the urgency of the current need for alternative supply sources, exploring in greater detail the feasibility of the strategies here proposed can greatly inform water management in the region.

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6 Appendices

6.1 Appendix A– Water Conservation Measures

Conservation Measures	How it works	Where it is appropriate (residential/commercial/etc.)	How much water can it save (in our region)	Cost to start	info sources
Installing faucet aerators (0.5 gpm) and shower aerators (0.5-2.5 gpm)	Aerators mix air into the water stream, separating it, and reducing the amount of water per minute.	residential, commercial	savings depends on current shower fixture	Free from Cal Am	EPA. 2011. Water sense. Bathroom sinks and accessories
Ultra Low flush toilets (<1.2 gallons)	Uses bowl design and increased flushing velocities to remove waste	residential, commercial	8 G per person per day	~$40 to convert toilet, $200-$500 for ULF toilet	EPA. 2011. Water Sense-products-toilets
Trigger nozzle for washing cars and outdoor irrigation	Different spray patterns and pressure allow you to control watering	residential, commercial	Depends on current outdoor water use	$15-$25	Sydney water. date unknown. Trigger nozzles. what you need to know
Fix faucet leaks	Fix leaking faucets, ie replace old washer	residential, commercial	pinhole leaks: 70 gals/day	$5-$20 depending on part	City of San Jose. 22009. Repairing Faucet Leaks
Fix irrigation leaks	Identify and replace any leaking lines or sprinkler heads	residential, commercial, golf courses	varies depending on size of leak and pressure of system, up to over ~6,300 G of water per month.	$5-75	EPA. 2011. Water Sense- publications-fix a leak week
Toilet leak	Check for leaking toilet flapper valves and replace	residential, commercial	up to 200 gals/day	$10-50	EPA. 2011. Water Sense- publications-fix a leak week

Outdoor landscaping watering time	water early in the morning or at night to decrease ET from heat and wind	residential, commercial, golf courses	up to 300 gals	$0-40 if install timer for irrigation	Mono Lake. 2011. Water Conservation
Ornamental landscaping-drought tolerant	Choose plants that are adapted to a mediterranean climate, preferably plants that are native to the central coast region	residential, commercial	can reduce outdoor water need by 20-50%	$300-2000 for 1000 sq ft yard	EPA. 2010. Conserving Water
High efficiency clothes washer (~20 gal/load)	Uses tumbling action in less water to rince and wash clothing	residential, commercial	conventional washers use: 50 gal/load, HE use 18-25 gal/load	$500.00-2000.00	PG&E. 2008. High efficiency washers
Rain water harvesting	install a rooftop harvesting system to capture rainwater for non-potable uses (toilet flushing, cooling systems, landscape irrigation)	residential, commercial-malls, industrial facilities that require/use non-potable water	Collection Area (sq. ft) x Rainfall (in/yr.) / 12 (in/ft) =ft^3/yr. Xft^3/yr x 7.43 (G/ft^3) = gal/yr For example, a 500 sq. ft roof that gets 18 in/yr. will produce 700 Cubic Feet or 5,573 gal/yr	simple system ~$1500 for non-potable uses	City of Portland. 2011. Rainwater harvesting
Eco (tea) lawn	apply compost tea to turf areas to stimulate microbial growth and improve root health	residential, commercial, golf courses	Uses 1/4 of water due to microbial moisture retention and deeper root systems and they are less susceptiple to drying	$6/gal (covers ~400 sqft)	MiniGreenhouseKits. 2011. Compost tea
Pools and spas maintenance	use a pool cover to cut down on evaporation. It will also keep your pool cleaner and reduce the need to add chemicals.	residential, commercial	Saves ~ 1,000 gallons a month in summer	$25-$150	California urban water conservation council. date unknown. Splash or sprinkle?

					comparing the water use of swimming pools and irrigated landscapes
Water efficient shower head	replace existing shower head with water efficient head	residential, commercial	0.5 to 2.5 gal/ minute	$19.99 - $50	U.S. Dep of Energy. 2011. Low flow shower heads
High efficiency dish washer (5.8 gal /use)	Instead of washing dishes by hand, fill machine to full, set on energy efficient cycle and air dry	residential, commercial	~5,000 gallons of water, and many hours of your time.	~$500	EPA. 2010. Conserving water
Gray-water recycling	Storing used lightly used water, from showers and clothes washing to flush toilets, and outdoor landscaping use	residential, commercial, golf courses	Saves 35% of water use.	$350-$2000	EPA. 2011. Water recycling and reuse