Not a Drop to Spare: Sustainable Water Management for the South Coast of Santa Barbara County

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Amanda Silver-Westrick, & Cody Wilgus

March 18th, 2016

Master's Group Project
Bren School of Environmental Science and Management
University of California, Santa Barbara

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BREN SCHOOL
ENVIRONMENTAL SCIENCE & MANAGEMENT
UNIVERSITY OF CALIFORNIA, SANTA BARBARA

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Signature Page

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The Group Project is required of all students in the Master of Environmental Science and Management (MESM) Program. The project is a year-long activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Group Project Final Report is authored by MESM students and has been reviewed and approved by:

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BOB WILKINSON

March ________ , 2016

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Abbreviations Guide

AF	Acre-feet
AFY	Acre-feet per year
C&E	Conservation and efficiency
Cachuma	Lake Cachuma
CCWA	Central Coast Water Authority
CY	Calendar year
DPR	Direct potable reuse
DWR	California Department of Water Resources
FMP	Fishery Management Plan
FY	Fiscal year
GCPD	Gallons per capita per day
GIS	Geographic information systems
HCF	Hundred cubic feet
ID #1	Santa Ynez River Water Conservation District, Improvement District No. 1
IPR	Indirect potable reuse
JPA	Joint Powers Authority
MG	Million gallons
NFMS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
O&M	Operation and maintenance
RFP	Request for proposals
SWP	State Water Project
USBR	United States Bureau of Reclamation
WTP	Water treatment plant
WWTP	Wastewater treatment plant
WY	Water year

Water Districts

Carpinteria	Carpinteria Valley Water District

Goleta	Goleta Water District
La Cumbre	La Cumbre Mutual Water Company
Montecito	Montecito Water District
Santa Barbara	Santa Barbara Public Works

Water Treatment Plants

Bella Vista	Bella Vista Treatment Plant
Cater	William B. Cater Treatment Plant
Corona del Mar	Corona del Mar Water Treatment Plant

Abstract

California's current drought has created a statewide shortfall in water supply, forcing water purveyors to examine ways to adapt to water shortages both currently and in the future. On the South Coast of Santa Barbara County, five water districts are working to meet State-imposed conservation requirements. and evaluate all current sources and demand-side management strategies as well as potential future supply options to increase portfolio resilience.

This report investigates the financial, energy, and environmental costs of each current and potential future water supply option on the South Coast. Models were created and case study evaluations performed to estimate production from additional future sources and expansion of select current sources.

Local surface waters comprise the majority of the aggregated South Coast water portfolio and are vulnerable to supply interruptions. Lost and reused water are a largely untapped source region-wide. Fixed financial costs, increasing energy prices, and environmental externalities are largely absent in long-term supply planning. Incorporating these missing cost elements and impacts as well as regional collaboration, sharing data and best management practices, between districts will increase supply reliability and mitigate inevitable uncertainties districts face during times of water scarcity now and in the future.

Executive Summary

In response to the current drought, municipalities and water agencies across California are searching for solutions to meet projected shortfalls in their water supplies. The five water districts on the South Coast of Santa Barbara County—Goleta Water District, La Cumbre Mutual Water Company, City of Santa Barbara, Montecito Water District, and Carpinteria Valley Water District—have a wide array of water supply and demand-side management options. South Coast water managers can take actions such as expanding recycled water capacity, investing in conservation communications campaigns, or constructing ocean desalination facilities. However, all of these options come with their own financial costs, energy demands, and environmental impacts. Additionally, these costs and impacts change as precipitation comes and goes, energy prices and emissions factors change, and critical species flourish and dwindle. These decisions are made by each individual water district, rather than the South Coast region as a whole, even though districts have overlapping interests, face similar decisions, and impose externalities that extend beyond their boundaries.

This report takes a regional approach to water costs and impacts along the South Coast of Santa Barbara County. It examines the supply and demand-side options and evaluates the financial, energy, and environmental costs of each. The analysis encompasses both existing and potential future supplies.

Objectives

We first sought to understand the multifaceted system of water management on the South Coast, spanning five water districts to bridge the gap between district-level management plans and statewide studies. We assessed the water resources available to the region, the built infrastructure, and the political bodies managing these resources.

Next, we mapped historical water production and demand across the five water districts to lay out the existing water resources and needs of the region as a whole. From there, we built models to calculate how much water could potentially be produced from untapped sources, such as residential greywater and stormwater capture.

We then analyzed and compared the financial costs, energy demands, and environmental impacts of these existing and potential future water supply options across the South Coast.

Lastly, we identified opportunities for regional collaboration and knowledge-sharing.

Methods

We performed a range of analyses, examining water production (including currently used sources and potential future sources), water demand, costs, and energy needs. Our calculations and models were conducted using data obtained directly through contact with water districts themselves, as well as from public budgets, comprehensive annual financial reports, board packets, and bid proposals.

Conclusions

The data gathered for this study reveal many conclusions for the South Coast. This report's findings include: historical water supply trends; historical water demand summaries; water produced by potential future sources; water sources' financial costs; water sources' energy requirements; and various environmental impacts of water production.

Historical Water Supplies

On the South Coast of Santa Barbara County, Lake Cachuma has historically been the primary water source, providing approximately 62% percent of the total annual supply. However, Lake Cachuma and other local surface reservoirs face significant vulnerabilities, including drought, siltation, and an impending biological opinion for steelhead trout. As local surface supplies have decreased in the current drought, South Coast water districts have supplemented their water needs with imported water and increased groundwater production.

Historical Water Demand

Residential water consumption accounts for the majority of water demand on the South Coast. Agricultural demand appears to be outside the control of the water districts; agricultural water consumption increases when crop prices increase and rainfall decreases.

Lost Water and Potential Future Sources

In a given year, an average of approximately 14,600 AF of treated wastewater is discharged into the ocean from WWTPs across the South Coast. This water could be captured through a variety of different programs, including potable reuse and greywater systems.

Overall, an average 74,100 AF of precipitation falls onto the South Coast each year. Approximately 7,000 AFY of urban stormwater runs off of South Coast land surfaces and into the ocean in an average year. Captured stormwater could be recharged into groundwater aquifers through spreading basins, over unconfined portions of the aquifers, or via injection wells. An estimated 200 to 600 AFY of this precipitation could be captured and used on-site through residential rain cisterns.

The South Coast loses water each year through pipe leaks in its infrastructure. Some of this water loss is inevitable, due to lack of resources for infrastructure replacement and maintenance. However, smart meters may help to identify some of these leaks and target pipe replacement efforts.

There is also a vast array of conservation and efficiency programs that could further decrease water demand. Specific examples modeled in this study include washer rebate programs, which alone could yield about 1,250 AFY in water savings, and lawn conversions, which could yield about 350 to 2,400 AFY in water savings.

Financial Costs

Variable and full-system cost analyses tell two different stories for the cost of water on the South Coast. Variable cost analyses, which include costs that change depending on how much water is produced from each source in a given year, yield wide and overlapping cost ranges without major cost differences between sources.

Full-system cost analyses, which include all of the costs that the districts are paying for each source in a given year (including fixed costs and debt service), yield different results. When these costs are accounted for, the two least expensive sources appear to be recycled (tertiary) and conservation/efficiency. The three most expensive water sources appear to be potable reuse, desalination, and State Water. Some years, State Water full-system costs can be up to five times as expensive as any other source.

Energy Requirements

Decentralized sources, such as greywater and residential rain cisterns, have the lowest energy requirements on the South Coast. Potable reuse, State Water, and desalination have the highest energy intensities of all sources, meaning that the most expensive water sources are also the most energy-intensive. These energy requirements have long-term cost and environmental implications.

Environmental Impacts

The energy intensities of South Coast water sources also translate to greenhouse gas emissions. Even when considering total water production volume, potable reuse, desalination, and State Water remain the highest greenhouse gas emitters (or potential emitters, since potable reuse and desalination have not yet been activated).

Different water sources also have significant marine and freshwater ecosystem impacts. For example, both desalination and potable reuse will impact coastal marine ecosystems through brine discharge. However, the biological extent and cost of these external impacts are currently unknown.

Recommendations

The South Coast of Santa Barbara County is in a unique position in that it has a diverse portfolio of water supply options. Local water agencies face a multitude of water management decisions and opportunities. Below are some of the major takeaways from the project:

I. South Coast water agencies should explore the feasibility, costs, and benefits of potential future water sources outlined in this study.
II. Fixed costs should be transparent and factored into decision-making processes.
III. Local water agencies should note, for long-term planning purposes, that the most expensive water sources on the South Coast are particularly vulnerable to fluctuations in energy prices.
IV. Identifying externalized environmental impacts of water decisions will enable water agencies to make more informed decisions.

Regional Collaboration

There are untapped opportunities for collaboration between South Coast water agencies and increased public transparency. Individual agencies and the public can reap considerable benefits from regional knowledge-sharing and data management, including:

- Highlighting best practices within individual agencies;
- Identifying opportunities for regional market transfers; and
- Serving an important role in public transparency.

We recommend the following two actions for knowledge-sharing and collaboration across South Coast water decision-makers:

I. Create common reporting standards across the South Coast.
II. Maintain the South Coast Regional Water Database.

Water supply planning is influenced by a varied and often unpredictable set of elements, including climate, politics, finances, economic conditions, and legal framework all come into play as water managers make supply choices. Diverse and resilient water portfolios can help mitigate some of the inevitable uncertainties that districts face. While many water choices come down to financial comparisons, there are options for cost reductions on the South Coast. There is also room to consider the environmental impacts of these decisions, and limit externalities when possible. A range of water supply options are available to South Coast decision makers. These options, along with regional collaboration efforts, can enhance water portfolios, helping the South Coast manage its water resources in a changing climate.

Introduction to South Coast Water

Water supply shortages are not unprecedented in California. After several decades of cyclical drought and recovery periods, local and state agencies have devoted considerable time and resources towards studying their water supplies and determining how to manage the water needs of the growing population and industry. Additionally, sources of water supply throughout California are diverse: surface water extraction, groundwater pumping, ocean desalination, imported water, and recycled wastewater may comprise some water supply options for a single city.

While localized and statewide studies are indeed crucial pieces to California's water management, there remains a need for more regional studies to incorporate adjacent local water agencies. Such studies are able to examine water supply and consumption trends by each district in detail, as well as identify potential opportunities for inter-agency collaboration over shared resources. This project examined the multifaceted system of water management on the South Coast of Santa Barbara County, spanning five water districts to bridge the gap between district-level management plans and statewide studies.

The region encompasses the cities of Goleta, Santa Barbara, and Carpinteria, as well as adjacent unincorporated areas, spanning 64,648 acres and comprising 213,053 residents. Water sources used by districts along the South Coast include groundwater, surface water reservoirs, imported water via the State Water Project, ocean desalination, and recycled wastewater. Local water agencies manage these sources to deliver water to their customers, which include residences, commercial and industrial buildings, schools, parks, and agricultural land. Beyond examining the amount of water derived from each source and local consumption, this report also analyzes the financial, energy, and environmental costs associated with sources to better understand the complexities and implications of water supply planning.

Moving forward, some terminology clarifications should be made:

- *Production:* the volume of water extracted or withdrawn from a source by a water district, up to the point of distribution, over a given period of time.
- *Demand:* the volume of water consumed by a customer of a water district, over a given period of time. *Total demand* is the volume of water consumed by all customers for a specified district or region, over a given period of time.
- *Acre-feet (AF):* a unit of water volume, equivalent to a foot of water evenly distributed over an acre of land. *Acre-feet per year (AFY)* is the volume of water in acre-feet for a year.
- *Water year (WY):* a 12-month period reflecting the precipitation cycle. To incorporate seasonality, water years begin October 1 and continue through September 30 of the following calendar year. The water year refers to the year in which the period ends (e.g., WY 2014 spans October 2013 – September 2014).

Water Districts

South Coast water supplies are managed by five water districts: Goleta Water District ("Goleta"), La Cumbre Mutual Water Company ("La Cumbre"), City of Santa Barbara ("Santa Barbara"), Montecito Water District ("Montecito"), and Carpinteria Valley Water District ("Carpinteria"). They operate autonomously and under the direction of their own boards or councils. Each of the districts manages a distinct landscape of customers, infrastructure, financial resources, political dynamics, and natural resource opportunities and challenges. See Figure 1 and Table 1 for geographic location and demographic information of South Coast districts.

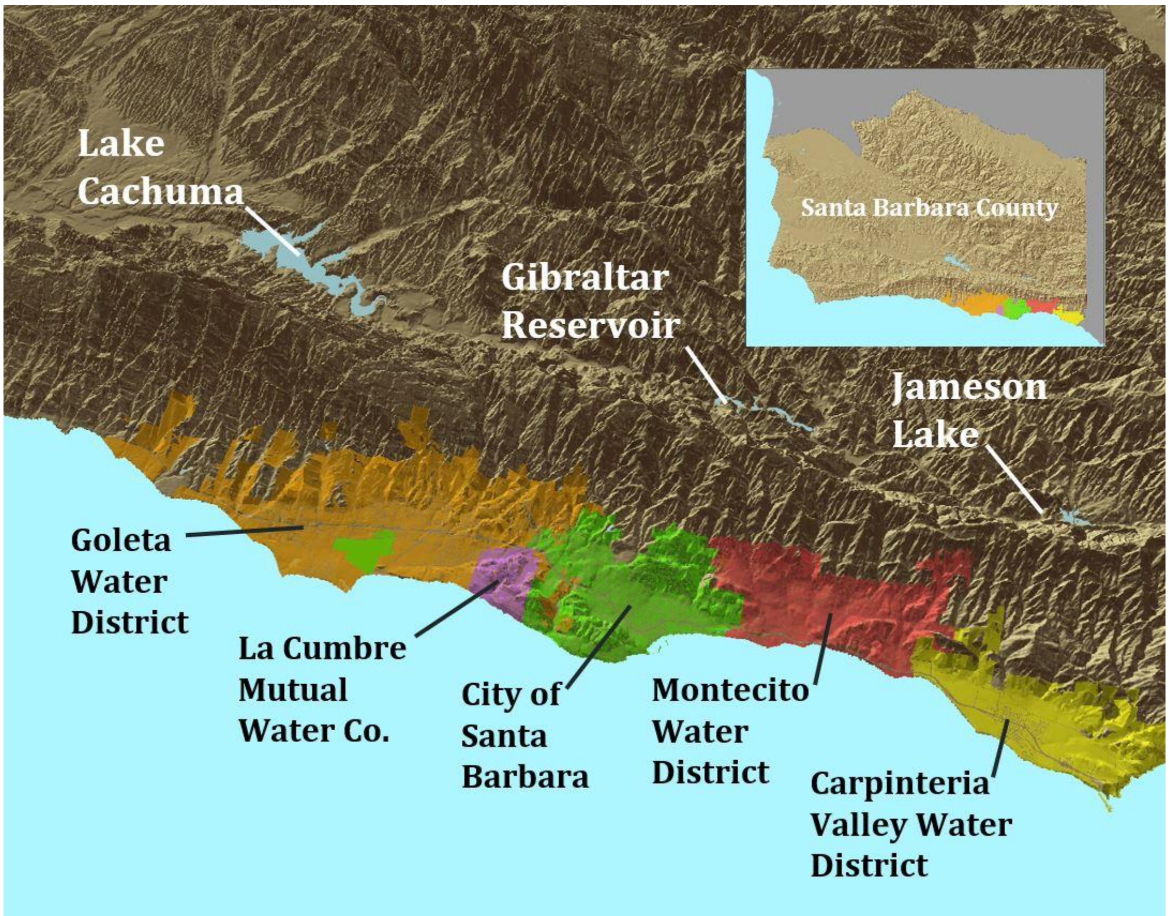

Figure 1. Map of South Coast water districts and local surface reservoirs.

Table 1. Demographic information of South Coast water districts based on 2010 census data. Source: County of Santa Barbara 2013 IRWMP

Area	Demographic Information											
	Population (2010)	Residential Units		Average Household Size	Median Age	Median Household Income	Single-Family Units		Multi-Family Units		Other Units	
		Total Units	Occupied Units				# of Units	% of Total Units	# of Units	% of Total Units	# of Units	% of Total Units
Goleta Water District	86,946	29,645	28,193	3.1	36.5	$66,921	16,645	57%	12,019	40%	981	3%
Hope Ranch*	3,653	1,626	1,452	2.5	53.1	$118,750	1,442	89%	184	11%	0	0%
City of Santa Barbara	88,410	37,132	33,220	2.7	36.8	$61,937	22,360	60%	14,618	39%	154	1%
Montecito Water District**	10,413	4,840	4,006	2.6	-	-	3,999	83%	813	17%	28	<1%
Montecito	*8,965*	*4,163*	*3,414*	*2.6*	*50.0*	*$110,375*	*3,626*	*88%*	*520*	*12%*	*17*	*<1%*
Summerland	*1,448*	*677*	*592*	*2.4*	*49.2*	*$63,654*	*373*	*55%*	*293*	*43%*	*11*	*2%*
Carpinteria Valley Water District	13,040	5,472	5,031	2.6	39.0	$63,834	2,602	48%	2,015	37%	855	15%

*Hope Ranch is the primary residential community served by La Cumbre Mutual Water Co.
**Montecito Water District serves both Montecito and Summerland.

Goleta Water District

The Goleta Water District was established in 1944 and makes up 29,000 acres along the western-most region of the South Coast.[1] This district encompasses the City of Goleta and extends westward as far as El Capitan Ranch and eastward to Santa Barbara City limits (Figure 1). Goleta Water District currently serves 86,946 people.[2] Agricultural and residential customers make up the largest demand sectors within the District. One of the District's single largest customers is the University of California, Santa Barbara (UCSB). This is a unique and significant water user for the region, bringing in a population of over 20,000 students and faculty utilizing university housing; multi-purpose buildings, including laboratories, classrooms, and offices; and extensive landscaped areas, 90% of which are irrigated by recycled non-potable water from Goleta Sanitary District.[3]

One challenge the District currently faces is satisfying water demand from development projects that were approved prior to the adoption of its SAFE Ordinance, which limits new annual service connections.[4] The District is contractually required to serve these projects, even under conditions of depleted water supplies.

Goleta Water District is governed by a Board of Directors consisting of five elected members with four-year terms. The Board is primarily responsible for representing Goleta at various community meetings, setting water rates, and hiring the General Manager of the District. The General Manager, along with the Assistant General Manager, oversee the offices and their respective managers who carry out the primary functions of the District: Administration, Operations, Engineering, and Water Supply and Conservation.[5]

La Cumbre Mutual Water Company

There is a 2,000-acre section within the eastern portion of the Goleta Water District boundaries that is served by La Cumbre Mutual Water Company. La Cumbre delivers water to 4,900 people in the Hope Ranch and Hope Ranch Annex communities. Its customers are predominantly low-density residences, with several golf courses and agricultural connections making up the rest of its customer base.[6] Hope Ranch operates on a septic system, while wastewater from Hope Ranch Annex is sent to Goleta Sanitary District.

City of Santa Barbara

The City of Santa Barbara is the only city on the South Coast that has its own water resources division responsible for supplying water and wastewater treatment services to its customers. It serves a population of 93,091 people across 12,460 acres, including several unincorporated areas such as Mission Canyon and Baker Pass.[7,8] The City's predominant customer classes are residential, industrial, and commercial. Santa Barbara has a small agricultural sector. It also serves a community college of 33,704 students, although not all of these students live within district boundaries. Santa Barbara is also a popular tourist destination, bringing in 6.1 million visitors annually, with many hotels and restaurants.[9,10] Wastewater is sent to El Estero Wastewater Treatment Plant, which is owned and operated by the City.

Daily operations are carried out by the Public Works Department with management decisions made by City Council, under recommendations by the Water Commission. The Water Commission is an advisory board made up of five members who are appointed by City Council to four-year terms with the duty to advise on all issues related to water supply management, including but not limited to infrastructure projects, rate changes, and supply acquisitions.[11]

Montecito Water District

Montecito Water District was incorporated in 1921, later expanding to include the nearby unincorporated community of Summerland, and currently serves 13,500 residents.[12] Of the 9,888 acres serviced by the District, approximately 6,883 acres are developed for residential or commercial use and 849 acres are zoned for agricultural use. Montecito is predominantly made up of low-density residential customers, minimal agriculture, and a liberal arts college, Westmont, hosting 1,180 on-campus students.[13]

Montecito is governed by a five-member board of directors, elected by voters for four-year terms. Daily operations are overseen by the General Manager.

Carpinteria Valley Water District

The easternmost district along the South Coast is the Carpinteria Valley Water District. The District was established in 1941 and covers 11,300 acres, largely encompassing the City of Carpinteria from the boundary of the Montecito Water District delineation on the west end to the Santa Barbara/Ventura County boundaries to the east.[14] The District also extends into a portion of the Los Padres National Forest to the north. It currently serves 14,616 people, and has the largest agricultural customer class on the South Coast.

Carpinteria is governed by a five-member Board of Directors whose members are elected to four-year terms. Daily operations and the 20-person staff are overseen by the District's General Manager.[15]

Water Resources

Along the South Coast, a variety of water supply sources exist. This report focuses both on existing water sources (in use within at least one of the water districts) and on selected potential future water sources. Existing supply sources are: Lake Cachuma, other local surface water (largely, Jameson Lake and Gibraltar Reservoir, along with their respective tributary creeks and tunnels), desalination, groundwater, recycled wastewater (non-potable), the State Water Project, and demand-side reduction strategies for efficiency and conservation. Potential future water sources are sources and production methods that could be implemented systematically on the South Coast. These sources include potable reuse, greywater, rainwater cisterns, and stormwater capture.

Lake Cachuma

Lake Cachuma is the area's largest local surface reservoir. It lies on the Santa Ynez River within the Santa Ynez Mountains. Water is delivered to the South Coast via the Tecolote Tunnel and South Coast Conduit. The Cachuma Project (including Bradbury Dam, Lake Cachuma, the Tecolote Tunnel, and the South Coast Conduit) was constructed by the United States Bureau of Reclamation (USBR). All components of the project were completed by 1956.[16] In the same year, a Joint Powers Authority (JPA), the Cachuma Operation and Maintenance Board (COMB), was created to manage much of the Cachuma Project. COMB is responsible for delivering water from Cachuma to the South Coast and for all operation and maintenance for Cachuma Project facilities, with the exception of Bradbury Dam, which is operated by the U.S. Bureau of Reclamation.[17] Goleta, Santa Barbara, Montecito, and Carpinteria are all Cachuma Member Units. The only member unit outside the South Coast is Santa Ynez River Water Conservation District – Improvement District No. 1 (ID #1).

Lake Cachuma has an operational yield of 25,714 AFY, with a total capacity of about 195,000 AF.[18] (Operational yield is the maximum volume of water from a reservoir that can be delivered to customers before exhausting the reservoir to the point where it could not meet a reduced water demand during conditions matching the most severe historical drought.) Since its construction, Lake Cachuma has lost about 10,000 AF of storage capacity to siltation.

Other Surface Water

"Other surface water" in this study refers to the smaller surface water reservoirs that provide water to Santa Barbara and Montecito. Goleta, La Cumbre, and Carpinteria do not have access to local surface sources other than Cachuma.

Santa Barbara receives water from Gibraltar Reservoir, Devil's Canyon Creek, and Mission Tunnel. Santa Barbara completed construction on Mission Tunnel in 1912 and Gibraltar Dam in 1920.[19] Since Gibraltar Dam was constructed, sedimentation has reduced its storage capacity by approximately 65%.[20] Santa Barbara also operates a small diversion structure on Devil's Canyon Creek.[21] Water from Gibraltar Reservoir and Devil's Canyon Creek is diverted into Mission Tunnel, which also receives groundwater inflow. In this report, these aggregated surface supplies connected to Gibraltar Reservoir are often just referred to as "Gibraltar" supplies.

Montecito receives water from Jameson Lake and Doulton Tunnel. Jameson Lake was created by the construction of Juncal Dam in 1930. Construction of Doulton Tunnel, which penetrates the Santa Ynez Mountains, was completed in 1928. Doulton Tunnel receives groundwater inflow and diverted water from Jameson Lake.[22] In this report, these aggregated surface supplies connected to Jameson Lake are often just referred to as "Jameson" supplies.

Ocean Desalination

Ocean desalination refers to the removal of salts, dissolved solids, and biological and organic chemical compounds from seawater.[23] In the early 1990s, as a response to the drought, Santa Barbara spent $35 million to construct the Charles E. Meyer Desalination Facility. The plant was equipped and permitted with a production capacity of 7,500 AFY, with the potential for expansion up to a maximum hydraulic capacity of 10,000 AFY. The drought ended with torrential rainfall in the winter of 1991-1992, before construction of the facility was completed. The city ran the plant for four months between March and June 1992 to test its operations before placing it in long-term standby mode.[24]

After the Santa Barbara City Council declared a Stage I Drought in 2014, Santa Barbara initiated preliminary designs to reactivate the Charles E. Meyer Desalination Facility. IDE Technologies, Inc. won the design-build-operate construction bid and has since begun construction. The facility is scheduled to come online at a capacity of 3,125 AFY in October 2016.[25] Santa Barbara is also exploring the possibility of expanding the plant capacity to 7,500 AFY if drought conditions persist.[26]

Groundwater

There are five primary groundwater basins offering usable groundwater storage for the South Coast: Goleta, Foothill, Santa Barbara (Unit 1), Montecito, and Carpinteria. The basins (except Foothill) are depicted in Figure 2.

The basins’ boundaries are defined by faults, impermeable geologic formations, inferred lithologic barriers, and/or administrative boundaries. The storage capacity, safe yield, water quality, and pumping demand vary between the basins and are discussed below.

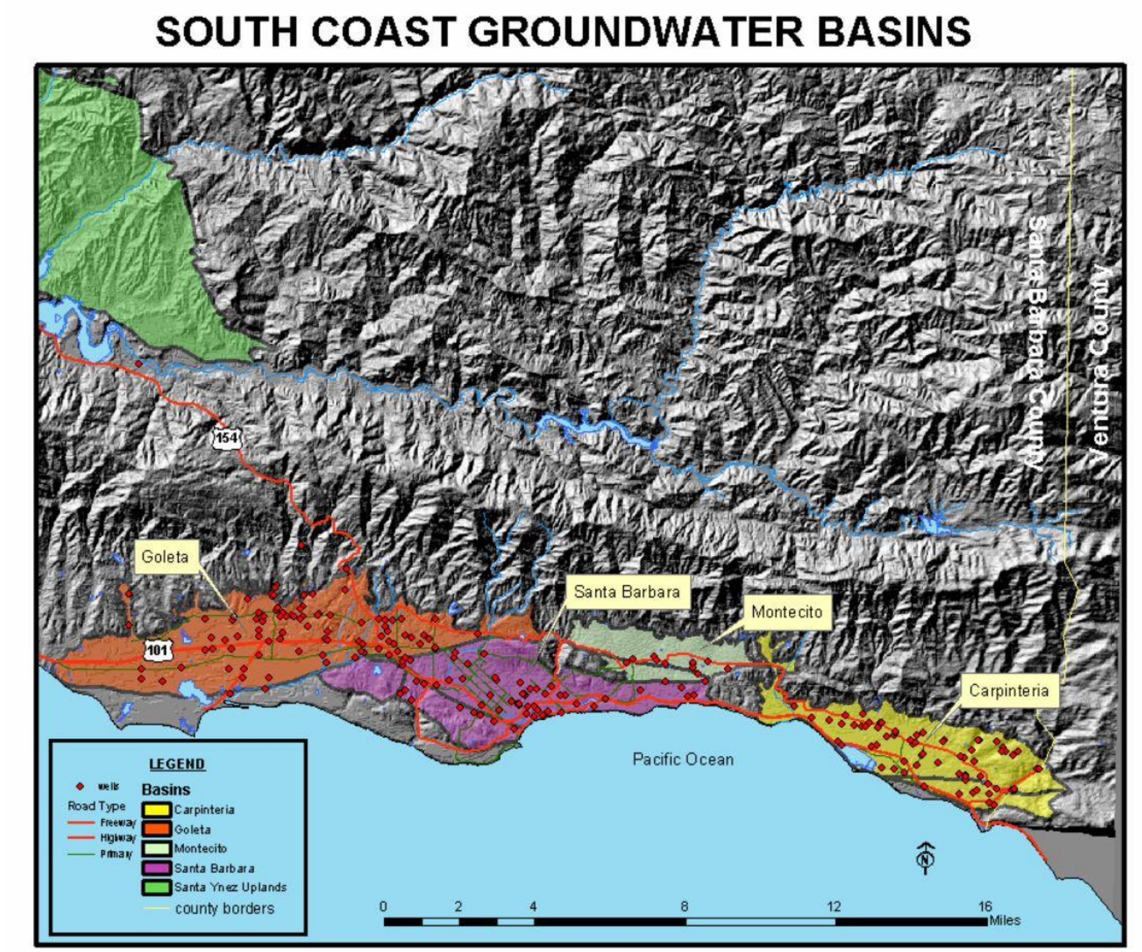

Figure 2. South Coast groundwater basins. Source: Santa Barbara County[27]

Goleta Groundwater Basin

The Goleta Groundwater Basin is approximately eight miles long and three miles wide.[28] It consists mostly of a central alluvial plain and is bounded by tertiary-age consolidated rocks.[29] To the north, the basin is bounded by the Santa Ynez Mountains while tertiary-age bedrock forms the boundaries on the east and the west. Historically, the basin has been protected from seawater intrusion by uplifted bedrock along the More Ranch fault. This fault also forms the southern boundary. The basin is divided into three sub-basins: West, Central, and North. Public supply wells, operated by Goleta Water District and La Cumbre, primarily pump from the Central and North sub-basins. The estimated safe yield of the Goleta Basin is 3,410 AFY, with around 40,000 AF of usable water in storage and a total storage capacity of 80,000 AF.[30]

Natural recharge of the basin comes from infiltration of precipitation over unconfined portions of the aquifer (primarily near the foothills), percolation from streambeds and irrigation waters, and subsurface inflow from adjacent consolidated rocks.[31] Confined portions of the basin are naturally recharged through subsurface horizontal flow. In addition to natural recharge, the basin is artificially recharged by injections from Goleta. In wet years, the District injects excess surface water supplies into the basin to store.

The Goleta Groundwater Basin is the only basin along the South Coast that has a "medium" priority level in the California Statewide Groundwater Elevation Monitoring (CASGEM) program – all other South Coast basins are designated as "very low" priority. The Goleta Basin is also the only adjudicated basin in the region. In 1989, Wright v. Goleta Water District ("Wright Judgment") adjudicated water rights to the Goleta Groundwater Basin. The court allocated superior groundwater pumping rights to overlying landowners, senior appropriative extraction rights to La Cumbre, and appropriative rights to Goleta Water District.[32] The original adjudication allocated 351 AFY to overlying landowners, 2,000 AFY to Goleta, and 1,000 AFY to La Cumbre. Since 1989, Goleta has acquired the rights to an additional 350 AFY through exchanges with overlying landowners. The Wright Judgment has allowed Goleta to store surplus water in the basin by deferring its annual production entitlement as well as injecting excess surface supplies.[33]

Foothill Groundwater Basin

The Foothill Groundwater Basin underlies 2,880 acres of land between the Santa Ynez Mountains and the Santa Barbara Groundwater Basin. Flow from the basin is bound on the west by the Goleta and Modoc Faults, on the south by the More Ranch and Mission Ridge Faults, and on the north and east by bedrock. Estimated usable water in storage for the basin is about 5,000 AF. Estimated total storage capacity of the basin is reported as 48,875 AF, with 15,215 AF of that capacity above sea level.[34,35] Pumping demand comes from the City of Santa Barbara, La Cumbre Mutual Water Co., and private well owners.

Santa Barbara Groundwater Basin

The Santa Barbara Groundwater Basin spans 6,160 acres between the Goleta and Montecito Groundwater Basins and is comprised of two storage units (designated as Storage Units 1 and 3) that are divided by the northwest-trending Mesa Fault. The Mission Ridge Fault defines the basin's northern boundary and impedes flow between the Foothill and Santa Barbara basins. The Montecito Fault provides an approximate boundary to the northeastern side of the basin. Safe yield of the Santa Barbara Basin is estimated to be 1,400 AFY, with 10,000 AF of total usable water in storage.[36] The total storage capacity is 108,570 AF, with 17,850 AF above sea level.[37]

Storage Unit 3 has a safe yield of 100 AF; however, the water quality of this unit is poor and is, therefore, not typically utilized. Estimated total storage capacity of Unit 3 is 26,458 AF, with 6,858 AF above sea level.[38]

Montecito Groundwater Basin

The Montecito Groundwater Basin encompasses 4,288 acres underlying the area served by the Montecito Water District. The northern boundary of the basin is defined by the Santa Ynez Mountains and the Arroyo Parida Fault. The eastern boundary is delineated by consolidated rocks and the southeast is bound by the Fernald Fault. The southern boundary is bound by the offshore Rincon Creek Fault and the Pacific Ocean. There is an administrative boundary that divides the Montecito Basin from the Santa Barbara Basin to the west. Safe yield is estimated to be 1,650 AFY, including yield from the Toro Canyon sub-basin to the east. There is a reported 16,100 AF usable water in storage and 96,850 AF of storage capacity, with 67,850 AF of that capacity lying above sea level.[39,40]

Carpinteria Groundwater Basin

The Carpinteria Groundwater Basin underlies 8,120 acres of the Carpinteria Valley. It contains two storage units separated by the Rincon Creek Fault. Annually, the basin receives 3,164 AF of inflow through natural subsurface flow, precipitation infiltration, streambed percolation, and irrigation percolation, while subsurface outflow is essentially zero.[41] The safe yield for the basin is between 3,600 and 4,200 AFY. The volume of usable water in storage is estimated to be around 16,000 AF, with a total storage capacity of 140,000 AF.

Carpinteria Valley Water District has used aerial imagery to estimate private well pumping from the basin to be over 70% of total annual withdrawals on average.[42]

Recycled Water

Recycled water (also known as reclaimed water) is the result of wastewater being treated to a usable level beyond the required discharge standards of the National Pollutant Discharge Elimination System (NPDES). Currently, recycled water on the South Coast is only used for non-potable needs, such as outdoor irrigation. An extra level of treatment, referred to as tertiary treatment, allows this highly-treated wastewater to return to consumers through an independent piping network for non-potable use.[43]

Recycled water is most commonly used for irrigating agricultural land, landscapes, and golf courses, as well as toilet flushing or vehicle washing. Currently, only Goleta and Santa Barbara have recycled water distribution systems to transport reclaimed wastewater to consumers with large areas of irrigated land.[44,45] These distribution systems are colloquially referred to as "purple pipe" infrastructure, due to the color of the pipes intended for recycled water. Some districts, including Goleta, have launched programs in which recycled water is delivered by trucks to customers without service connections.[46]

State Water Project

The State Water Project distributes water throughout California. Water deliveries originate from many reservoirs and rivers north of Sacramento and the Sacramento-San Joaquin Bay-Delta. The project extends down as far south as San Diego. The South Coast bought rights to SWP deliveries when the Project first began in the 1960s; however, the South Coast connection was not built until the public voted in 1991 to access these entitlements.[47] Full delivery was received by 1997 after the construction of a pipeline extension to reach Lake Cachuma.[48] Surplus State Water for all South Coast members is stored in the San Luis Reservoir in Merced County.[49] All five water districts receive State Water. Deliveries are facilitated through a JPA, the Central Coast Water Authority (CCWA). CCWA contracts with DWR on behalf of Santa Barbara County to deliver State Water to the South Coast and other areas in the region.[50]

Demand Reduction

While the terms "conservation" and "efficiency" are often used interchangeably when discussing water demand reduction, it is important to make a distinction between the two for the purposes of this report. Efficiency includes all actions taken or programs implemented to reduce demand through water-saving technologies. These include, but are not limited to, plumbing retrofits, high-efficiency appliances, and smart landscape retrofits. However, adoption of efficient technology can vary widely depending on consumer characteristics.

All water purveyors along the South Coast participate in Santa Barbara County's Regional Water Efficiency Program, providing information and assistance to promote the efficient use of urban and agricultural water throughout the County since 1990.[51] The program "coordinates cooperative water conservation efforts among purveyors, co-funds projects and programs, acts as a clearinghouse for information on water efficiency, manages specific projects and programs, and monitors local, state and national legislation related to efficient water use."[52] Goleta, Santa Barbara, Montecito, and Carpinteria are also members of the California Urban Water Conservation Council, which seeks to maximize urban water conservation and efficiency throughout California by providing tools, research and training, and collaborative approaches through best management practices.[53]

In addition to resources provided by the County and external organizations, many of the South Coast water purveyors maintain in-house efficiency programs. The City of Santa Barbara, for example, operates an extensive portfolio of long-term efficiency programs focused towards indoor and outdoor residential efficiency as well as commercial and industrial efficiency. Programs include water check-ups, which evaluate indoor and outdoor water use for both residential and commercial customers to identify leaks and provide information about other applicable rebate programs.[54] Goleta and Carpinteria, in addition to Santa Barbara, participate in the Smart Landscape Rebate Programs, offering partial reimbursement for the cost of pre-approved irrigation equipment, water-wise plants, and other efficient outdoor devices.[55,56]

Along with efficiency measures, conservation is a significant component of demand reduction. Conservation includes any behavioral changes at the individual account level that reduce water consumption. This reduction may be due to either consumer awareness or mandated reductions and can result in long- or short-term savings. Conservation measures are often managed alongside efficiency programs and incorporated as an additional demand management strategy during times of water shortage.

Water conservation has become a way of life for California water providers. The Water Conservation Bill of 2009 (SBX7-7) requires a statewide 20% reduction in urban per capita water use by 2020, with compliance required for state water grants and loan eligibility.[57] A benchmark reduction of a cumulative 10% statewide was set for December 31, 2015.[58] This legislation requires all urban water providers to include baseline water use, reduction targets, and compliance analyses in their Urban Water Management Plans (UWMPs).[59]

In addition to ongoing conservation programs, mandatory conservation measures during times of water scarcity have further increased conservation on the South Coast and throughout California. In 2014, Governor Jerry Brown declared a State of Emergency due to severe drought conditions, requiring a 25% reducing in water use statewide. [60,61] Since June 2015, the South Coast water districts (except La Cumbre) have achieved the following mandatory conservation standards: 12% for Goleta and Santa Barbara, 32% for Montecito, and 20% for Carpinteria.[62] These standards have largely been met by restricting outdoor water use. Another factor that may also influence water demand is water rates. For a discussion of local water rates, see Appendix A.

Potential Future Sources

Beyond current sources on the South Coast, there are alternative water sources which South Coast districts may consider including within their supply portfolios in the future. We considered the following supply options as potential future sources for the South Coast's overall water supply portfolio: potable reuse, greywater, rainwater cisterns, and stormwater capture.

Potable Reuse

Potable reuse refers to the recycling and treatment of wastewater to drinking water quality standards. Direct potable reuse (DPR) involves introducing this treated wastewater directly into a potable water distribution system. Indirect potable reuse (IPR) involves injecting the treated wastewater into an environmental buffer, such as a groundwater aquifer, before it is introduced into the potable system.

Under the current law in California, water districts are allowed to implement IPR. Orange County and San Diego have both implemented successful IPR programs.[63] DPR is not yet authorized, but regulatory obstacles may soon be lifted. Senate Bills 918 (2010) and 322 (2013) require the Department of Public Health to investigate the feasibility of developing uniform water recycling criteria for DPR by December 31, 2016.[64]

There are no concrete plans for IPR or DPR along the South Coast. However, water districts are watching closely for regulatory changes that impact their supply options. In a January 2016 public meeting, representatives from Santa Barbara stated that the district is investigating the feasibility of using the reverse osmosis infrastructure at the Charles E. Meyer Desalination Plant as a potable reuse facility instead.[65]

In a Long Term Supplemental Water Supply Alternatives Report commissioned by the County, RMC Water and Environment identified potential costs for both IPR and DPR projects along the South Coast.[66] Additionally, Santa Barbara is currently officially evaluating the feasibility of potable reuse.[67] As the regulatory environment changes, it is likely that IPR and DPR will be seriously considered as water supply options for the South Coast.

Greywater

Greywater is untreated wastewater from hand washing, laundry, and bathing.[68] Instead of being sent down the drain through the sewer to be treated by a wastewater treatment plant, greywater can be diverted to irrigate outdoor landscaping or even toilet flushing. The 2010 California Plumbing Code allows for residential clothes washer greywater systems (provided that no cutting of existing plumbing is needed) as long as a list of requirements is met (see Appendix B for greywater fact sheet).[69] Additionally, AB849, which was passed by the California legislature in 2011, stipulates that a local jurisdiction cannot be more restrictive on greywater use unless the jurisdiction holds public meetings and makes specific justifications for imposing such restrictions.[70] The County of Santa Barbara allows for laundry-to-landscape greywater use without a permit and in January of 2016 it began easing requirements for bathroom (shower, bath, and faucet) greywater system permits.[71]

Greywater does not include any wastewater from toilets, washing machines laundering soiled diapers, or dish water due to high contaminant loads. There are residential greywater systems used throughout the South Coast; however, it is unknown what proportion of households has these systems.

Stormwater and Rainwater Capture

Stormwater is rainwater that falls onto surfaces and does not evaporate or infiltrate the soil. Developed areas increase stormwater runoff by increasing impervious surfaces like roads, parking lots, buildings, and other built structures. There is the potential to capture and use this water to supplement water supplies while at the same time providing additional benefits, including reduction of flood risk, surface and coastal ocean water contamination, and wastewater treatment demands.

One way stormwater can be utilized is by modifying landscapes to allow for more infiltration into the soil, either through large-scale spreading basins or decentralized low-impact development. Stormwater can also be injected directly into groundwater aquifers through injection wells if the ground surface is not hydraulically connected to the producing aquifer. Due to health and safety regulations, direct injection would require additional treatment and residence time in the aquifer before the injected water can be pumped back out for potable use.

Another way of harvesting runoff is through rooftop capture, where rainwater falling on roof area is diverted into a rain barrel or cistern. The stored rainwater can then be used at a later time on-site for landscape irrigation, offsetting the demand for potable water.[72]

Methods

There is no central water data repository for the South Coast. Each district manages its own water data with relatively little involvement from the County. Data collection was, therefore, a significant component of this project. This data was compiled and organized into an Excel-based South Coast Regional Water Database, which became a major deliverable.

Data collected for this project includes information from water district annual reports and budgets, construction bids, feasibility studies, state and county reports, literature reviews, and personal communications with the districts. Using the South Coast Regional Water Database as a tool for water analysis, we were able to track South Coast-wide trends within the following areas: local water demand via metered sales; demand-side reduction programs by district; and production quantity, financial costs, and energy requirements by water source.

Additionally, existing literature, technical studies, and insights from local stakeholders and external experts were used to evaluate the reliability and feasibility of different supply options. Spatial data for the South Coast, including topographic features and water conveyance and storage systems, were gathered from individual water districts and the County. These shapefiles were used to produce GIS maps and conduct geographic analysis for potential future sources.

Historical production and financial data limitations varied by water source and by district. We analyzed only timeframes for which data was available from all participating districts. While some districts' annual data are available back to the early 1990s, data from other districts are limited to the early 2000s. For each comparison of different sources, the included years are noted.

Data Collection & Management

Data for our analyses were obtained from various documents containing public information published by each South Coast water district on their websites as well as Santa Barbara County. Such documents include water district, municipal, county, and wastewater district website pages; Urban Water Management Plans (UWMPs); Integrated Regional Water Management Plans (IRWMPs); budgets; Comprehensive Annual Financial Reports; construction bids; and council/board meeting packets. Where South Coast-specific data was not reported or available by other means, studies conducted by non-governmental organizations, such as WateReuse Research Foundation, California Urban Water Conservation Council, and National Resource Defense Council, were obtained as part of a literature review for California-specific information.

Several meetings were conducted separately with representatives from Goleta, La Cumbre, Santa Barbara, Montecito, and Carpinteria. In May 2015, meetings with each district included an introduction to this project and a discussion about the history and current position of each district in terms of supply and demand. Communication with designated data contacts from each district continued throughout summer and fall of 2015 to collect historical supply and demand as well as demographic data. A progress meeting was held with each district (except La Cumbre) in January 2016 to present our analyses and preliminary results in order to receive input and clarification.

We also communicated with representatives of Goleta Sanitary District and Santa Barbara's El Estero WWTP to obtain data on their respective wastewater influent and effluent, recycled water production technologies, and financial costs. An informational meeting was conducted with the Central Coast Water Authority to obtain data specifically related to the State Water Project. Information and data collected from these communications were compiled and continually updated in the South Coast Regional Database.

Water Demand

For our analysis of South Coast water demand, we used metered sales data by customer class from each of the water districts. Goleta provided monthly metered sales between January 2003 and December 2014 for the following customer classes: single family residential, multi-family residential, commercial, temporary, institutional, agricultural irrigation, agricultural (Goleta West Conduit), conveyance, landscape irrigation, fire department, and recycled distribution. La Cumbre provided monthly data between January 1999 and April 2015 for the following classes: residential & commercial, recreation, and agricultural irrigation. Santa Barbara provided monthly data between January 2003 and December 2014 for the following classes: single family residential, multi-family residential, commercial, industrial, irrigation, and recycled water. We retrieved water sales data for Montecito from a district board packet from October 2015.[73] This document provided total monthly sales between July 1996 and September 2015 without providing specific sales to each customer class, other than for the current month (October 2015). In order to estimate water usage by customer type, we applied the proportion of sales from that month as a weighted percentage for all the previous months, making the assumption that there was negligible redistribution of water demands across the customer classes. Carpinteria provided monthly metered sales from July 2010 to June 2015 and annual data back to 1983 for the following customer classes: residential, commercial, irrigation, public, and industrial.

It should be noted that there is an additional demand for water that is supplied through private wells, mostly for private outdoor irrigation uses. Some districts, like Carpinteria, have attempted to estimate private well pumping using aerial photography and crop needs. Goleta has an adjudicated groundwater basin, so any existing rights to that water have been allocated. Unmetered usage exists throughout the region, making a certain portion of demand impossible to calculate. For this study, metered sales provide a measure of the water demanded from the water districts and a way to gauge how much water the districts will need to produce from various water sources.

Methods by Water Source

Each water source on the South Coast comes with distinct capacity and infrastructure, and a different set of associated costs. Because of these differences, our methodologies are separated by source. Our methods have been standardized across sources to the greatest degree that the data allows, however, discussing each source individually allows us to preserve detail. This section includes methodologies for determining supply (historical, current, and/or future, as appropriate), financial costs, and energy costs.

Data on supply volume for each water source played a fundamental role in our analysis. For each water source along the South Coast, we compiled past and current annual supply amounts within the South Coast Regional Database, for as far back as data were available. We also included district-reported predicted supply amounts from each source for WY 2016. Data sources are discussed in detail in the subsections below. It is important to note that, within this report, the terms "supply" and "production" are used interchangeably. While other publications sometimes distinguish between the two, we found it overly complicated for our purposes.

Next, we analyzed the financial costs of each South Coast water source. Most of these costs were gleaned from line items in public budgets. For each district, we collected and analyzed annual financial costs of extracting and treating water from each water supply source. Data availability depended on not only the availability of annual budgets, but also the extent to which each district elucidated their line item costs.

Our financial cost analysis took a two-pronged approach. First, we calculated the *variable costs* of each water source across the South Coast. Variable costs are dependent on the total amount of water produced. These costs are reported on a marginal basis ($/AF).They include O&M supplies, chemical treatment, energy, and testing. Second, we calculated the *full system costs* of each water source, which include both the variable and fixed costs that districts pay for each water source, regardless of how much water is produced from that source. Fixed costs include O&M equipment, agency fees, and annual debt service and are paid annually regardless of water production for a given year. This analysis does not include personnel or labor costs, except where noted, as these are often more reflective of the size of the district than the cost of a particular water source.

It is also important to note that our full system analysis does not include sunk costs that have been paid off in full by the districts prior to the years included in our analysis, since these costs are not incurred by the districts now or moving forward. Drawing the temporal lines here can undoubtedly skew the comparisons between water sources. For example, if a district paid a large initial cost out-of-pocket for a system right before our years of consideration, that water source might appear less expensive than a source for which they took out a capital loan. Nonetheless, we believe this full system analysis still tells an important story, and reflects often-unacknowledged fixed costs. A true full system cost analysis would include all costs, both sunk and current. However, time constraints and a lack of data availability made it infeasible for this study.

Finally, we determined the total annual energy (kWh/AF) needed to extract or convey water from each district's source and to treat it at the respective district's water treatment plant. Energy data were determined from district and county budgets and construction bids. Where data were not available, we turned to local/California-specific studies. For more detail regarding the energy analysis for this report, see "Methods – Energy Demand."

For each potential future source, GIS surveys and models were used to measure the amount of water that would be available for a given year. Financial and energy costs were derived through literature reviews and consultations with field experts.

Existing Sources

The following water supply sources currently comprise the entire water supply portfolio of the South Coast: Lake Cachuma, other local surface waters (primarily Jameson Lake and Gibraltar Reservoir), ocean desalination, groundwater, recycled water, SWP deliveries and market exchanges, and conservation and efficiency measures.

Lake Cachuma

Data on historical Cachuma production were provided by the districts. All districts (except La Cumbre, which is not a Cachuma Project member) supplied monthly data for May 1987 through December 2014. Data availability in previous years varied by district, and years without information from all districts and all water sources were not included in our overall supply analysis. Exchange water between South Coast districts and ID #1 was considered to be part of State Water. (In some cases, South Coast districts exchange part of their SWP supply for ID #1's Cachuma allocation, which reduces costs and simplifies deliveries for all parties.) Even though the physical water comes from Lake Cachuma supply, the paper water is part of the State Water allocation rather than the Cachuma entitlement.

Predicted Cachuma allocations for 2016 are zero.[74]

For Cachuma water, districts make payments to COMB, Cachuma Conservation Release Board (CCRB), and USBR, although itemization of costs varies widely across districts. In addition, Carpinteria is not currently a CCRB member. For the financial portion of our analysis, cost figures were obtained from district budgets. Generally, the costs analyzed came from FYs 2011-15.

For Goleta, estimated actual costs for FYs 2011-15 were each obtained from the following years' budgets (e.g. costs for FY 2011 are found in the budget for FY

2012).[75,76,77,78,79] The items included in the costs were: CCRB, COMB: Water Entitlement, COMB: O&M, COMB: Cachuma Renewal Fund, COMB: Safety of Dam Act. These costs were broken down in the same manner across all budgets from FYs 2011-16.

Cost data provided for Santa Barbara was limited to two recent years. Adopted costs for FY 2012 came from the FY 2013-2014 two-year financial plan,[80] and adopted costs for FY 2014 came from the two-year financial plan for FY 2014 and 2015.[81] Only total "anticipated" costs were mentioned in the financial plans. Santa Barbara's 2010 UWMP contains assumed annual costs for Cachuma water,[82] but these were not used in our calculations because they provide only a general guideline.

Montecito costs also come from the district's budgets. Actual costs for FY 2011 come from the FY 2013 budget.[83] Actual costs for FY 2012 and FY 2013 come from the FY 2014 budget.[84] Adjusted budgeted costs for FY 2014 also come from the FY 2014 budget. Projected costs for FY 2015 and proposed costs for FY 2016 come from the FY 2015 budget.[85] For FYs 2011, 2012, 2015, and 2016, costs are itemized as COMB, CCRB, and USBR. For FYs 2012 and 2013, costs are broken down as USBR, COMB Operations, CCRB – Budget Assessments, and COMB – Special Assessments.

Carpinteria has not been a CCRB member since 2011, which is reflected in its budgets. Actual costs from FYs 2011-14 came from each of the following years' budgets.[86,87,88,89] Estimated actual costs for FY 2015 and budgeted costs for FY 2016 are both from the FY 2016 budget.[90] For FYs 2012-16, costs are itemized as: Renewal Fund – Cachuma Project, COMB Operating, COMB Fisheries (FY 2016 only), COMB Special Project, and COMB Safety of Dam Act. FY 2011 included the following costs, as well as CCRB Research, CCRB Legal, CCRB Administrative, and CCRB Projects.

Costs of treatment for Cachuma water were calculated based on the costs of treatment at Corona del Mar and Cater. Since water coming from Lake Cachuma is mixed with State Water, it is impossible to separate the two at the treatment stage. Therefore, the unit costs of State Water treatment at each plant are the same as the unit costs of treatment for Cachuma water at that plant.

Total costs per AF were calculated by year for FYs 2011-15 (when possible) within each district using the costs listed above and the year's Cachuma usage. Cachuma usage came from annual summary reports included in COMB board packets.[91,92,93,94]

Cachuma water reaches the districts through gravity flow, requiring only very minimal pumping. For the purposes of this report, we consider the energy costs of extraction to be zero, as have previous studies.[95,96] Additional energy costs come from treatment, either at Corona del Mar or Cater. Energy for treatment at Corona del Mar was calculated from the total amount of water treated in WY 2014 and the total energy usage of the plant during the same time period.[97] Energy for treatment at Cater was determined in a study by the Santa Barbara Public Works Department.[98] Although an emergency pumping project had to be implemented at Lake Cachuma in late 2015 as the lake level fell below the intake tower, we did not include this atypical energy need in our calculations.

Other Surface Water

For the purposes of our analysis, we grouped together Devil's Canyon and Mission Tunnel groundwater inflow into "Gibraltar," and Doulton Tunnel into "Jameson." Historical annual surface reservoir production data for Santa Barbara and Montecito came from Santa Barbara County Public Works.[99,100,101] In 2016, Santa Barbara anticipates zero AF production from Gibraltar.[102] Jameson 2016 prediction ranges were obtained from Montecito board packets.[103,104]

Financial costs for Gibraltar's supplies, services, and non-capital equipment were pulled from the City of Santa Barbara's adopted financial plans.[105,106] Financial costs for Jameson came from Montecito's annual budgets.[107,108]

Gibraltar water is treated at Cater and Jameson water is treated at Bella Vista. Cater treatment costs came from the City of Santa Barbara's adopted financial plans.[109,110] Bella Vista treatment costs came from Montecito's annual budgets.[111,112] The unit costs of treatment at each plant were applied to the volume of local surface water being treated in each year.

Like Cachuma, Gibraltar and Jameson water conveyance to districts is gravity-fed, requiring only very minimal pumping. For the purposes of this report, we consider the energy costs of extraction to be zero, as have previous studies.[113,114] Additional energy costs come from treatment, either at Cater or Bella Vista. Energy of treatment at Cater was determined in a study by the Santa Barbara Public Works Department.[115] Energy requirements were assumed to be similar for Bella Vista.

Desalination

Santa Barbara is planning to incorporate the water produced from the revitalized Charles E. Meyer Desalination Facility into its water supply portfolio in fall 2016.[116] This analysis assumes that the plant will produce to its full capacity each year it is online: 3,125 AFY. Santa Barbara is currently considering increasing the plant's capacity to 7,500 AFY, and the Request For Proposals for the desalination revitalization project requested construction bids for the 7,500 AFY production level as well.[117] Thus, this report includes desalination at 3,125 AFY and at 7,500 AFY as an expected production source and future potential source, respectively, in its supply analyses.

All construction and operating costs were taken from the IDE Technologies bid to the City of Santa Barbara for revitalizing the Santa Barbara desalination plant. The City announced capital costs of $55 million from the State Revolving Fund to finance the project at 3,125 AFY.[118] Thus, at a 1.6% interest rate for 20 years, we determined the annual debt service.[119] To determine total variable costs, we summed the annual chemical, energy, and O&M supplies costs as itemized in the bid. Total annual fixed costs include annual debt service from rehabilitating the plant (i.e. annuity of the State loan) plus the annual plant O&M fixed costs including equipment, preventative maintenance, repair, sewer and potable water fees, and operations performance insurance. To determine marginal costs of operating at predicted value for this next year, we assumed the plant would produce at the full scheduled capacity of 3,125 AFY. Finally, to calculate the debt service of increasing production to 7,500 AFY, we assumed an additional capital cost of $30 million, as projected by the City.[120]

Energy requirements of the desalination plant at both production capacities were itemized in the construction bid as well.[121]

Groundwater

Groundwater is used by all South Coast water districts to varying degrees. Monthly pumping data was from each of the districts with the following time frames: January 1983 to December 2014 for Goleta, January 1999 to July 2015 for La Cumbre, May 1987 to June 2015 for Santa Barbara, January 1985 to March 2015 for Montecito, and January 2004 to August 2015 for Carpinteria (with additional annual data going back to WY 1985).

Financial costs for groundwater production were retrieved from district budgets. Variable costs included water treatment, water testing, and energy. Fixed costs incorporated capital projects, debt services, and maintenance of wells. Available budgets were collected from FYs 2010-15 for Goleta.[122,123,124,125,126,127] Santa Barbara groundwater capital costs were available for FYs 2003-15.[128,129,130,131,132,133,134,135,136,137,138,139,140] Santa Barbara budgets did not provide variable costs for groundwater, however, the City website states that variable costs range from $120-610/AF.[141] While we considered this range in our analysis, it is not clear which expenses and years are included in the City's estimate. Montecito groundwater operating expenses were assessed using budgets from FYs 2010-14.[142,143,144,145] These budgets did not itemize capital costs and debt services as they relate to groundwater so they could not be included in full-system costs. Carpinteria's groundwater expenses were obtained from budgets between FYs 2010-15.[146,147,148,149,150,151] La Cumbre is a private non-profit entity, owned by the landowners, and does not provide public budget documents. Staff from La Cumbre did provide their own estimates for variable groundwater costs, which range from $60/AF from the Foothill Basin to $145/AF from the Central Goleta Basin. As with Santa Barbara's reported variable costs, these were considered in our analysis but it is unclear how they vary from year to year.

Energy requirements for groundwater pumping were retrieved from two previous studies on water supply energy intensity for the Goleta Water District and the City of Santa Barbara.[152,153] Due to the lack of additional energy intensity data from the other districts, we use the range of estimates provided in these two reports to approximate the energy demand of groundwater across the South Coast. It should be noted, however, that energy intensity for groundwater production varies depending on the depth of the water table, treatment methods, facility requirements, and other conveyance needs, which are unique for each basin.

Recycled Water

Only Santa Barbara and Goleta have recycled water programs (i.e. tertiary treatment of wastewater and purple piping to redistribute reclaimed water to customers). To find actual recycled water deliveries from FYs 2012-15, we referred to data received from personal communication with Goleta[154] and Santa Barbara[155] regarding historical deliveries. Historic deliveries data for recycled water deliveries was provided for the following timeframes: August 1994 to January 2014 for Goleta and May 1992 to May 2014 for Santa Barbara. For predicted deliveries in FY 2016, we referred to the Goleta Sanitary District's FY 2016 Budget[156] and Santa Barbara Public Works Recycled Water.[157] Goleta estimates FY 2016 recycled water production to be 1,325 AF,[158] while Santa Barbara's expected annual demand is 800 AF.[159]

To calculate Goleta's variable and full system costs, we used annual proposed budget costs found within the Goleta Sanitary District's "Reclamation Facilities" section of its budgets from FYs 2012-16.[160,161,162,163,164] Goleta Sanitary District's budgets were itemized for variable costs as follows: operating materials (chemicals, lab supplies), utilities (Southern California Edison), and repair and maintenance (materials). Goleta Sanitary District's budgets were itemized for fixed costs as follows: machinery and equipment, capital projects/outlay, and office supplies.

To calculate Santa Barbara's variable and full system costs, we used the "Recycled Water" sections of the Adopted Two-Year Financial Plans from FYs 2014-17; with actual costs for FYs 2012 and 2014, projected costs for FYs 2013 and 2015, adopted costs for FY 2016, and proposed costs for FY 2017.[165,166] Santa Barbara's budgets for variable costs were only itemized as supplies and materials, where fixed costs were not included since they only included personnel expenses. Due to Santa Barbara's replacement of its tertiary treatment system in 2014 and 2015, FY 2015 was excluded from cost calculations due to non-potable water from Valle Verde Well augmenting the recycled water supply[167] from June 14, 2014, to October 30, 2015.[168]

The Tertiary Filtration Replacement Project, which took the Santa Barbara recycled water program offline for over a year between 2014 and 2015, cost $12.34 million.[169] Santa Barbara Department of Public Works was able to pay for these capital costs out-of-pocket, eliminating the need for loans.[170] Although the Tertiary Filtration Replacement Project was a large capital expenditure, it was not reflected in budget line items. Because of the limitations presented by Santa Barbara's recycled water supply and financial data availability and discrepancies, this report excludes Santa Barbara's recycled water program from our variable and full system financial costs analysis.

Energy demand was estimated using a report from the WateReuse Foundation and include all energy required beyond the secondary treatment level (tertiary treatment requirements only), which is the minimum ocean discharge requirement for all South

Coast sanitary districts and wastewater treatment facilities. In this study, the reported treatment energy requirements include a range depending on the treatment technology and therefore our analysis includes the median energy requirements for extraction and treatment.[171]

State Water Project

Data on State Water Project deliveries was provided by the districts. All districts provided monthly data from October 2000 to December 2014. This data was used to examine the historical supply of State Water. Allocation percentages from 1996-2016 were obtained from DWR bulletins.[172] Although most districts did not separately note exchange water between South Coast districts and ID #1, this was considered to be part of State Water. Although the physical water comes from Lake Cachuma supply, the paper water is part of the State Water allocation rather than the Cachuma entitlement. Other occasional market water purchases may be included in State Water supply figures provided by the districts, however, these were not itemized in our data.

Overall future state water allocation predictions come from DWR's State Water Project Delivery Capability Report.[173] Allocation amounts for WY 2016 specifically are announced in notices from the SWP Analysis Office.[174] Additional information on future supply for 2016 can be found in some district budgets.[175]

For financial information, CCWA is a consistent source of costs across all districts. The entirety of State Water costs to the districts is paid to CCWA. Fixed and variable costs are itemized in CCWA budgets. Payments broken down by district were obtained for FYs 2011-16. These payments come from the budget in the same FY (e.g. projected costs for FY 2011 in the FY 2011 budget). Thus, the costs used are projected values. Items included in the cost analysis include CCWA costs and DWR costs. The CCWA costs for FYs 2014-16 are: CCWA fixed O&M costs, CCWA variable O&M costs, CCWA bond payments & O&M credits, and Warren Act and Trust Fund charges.[176,177,178] DWR costs itemized in the same years are: transportation capital, Coastal Branch extension, water system bond revenue surcharge, transportation minimum OMP&R, Delta water charge, and DWR variable costs. Between FYs 2011-13, the budget format was slightly different. We based our calculations on the following items: CCWA fixed, CCWA variable O&M, debt service, DWR fixed, DWR variable O&M, and total SWP charges.[179,180,181] In addition, CCWA provides the total variable costs per AF of both Table A and Exchange water. These figures are predicted in the budget for each fiscal year (cited above). For Table A amounts, these variable costs generally include "the CCWA power and chemical costs, adjustments for the variable Regional Water Treatment Plant Allocation (retreatment charge and credits), DWR variable costs and Warren Act and Trust Fund."[182] For Exchange water, the total variable costs include "the CCWA variable costs paid by ID#1, the Polonio Pass Water Treatment Plant fixed and capital amounts paid by ID#1 to the South Coast project participants, and the DWR variable costs paid by the South Coast exchange participants."[183]

Itemized actual costs were unavailable on a district-by-district basis. However, total actual payments were available by district. Total actual payments by district for 1999-2012 were obtained from CCWA Comprehensive Annual Financial Reports.[184,185] Total actual payments for FYs 2013-15 come from the Comprehensive Annual Financial Report for the same fiscal year (e.g. costs from FY 2013 are found in the Comprehensive Annual Financial Report for FY 2013).[186,187,188] For consistency with per-unit financial calculations, estimated actual delivery amounts from CCWA documents were used. These supply amounts are listed in the Comprehensive Annual Financial Report of the corresponding fiscal year, and were available for FYs 2008-15.[189]

Full-system unit costs of State Water were determined annually for each district. Supply amounts provided by CCWA were divided by the total cost paid by districts in the corresponding year. To break out variable costs, the aggregated variable costs listed in CCWA budgets (mentioned previously) were used.

Energy costs of State Water include extraction, conveyance, and treatment. Energy required to extract and transport water to Lake Cachuma comes from a 2014 study on the energy-water nexus at UCSB.[190] Additional energy costs come from treatment, either at Corona del Mar or Cater. Energy of treatment at Corona del Mar was calculated from the total amount of water treated in WY 2014 and the total energy usage of the plant during the same time period.[191] Energy of treatment at Cater was determined in a study by the Santa Barbara Public Works Department.[192] As with the Cachuma analysis, although an emergency pumping project had to be implemented at Lake Cachuma in late 2015 as the lake level fell below the intake tower, we did not include this atypical energy need in our calculations.

Conservation and Efficiency

Although a distinction was previously made between what constitutes "conservation" and "efficiency" for the purposes of this study, the South Coast districts often consider such programs collectively. Montecito and La Cumbre were excluded from this analysis because neither district reports supply or financial figures for their respective programs. This analysis includes all financial costs spent on conservation and efficiency programs by South Coast districts that are currently implemented and corresponding water savings (when available). For discussion of potential future efficiency programs, see "Methods – Potential Future Sources" and "Opportunities for Expansion – Conservation and Efficiency Opportunities".

Reported capital costs (services and supplies) for conservation and efficiency programs were obtained for Goleta from FYs 2011-16 budgets, with budgeted costs for all years;[193,194,195,196,197,198] and Carpinteria from FYs 2009-16 budgets,[199,200,201,202,203,204,205,206] with actual costs for FYs 2009-14, estimated costs from FY 2015, and combined budget costs (budget + drought impact) from FY 2016. These expenses are represented as range of the highest and lowest expense year from each district. In 2013, Goleta conducted a report evaluating cost, benefit-cost analysis, and potential water savings for 3 conservation program packages.[207] This study was excluded from this report's conservation and efficiency analysis since none of the program packages as a whole have been adopted by Goleta, as of March 2016 (See Appendix C for details regarding Goleta's technical analysis).[208]

For Santa Barbara, annual expenditures, annual estimated water savings, and marginal cost of saved water for all conservation and efficiency programs were obtained from the "City of Santa Barbara Water Conservation Technical Analysis,"[209] a spreadsheet including input and results for the "Long-term Conservation Program for 2014-2040."[210] Annual expenditures and marginal cost of saved water for Santa Barbara include personnel expenses, since expenses are not itemized per program. All costs and water savings ranges for Santa Barbara includes all activities in Program B with a utility benefit-cost ratio greater than 1.0.[211] Santa Barbara's model has been used as a proxy for the South Coast for the cost comparison analysis of this report since Goleta and Carpinteria do not report water savings associated with particular programs. Due to the limited extent of South-Coast-specific data, we have included case studies in our discussion as well, which give a broad overview of successful conservation and efficiency strategies (see "Opportunities for Expansion – Conservation and Efficiency Opportunities").

Since this analysis was performed from a utility perspective, no energy is required for extraction and treatment on the part of the districts. However, energy requirements and their resulting costs could be imposed on customers that participate in such programs.

Potable Water Treatment Plants

Water from most sources pass through one of the WTPs on the South Coast before distribution. In Goleta, all water from Lake Cachuma is treated at Corona del Mar.[212] In Montecito, Bella Vista and Doulton WTPs treat groundwater and surface water from Jameson, Doulton, and other surface bodies.[213] The largest WTP in the region is Cater in Santa Barbara. Cater primarily treats Cachuma water (and SWP deliveries by way of Cachuma) for La Cumbre, Santa Barbara, Montecito, and Carpinteria.[214] Additionally, Cater treats water for Santa Barbara from Gibraltar, Mission Tunnel, and groundwater.[215] All water treatment costs have been included as variable costs ($/AF) with their relevant sources. Sources cited which would not require WTP processing include recycled water, desalination (as those potable treatment costs are included in the plant construction bid), efficiency, conservation, and potential future sources. Groundwater in Goleta is treated at facilities near those wells.[216]

The annual costs associated with Cater were taken from Santa Barbara's 2014-16 budget reports.[217] Actual costs for FYs 2014-15 and projected costs for FY 2016 include O&M supplies and services, capital equipment, non-capital equipment, chemical cost per MG, and total water treated. The budget itemized salaries and benefits for employees as well, so we excluded those to maintain consistency across all sources. Variable costs were summed for each year: O&M supplies and services as well as chemical costs.

Fixed costs were also summed for each year: capital equipment and non-capital equipment. In addition to these fixed costs, districts using Cater are also making annual debt service payments for a State Revolving Fund Loan in 2011 for $20.3 million for 20 years at 2.5017% interest rate,[218] which are also included as fixed costs for Cater. We averaged the costs for the three years, which we used as the basis for comparison for variable, fixed, and full system costs.

To determine the amount of water from each source passing through Cater, we used Santa Barbara's 2013-14 Water Supply Management Report.[219] To calculate each source's marginal cost of treatment at Cater, we multiplied the percent of total water treated at Cater derived from each source within Santa Barbara, by the variable costs and total costs reflected in the budget. For the sources used by La Cumbre, Montecito, and Carpinteria, the amounts of water treated from SWP and Cachuma for those districts were found within COMB meeting board packets: all water entering Cachuma Reservoir for WY 2015, which includes SWP deliveries, and the withdrawals by water district.[220]

For Montecito, the costs of Bella Vista and Doulton WTPs were found in Montecito's FYs 2014-16 budgets.[221,222,223] Because the associated water treatment costs are not itemized other than "Treatment Operations", we assumed the "Treatment Operations" costs were all variable; no fixed costs were listed. We averaged the costs for the three years as the variable and full system costs. To find the amount of water from each source (groundwater, Jameson, Doulton, and other surface reservoirs), we referenced the Montecito groundwater and other local surface water data compiled in our South Coast Regional Database, which was averaged from 2014-16. We then multiplied the percentage of water entering the WTPs from each source by total variable and full system costs.

In Goleta, the costs of Corona del Mar were taken from budgets from the Goleta Water District for FYs 2013-15.[224,225,226] Costs were itemized in the budgets, allowing us to categorize variable and fixed costs. Variable costs for treatment at Corona del Mar include treatment (chemicals and processes), water testing, and utilities. Fixed costs include maintenance, equipment, and services and supplies. We averaged these costs over three years. Because SWP and Cachuma deliveries are the only sources treated at Corona del Mar, we simply tracked the average deliveries to Goleta during this time in COMB reports.[227] SWP deliveries are mixed with Cachuma water, so there are no differences in water quality or treatment required for each source by the time they reach Corona del Mar.

Potential Future Sources

We considered the following supply options as potential future sources for the South Coast's overall water supply portfolio: potable reuse, greywater, rainwater cisterns, stormwater capture, and efficiency measures. For these potential future sources, we consulted local studies and built models using local data parameters.

Potable Reuse

To calculate total potential water production via potable reuse (either direct or indirect), we used average effluent data from South Coast WWTPs from 2012–2014.[228,229,230,231,232,233,234,235,236,237,238,239,240,241,242,243] For this analysis, it is assumed that potable reuse production is only limited by the amount of effluent sent to each WWTP minus water lost through brine discharge produced in the advanced treatment process. We assumed that 15% of effluent would be lost as brine discharge, as was assumed in the RMC Water and Environment's Long Term Supplemental Water Supply Alternatives Report for Santa Barbara County.[244]

Full system costs for IPR and DPR for each district were obtained from the 2015 RMC Study.[245] In the South Coast full system cost analysis, the lower limit of the marginal cost range for potable reuse represents the lowest unit cost across the South Coast districts, while the upper limit represents the highest. RMC's anticipated implementation timeframe is 5-10 years. Variable costs were not itemized in their report, therefore we excluded potable reuse from our variable cost comparison.

For the purposes of the energy and greenhouse gas emissions calculations, potable reuse production volume was estimated to be 7,500 AFY - the expanded capacity of Santa Barbara's desalination facility.

Anticipated energy requirements for the production of potable reuse were obtained from a report co-written by WateReuse, American Water Works Association, Water Environment Federation, and National Water Research Institute.[246] Energy requirements for advanced treatment were added to the energy requirements for tertiary treatment (non-potable recycled water energy requirements), and therefore reflect the total energy required to treat wastewater beyond South Coast NPDES permit standards.

Greywater

Greywater production from washing machines and showers was estimated for South Coast single- and multi-family residences. For washing machines, we assumed that the average person washes 2.59 loads of laundry per week and the average washer uses 24.2 gallons of water per load. For showers, we assumed the average person takes 4.7 showers per week with the water running a total of 9.3 minutes per shower at an average flow rate of 1.7 gallons per minute. These assumptions were provided by Pacific Institute’s Water Efficiency Calculator (WECalc) data and assumptions (see Appendix B for additional detail).[247] To calculate total greywater production for the South Coast, we used population data by district retrieved from Santa Barbara County.[248] We considered 25%, 50%, and 75% participation scenarios for single-family and multi-family residences.

Residential outdoor irrigation was estimated for each district using metered sales data obtained from the districts, and we included the minimum monthly residential water sold between 2006 and 2014, assuming that any additional water sold to residential customers was used for outdoor irrigation. We then subtracted the minimum usage from the actual usage for each month.

Cost ranges for the installation of greywater systems were retrieved from Grey Water Action.[249] These are rough average costs, and may vary depending on the size and complexity of the system. We assumed little to no energy would be required for laundry-to-landscape systems and, therefore, did not factor in additional energy costs for greywater diversion to landscapes.

Rainwater Cisterns

Rainwater capture using residential cisterns was estimated using methods outlined in a study published by the Natural Resources Defense Council (NRDC) on rooftop rainwater capture.[250] We conducted a GIS survey of South Coast parcels to measure the average roof area of single-family households for each district. This analysis was restricted to single-family households due to physical constrains with greater variability in landscaping needs for other customer classes (such as commercial and multi-family).

System capture efficiency was set at 80%. In order to factor in system balances and storage limits, we used estimated outdoor water demand from metered sales data. If measurable precipitation had occurred within 48 hours, no irrigation would be required and, therefore, the system would not be utilized. If the system was at capacity when it rained, no additional water would be captured and this would not be included in the total accumulated water.

We considered 25%, 50%, 75% participation scenarios for potential rainwater capture systems. Daily precipitation and temperature data from 2006 to 2015 water years were retrieved from the California Irrigation Management Information System (CIMIS), Santa Barbara Station ID #107.[251]

Cost estimates were based on full-system rainwater cistern retail price searches.[252,253] The sampled products had capacities large enough to meet the average residential capacity constraint of 250 gallons per 500 square feet of roof area for each district. As with greywater, we assumed the water conveyed from capture to application would be gravity-fed and not require additional treatment, excluding the need for energy.

Urban Stormwater Runoff

To estimate average annual stormwater runoff for the South Coast, we used the Soil Conservation Service's curve number method.[254] GIS data from the National Land Cover Database (NLCD) and Natural Resources Conservation Service's Soil Survey Geographic database (SSURGO) allowed us to classify each of the districts' parcels by bare hydrologic soil class and percent imperviousness.[255,256] Precipitation data from CIMIS between WYs 2006-15 were used to estimate average annual urban runoff. We considered 10%, 25%, and 50% capture potentials for this runoff volume. (See Appendix D for detailed assumptions and equations.)

We also consulted with South Coast water districts to assess the costs required to inject treated stormwater into groundwater aquifers. Goleta provided their estimated cost per AF associated with the design and construction for either upgrades of existing structures or new injection wells in addition to the cost of treatment for injection and extraction from the basin (though this was not targeted for urban stormwater runoff but rather spilled Cachuma water).[257,258]

An alternative way to allow stormwater runoff to infiltrate into groundwater basins is through centralized spreading basins or low-impact development. High property costs along the South Coast may prohibit the feasibility of large spreading basins but could be explored in future studies or in other regions. The diversion of stormwater to existing agricultural fields may offer the opportunity of recruiting existing land uses for infiltration, however, pre-treatment and conveyance would be important factors to consider.

Low-impact development (LID) offers a decentralized option for increased stormwater infiltration. It is important to note that natural stormwater infiltration will only recharge groundwater supplies if the land-surface is hydraulically connected to the aquifer. According to hydrogeological studies and local experts, most of the producing aquifers used for public supplies are confined, with a consolidated layer of low hydraulic conductivity lying between the developed surface and the aquifer. Still, there are benefits to LID not directly connected to increased water supplies, including reduced flood risks, improved freshwater and marine ecosystem impacts from reduced urban runoff, and even lower development costs compared to conventional practices, in part due to lower stormwater management costs. While the economic benefits of LID vary widely between types of projects and are difficult to attribute to increased available water supplies (as with other sources examined in this study), we have provided tables in Appendix E of case studies comparing conventional development to LID costs provided by a 2007 study from the EPA.[259]

Efficiency Measures

To begin to estimate opportunities for increased efficiency on the South Coast, two types of efficiency programs were chosen to demonstrate the extent of their potential savings: washer rebates for high efficiency (HE) machines (for single- and multi-family units) and turfgrass replacement for single-family parcels. The scope of efficiency measures for this report is limited to these two programs due to the availability of local water savings data, and this limitation prompted a literature review of case studies to highlight additional expansion of efficiency opportunities within the region (See Additional Considerations section for conservation and efficiency program case studies).

An evaluation of the potential implementation or expansion of the described efficiency programs only includes estimates for water savings since financial needs can be variable between districts based on the details of the programs and district size. Similar to current conservation and efficiency programs, no energy is required from the district perspective, but implementation at the unit level could result in changes in energy demand for the consumer.

The washer rebates for HE machines program from the City of Santa Barbara's Long-term Conservation Program for 2014-2040[260,261] was used as a proxy for water savings for single- and multi-family customers, applying a weighted average of total participation and annual water savings at the end-life of the program. Further details regarding calculations can be found in Appendix C.

Lawn conversion estimates for single-family homes includes any removal of turfgrass and replacement with a landscape with a lower water demand, including artificial turf, climate appropriate landscapes, or permeable hardscapes. A GIS survey was conducted using aerial imagery to determine the average lawn size within each district from a random sample of single-family parcels. Survey results were then applied to a range of values of observed water savings following turf removal in California.[262] For detailed information about sampling technique and calculations, see Appendix C.

Water Leaks

We estimated annual South Coast water loss from leaks using a literature review of national, regional, and California-specific studies on potable water supply leaks. Household leak estimates were calculated using the range reported by EPA's WaterSense® partnership program, which states that 10 percent of U.S. homes have leaks that lose at least 90 gallons or more per day and the average household loses an estimated 10,000 gallons of water from leaks each year.[263] County household data was used to calculate the expected water loss from leaks for each district based on this estimate.

We then estimated water loss from leaking of district pipelines. United States public water systems have an estimated 3.3-12.7% of unaccounted-for water loss.[264] Actual leakage from a pipeline is dependent on many variables, including its age, material, length, hydraulic stress, geophysical stress, soil corrosivity, and the corrosivity of the water being sent through the pipeline. The California Department of Water Resources provides results from a detailed leak detection survey of 47 California water utilities and found that the average water loss from leaks accounts for 10% of the total water supplied by the utilities.[265] To incorporate leakage dependent on length and age of the pipeline, we used the average reported leak rates of 150-300 liters/hour/kilometer for aging infrastructure and 100-200 liters/hour/kilometer for newer mains, provided by Twort et al. (1994).[266] We then used ten-year average annual production to estimate leakage based on water supplies and total kilometers of distributional pipeline for each district to calculate leakage based on pipeline length.

Energy Demand

The energy demand analysis of this report includes all energy required to extract water from its source (e.g. convey State water from the Bay-Delta to Cachuma; collect wastewater and convey to recycled water treatment facility) and treat water to potable standards up to the point of but not including local distribution. An assumption was made that energy requirements for distribution would be similar across all sources since they are often mixed after treatment. Most existing sources, with the exception of non-potable recycled (tertiary) water, are also feed into the same regional, gravity-fed distribution system. New water sources located on the coast, such as desalination or potable reuse, may require more energy to pump inland. These energy requirements and costs are currently unknown.

For details regarding energy requirements by supply source, see "Methods by Water Source."

Environmental Impacts

This analysis also incorporates the environmental costs associated with water production. Environmental impacts include greenhouse gas emissions and ecological effects.

Greenhouse Gas Emissions

To calculate the annual greenhouse gas emissions associated with each water source along the South Coast, we used the equation below:

Annual Water Production Volume (AF) x Energy Intensity (kWh/AF) x Emission Factor (metric tons CO_2/kWh) = Annual Greenhouse Gas Emissions (metric tons CO_2)

Annual water production volumes for Cachuma, other local surface, recycled (tertiary), groundwater, and State Water Project were calculated by averaging annual total production from 2004 to 2014. Greywater, residential rain cisterns, and conservation/efficiency annual production were calculated using potential yield models described in their respective methods sections. For each potential future source, a participation rate of 25% was assumed. Other participation rates and their respective yields are examined in earlier sections of this report. Desalination annual production was delineated into the two production capacities outlined in the IDE Technologies construction bid: 3,125 AFY and 7,500 AFY.[267] Similarly, for the purposes of greenhouse gas emission calculations, potable reuse annual production was also estimated at 7,500 AFY. Considering that Santa Barbara is currently investigating the feasibility of using the reverse osmosis infrastructure at the desalination facility as a potable reuse facility instead, the production capacity for potable reuse was taken from the desalination facility's expanded capacity (See Methods by Water Source section for energy intensity data sources).

We used a greenhouse gas emission factor of 3.7×10^{-4} metric tons CO_2/kWh. Southern California Edison, the energy provider for the region, calculated this factor as the average greenhouse gas emissions per unit of electricity for their 2013 energy portfolio.[268]

We also calculated the potential cost of carbon offsets for the water supply. To do so, we averaged daily 2015 prices of California carbon allowance futures, as reported over time from ICE End of Day Reports and compiled by the California Carbon Dashboard.[269] This calculation yielded an average price of $12.77 per metric ton of CO_2 equivalent in a California carbon offset market.

Ecosystem Impacts

To examine the ecosystem impacts of South Coast water sources, we conducted a literature review and communicated with local stakeholders. Early in our investigation, we found that we could classify two main ecosystem types impacted by South Coast water sources: freshwater and marine ecosystems.

Results

After compiling and synthesizing all available data, we first examined historical supply and demand trends for existing sources and water needs across the districts. We then calculated potential water production from alternative sources, such as greywater and efficiency programs. Finally, we determined financial costs, energy requirements, and other environmental impacts for each existing and potential future sources in the South Coast's water supply portfolio.

Historical Supply Trends

South Coast districts' average water production by source, between 2004 and 2014, is illustrated in Figure 3.

Figure 3 shows the geographic distribution of supply sources across the districts. For example, recycled water production (purple) is limited to Goleta and Santa Barbara; while La Cumbre relies solely on groundwater and SWP for its entire supply. Cachuma is a significant component of all districts' annual portfolios, with the exception of La Cumbre.

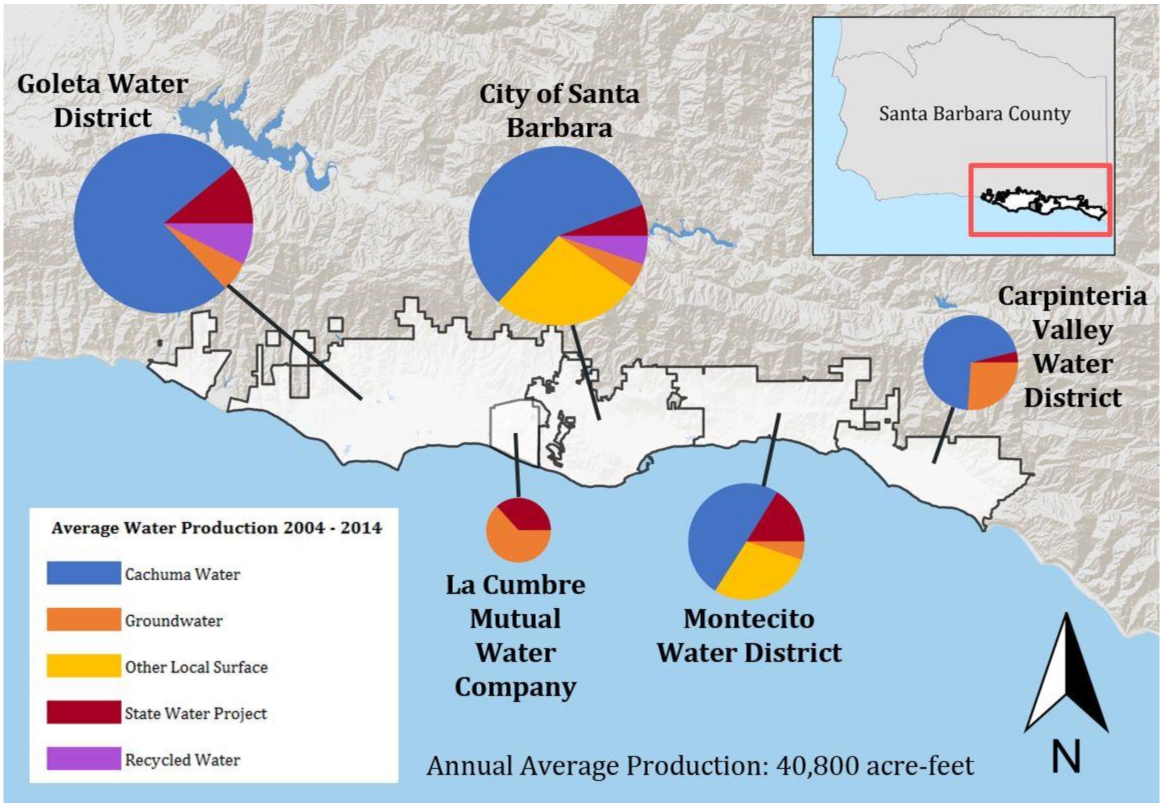

Figure 3. Map of South Coast districts' historical average water production by source (2004 - 2014). Pie charts are proportionately sized for each district's share of total regional production. Total South Coast annual average production across this time period was 40,800 AFY. "Recycled water" refers to centralized non-potable tertiary treatment.

The temporal distribution of water supply production across the South Coast is shown in Figure 4.

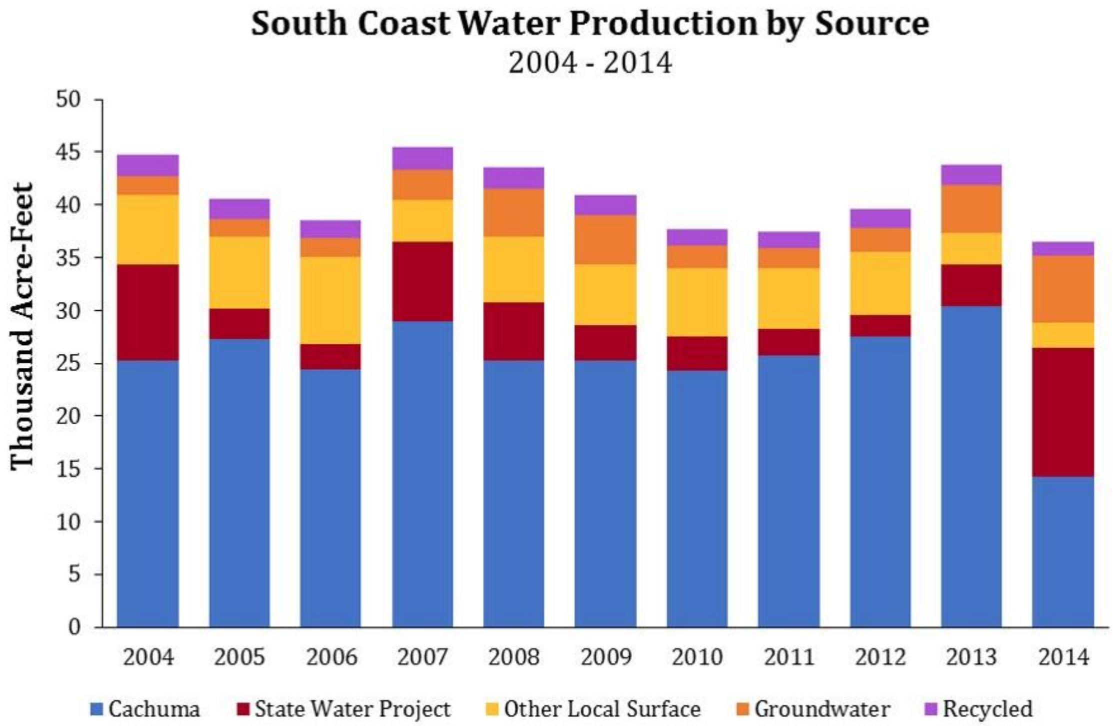

Figure 4. South Coast water production by source (WY 2004-14). State Water Project (red) includes Table A deliveries, carryover, and market exchanges. See Appendix G for an estimated breakdown of State Water delivery types. "Recycled water" refers to centralized non-potable tertiary treatment.

Figure 4 illustrates changes in production by year since 2004. Cachuma and other local surface supplies dwindled in 2014, presumably in response to the drought. As a result, imported water and groundwater production expanded to compensate for the shortfall. Each district's individual historical water production (2004-14) can be found in Appendix H.

Figure 5 aggregates water production by source across this time period, and displays each source's average proportion of total supply production.

From 2004 to 2014, the South Coast relied on Cachuma for approximately 60% of its total supply production. Other local surface supplies accounted for another 14% of total production. This means that, on average, the South Coast relies on surface sources for approximately 76% of its annual water supply. In a region prone to drought, this creates considerable climatic vulnerability.

Recycled (non-potable) water accounted for less than 5% of total supply, which may be attributed to limited purple pipe infrastructure.

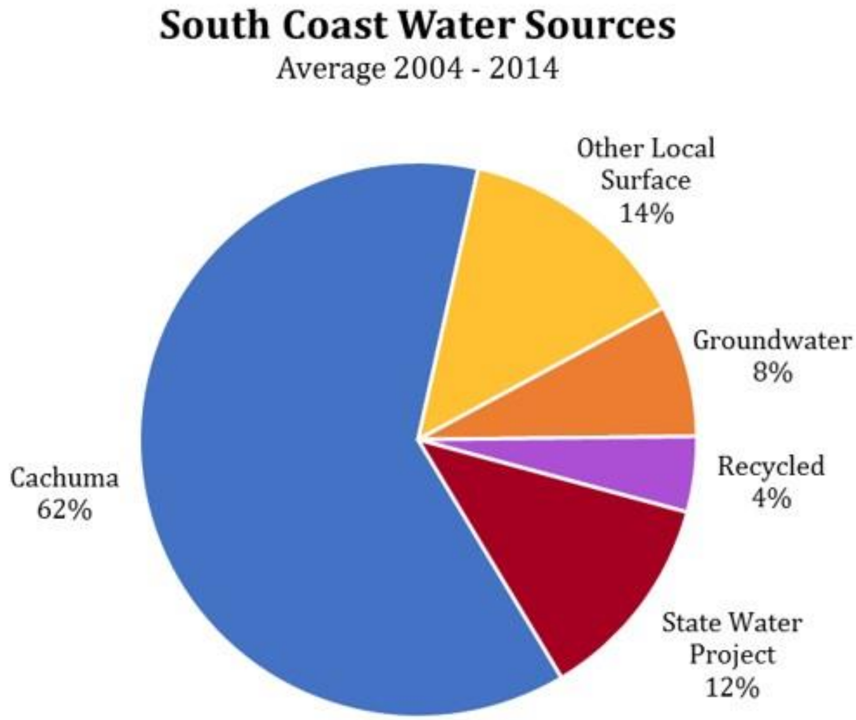

Figure 5. South Coast water sources, as percentages of total average annual production (2004 - 2014). "Recycled water" refers to centralized non-potable tertiary treatment.

Historical Demand

Historical water demand across the South Coast, calculated using metered sales data, is illustrated in Figure 6. Historical demand by district can be found in Appendix H.

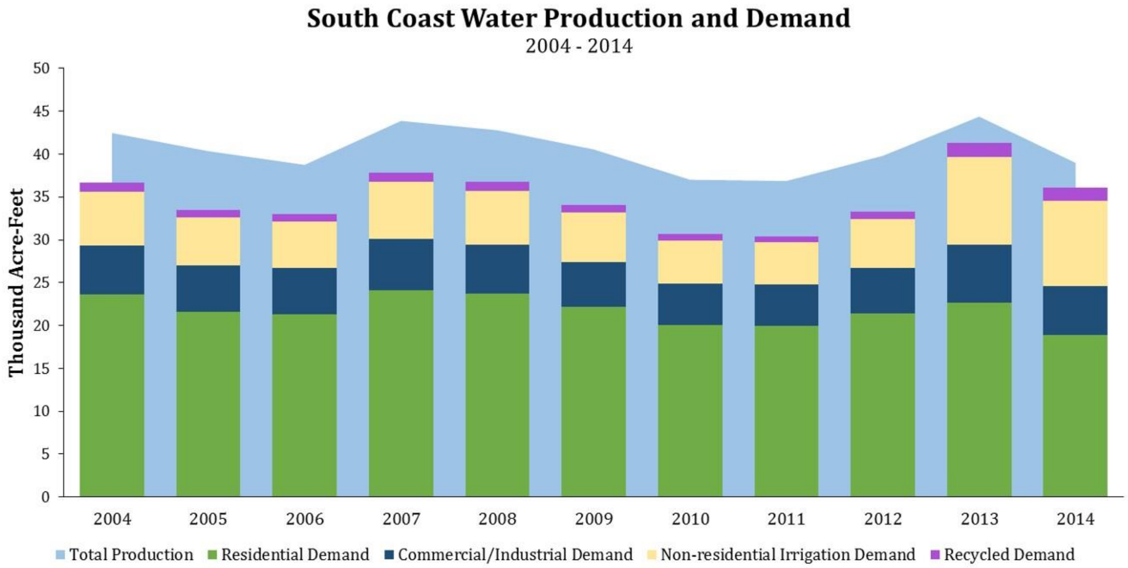

Figure 6. South Coast water production and demand (2004 – 2014). Historical demand by customer class displayed in stacked column graph. Total water production volume displayed in background area graph in light blue.

Aggregated water demand on the South Coast ranges from about 31,000 to 41,000 AFY (Figure 6). Production consistently exceeds demand across the decade. This may be explained by the districts' unmetered internal water usage, as well as their desire for a small buffer of water supply for emergencies and other unanticipated demands.

An increase in demand from non-residential irrigation customers, a rough doubling, was observed between 2012 and 2013. This can be at least partially explained by an increase in price of avocados, which in turn incentivized local farmers to intensify their production of avocados.[270]

The sector with the largest demand by volume on the South Coast is residential, which includes both single- and multi-family consumers, ranging between about 20,000 and 24,000 AFY or over half of overall annual demand. The efficiency analysis portion of this report is focused on residential programs due to the relatively large water needs for residential customers.

Residential Efficiency

Water savings results from both the washer rebates for HE machines and lawn conversions can be found in Table 2 and Table 3, respectively.

Across South Coast districts, washer rebates would account for about 1,250 AFY in combined water savings for single- and multi-family households (Table 2). Potential water savings from lawn conversions are highly variable given climate, watering practices at the account level, and participation in the program. The South Coast as a whole could save between about 350 and 2,400 AFY by converting turf lawns to artificial turf, climate appropriate landscape, or permeable hardscape (Table 3).

Table 2. Calculated potential annual water savings for South Coast-wide washer rebate for high-efficiency machines program for single- and multi-family homes. Results are for the end-life of the program, based on the City of Santa Barbara's "Long-term Conservation Program for 2014-2040" model (12 years).[271]

	End of Program Annual Water Savings (AFY)	
District	**Single-Family**	**Muti-family**
Goleta	245	70
La Cumbre	24	3
Santa Barbara	311	273
Montecito	77	3
Carpinteria	228	14
South Coast Total	**886**	**363**

Table 3. Calculated average annual water savings for potential turfgrass replacement to a lower water demand landscape based on various observed savings from 9 California water agencies for 25%, 50%, and 75% program participation.

	Average Annual Water Savings (AFY, 25% participation)			
District	**Minimum**	**Maximum**	**Southern California**	**Mean**
Goleta	128	665	427	294
La Cumbre	26	134	86	59
Santa Barbara	89	464	298	205
Montecito	70	360	232	160
Carpinteria	35	180	116	80
South Coast Total	**348**	**1,803**	**1,159**	**798**

	Average Annual Water Savings (AFY, 50% participation)			
District	**Minimum**	**Maximum**	**Southern California**	**Mean**
Goleta	256	1,330	855	589
La Cumbre	52	268	172	119
Santa Barbara	179	927	596	411
Montecito	139	721	463	319
Carpinteria	69	360	231	159
South Coast Total	**695**	**3,606**	**2,318**	**1,597**

	Average Annual Water Savings (AFY, 75% participation)			
District	**Minimum**	**Maximum**	**Southern California**	**Mean**
Goleta	385	1,995	1,282	883
La Cumbre	78	402	259	178
Santa Barbara	268	1,391	894	616
Montecito	209	1,081	695	479
Carpinteria	104	540	347	239
South Coast Total	**1,043**	**5,408**	**3,477**	**2,395**

While Goleta, Santa Barbara, and Carpinteria all currently implement the County's Smart Landscape Rebate Program, greater incentive for lawn conversion in addition to irrigation equipment that increases efficiency of turf watering would result in larger overall water savings from the residential customer class.

While various participation scenarios were explored for lawn conversion programs, output from Santa Barbara's "Long-term Conservation Program for 2014-2040"[272] indicates about 30% participation of all single-family homes for the lifetime of the Smart Landscape program. Therefore, a lower participation for lawn conversions (about 25%) is a more likely scenario, at least for the given timeframe. Reported observed savings from water agencies in the CUWCC study[273] were not identified for a particular agency or region. Given South Coast climate, we estimate actual savings will range between the minimum and Southern California average.[274]

Cost estimates for these programs are not included for the potential washer rebates and lawn conversion programs since financial needs can vary greatly between districts based on the details of the programs and district size.

Conservation in Response to drought

Conservation during the current drought is commonly communicated in terms of per capita use (GCPD). Residential GCPD for the South Coast districts has been compiled for June 2014 to December 2015 (Figure 7). La Cumbre and Montecito both began the study period with use rates exceeding 200 GPCD, with rates falling substantially during winter 2014-15. Usage rates for both districts began to rise again after February 2015, then appeared to level off between 150-200 GPCD, although this does not constitute a statistically significant trend. Goleta, Santa Barbara, and Carpinteria began the study period with the lowest water use rates on the South Coast, and have achieved some conservation with the drought, although they have less room to conserve than the districts with higher use. Their use generally follows a trend common to Southern California, with usage decreasing in winter due to greater precipitation.

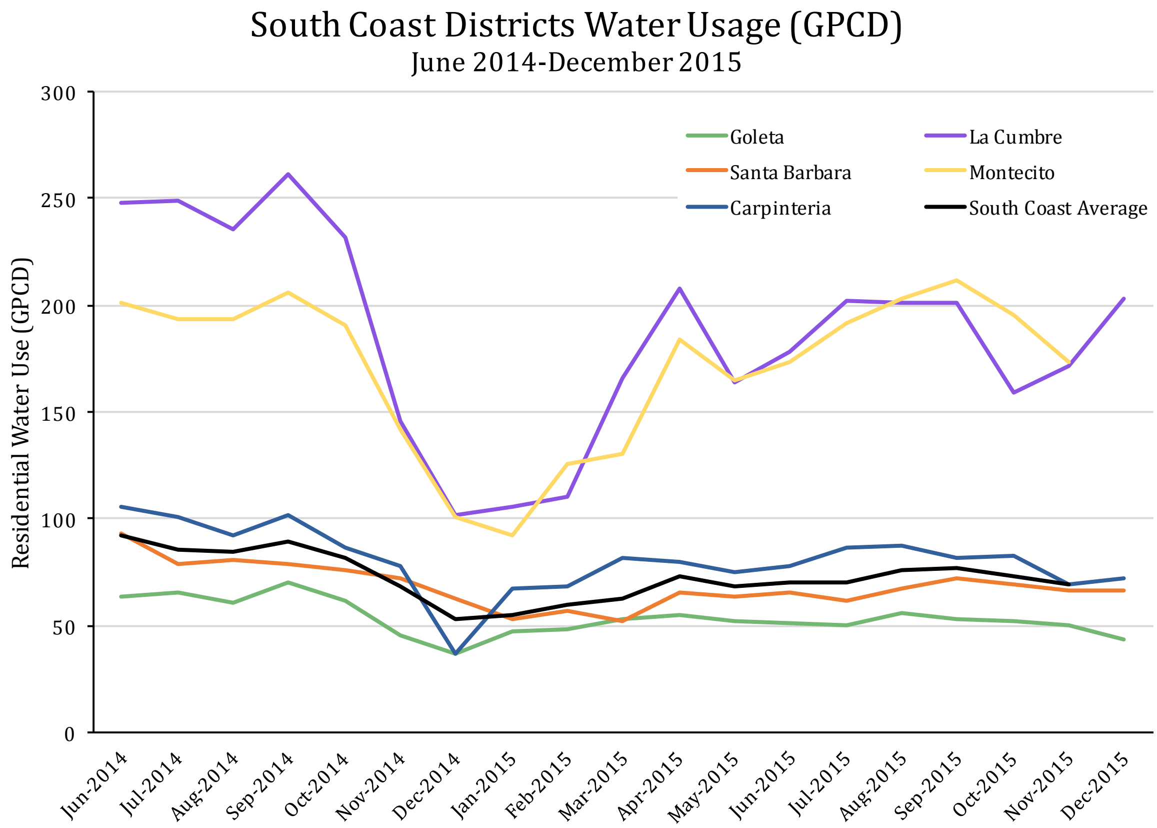

Figure 7. South Coast districts water usage. Water usage for residential customers in each district, and average across South Coast (gallons per capita per day) from June 2014-December 2015. Mandatory reporting to the state began in June 2015.

Since June 2015, California has mandated various levels of water savings for districts. Districts are required to report residential GPCD usage figures to the state each month, and conservation is compared to the same month's usage rate in 2013. Goleta and Santa Barbara must meet a conservation target of 12%, Carpinteria has a target of 20% savings, and Montecito has a target of 32%. Although districts were required to meet state standards beginning in June 2015, we calculated savings beginning in June 2014 in order to gain perspective over a longer timeframe. District savings from June 2014 to December 2015 have fluctuated, although water use is generally lower than in 2013 (Figure 8). As a private mutual water company, La Cumbre is not required to report savings to the state or meet a particular standard. However, its savings are included here to give a complete picture of the South Coast response to the drought.

Overall, water savings can fluctuate greatly from month to month. Montecito has been meeting or exceeding its conservation standard since June 2014, having had the highest per capita use on the South Coast to begin with. Santa Barbara has also well exceeded its standard. Goleta's ability to meet its 12% conservation target decreased at the end of 2015. Like Santa Barbara, Goleta maintains one of lowest per capita use rates in California. Carpinteria has notably not met conservation standards in three out of seven months of state-mandated reporting (June 2015-December 2015). This is potentially attributable to agricultural demands. Mandated conservation has been generally effective on the South Coast, but this is not necessarily a permanent solution.

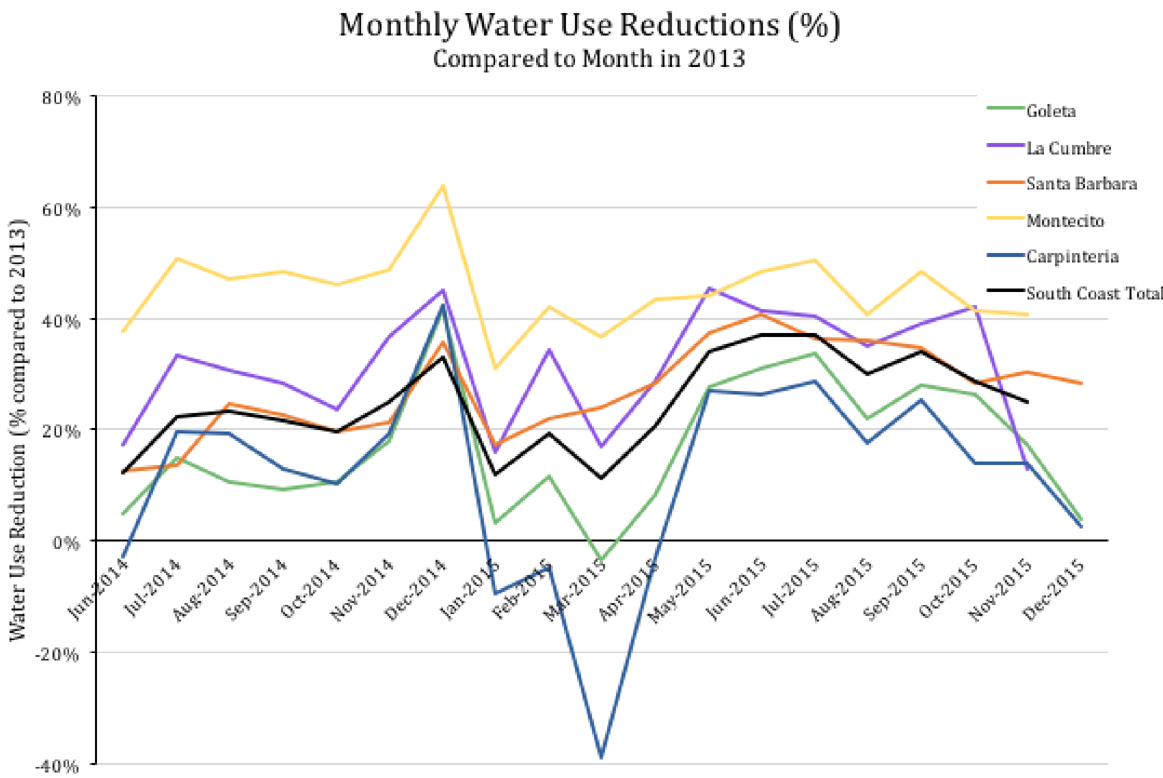

Figure 8. Monthly water use reduction. Percent water use changes from June 2014-December 2015, compared to the same month in 2013. Negative reduction indicates an increase in water use.

Several factors can influence the longevity of conservation savings. Regional reductions in savings during the winter months may be attributable to behavior patterns. Winter rains, even ones that do little to replenish water supply options, tend to create a public perception that water is less scarce, which increases water use. Multiple studies also cite a post-drought “rebound effect,” in which customers return to their previous patterns of water use when the shortage is alleviated.[275,276] However, some efficiency technologies can help reduce the rebound effect and create more permanent reductions.

Water Leaks

Estimated annual water loss from household leaks and district water main leaks are shown in Table 4 and Table 5, respectively. South Coast households could be leaking from approximately 900 AFY to as much as 2,700 AFY. District water main leakage may be on the order of 800 to 4,000 AFY across the region.

Table 4. Estimated range of water lost from household leaks (AFY). Calculations based on the assumed national household leakage reported by WaterSense®.

	Estimated Range of Household Water Leakage (AFY)		
District	**Low**	**Mid**	**High**
Goleta	336	680	1,024
La Cumbre	19	39	58
Santa Barbara	434	877	1,321
Montecito	56	114	172
Carpinteria	54	110	165
South Coast Total	**900**	**1,819**	**2,739**

Table 5. Estimated range of water lost through district water main pipelines (AFY). Calculations based on pipeline length and age use ranges provided by Twort et al. (1994) and on total supplied water provided by California Department of Water Resources (DWR).

	Estimated Range of District Water Main Leakage (AFY)				
	Twort et al. (1994)				DWR
	Newer Infrastructure		**Older Infrastructure**		**10% of Supplied Water**
District	100 l/hr/km	150 l/hr/km	200 l/hr/km	300 l/hr/km	
Goleta	309	463	617	926	1,438
La Cumbre	26	39	53	79	187
Santa Barbara	382	573	763	1,145	1,376
Montecito	79	118	158	237	606
Carpinteria	86	129	171	257	427
South Coast Total	**881**	**1,322**	**1,762**	**2,644**	**4,034**

These estimated ranges are large and actual water leakage along the South Coast will vary depending on the age and material of infrastructure, along other variable factors imposing stress on the system.

Potable Reuse

Between 2012 and 2014, a total of 43,921 AF of treated effluent was discharged to the ocean from WWTPs across the South Coast.[277] Table 6 displays the potential maximum water production volumes for potable reuse from those effluent streams. This additional source would be available for either IPR or DPR.

Table 6. Annual WWTP effluent and potable reuse potential (AF). Summerland falls under the jurisdiction of Montecito for water supply but operates a separate WWTP. South Coast totals are displayed in bold.

		Annual WWTP Effluent and Potable Reuse Potential (AF)					
		Goleta	Santa Barbara	Montecito	Summerland	Carpinteria	South Coast Total
Annual Effluent	2012	4,369	8,177	896	119	1,488	**15,050**
	2013	4,732	7,865	868	112	1,400	**14,976**
	2014	4,208	7,492	766	102	1,328	**13,896**
	3-Yr Avg.	4,436	7,845	843	111	1,405	**14,640**
15% Lost as Brine Discharge		665	1,177	126	17	211	**2,196**
Total Potential Potable Reuse Production		3,771	6,668	717	94	1,194	**12,444**

It is important to note that these totals are maximums, and could not be yielded in full in conjunction with other water recycling, conservation, or efficiency measures. If non-potable recycled water demand were to expand, the water available for potable reuse would also decrease.

Stormwater Capture

Between 2004 and 2014, an average of 74,100 AF of rainwater fell within district boundaries per year across the South Coast. This volume is approximately twice as much water as the region uses in a given year. Analysis using the SCS curve number method results in an estimated average of 6,991 AFY of urban stormwater runoff along the South Coast. It should be noted that runoff is dependent on the frequency and intensity of storms. While this estimate is an average based on daily precipitation data over 10 years, wet years could see total runoff approach 20,000 AF and dry years under 1,000 AF (see Appendix D for detailed 1996-2015 annual runoff estimates and curve number sensitivity analysis results).

One question that these results raise is: if less than 10% of annual rainfall results in runoff, where is the other 90% going? The other fates of precipitation include soil infiltration and evapotranspiration. Assuming our estimates are accurate (see discussion on limitations of the curve number method and sensitivity analysis in the Limitations of Analysis section), one explanation for the low runoff-to-rainfall ratio on the South Coast is that much of the precipitation falls at intensities too low to exceed infiltration and evapotranspiration rates. Daily precipitation data show that nearly 90% of precipitation days have rainfall intensities less than ¾ of an inch per day, about the minimum rainfall needed to produce runoff on the average urban surface along the South Coast (see Appendix D for precipitation intensity distribution table). While the average runoff-to-rainfall ratio is less than 10%, we would expect the ratio to increase to as much as 20% in very wet years, depending on the intensity and frequency of storms.

Unused runoff water could be captured and used to recharge groundwater aquifers, either through spreading basins or injection wells. Table 7examines three different urban stormwater runoff capture potentials: 10%, 25%, and 50%.

Table 7. Urban stormwater runoff (AFY) for South Coast water districts from rainfall falling within district boundaries (WYs 2006-15 average).

	Urban Stormwater Runoff (AFY)			
District	**Total**	**10% Capture**	**25% Capture**	**50% Capture**
Goleta	3,318	332	830	1,659
La Cumbre	159	16	40	79
Santa Barbara	1,584	158	396	792
Montecito	924	92	231	462
Carpinteria	1,005	101	251	503
South Coast Total	6,991	699	1,748	3,495

Another means of collecting rainwater from impervious surfaces is by connecting cisterns to rooftop rain gutters. Table 8 provides estimated annual rooftop rainwater capture from single family homes with 25%, 50%, and 75% participation across the South Coast.

Table 8. Rooftop rainwater capture estimates (AFY) for single family households (WYs 2006-15 average).

	Single Family Residential Rain Cisterns (AFY)		
District	**25% Participation**	**50% Participation**	**75% Participation**
Goleta	65	129	194
La Cumbre	15	29	44
Santa Barbara	68	136	204
Montecito	41	83	124
Carpinteria	10	20	30
South Coast Total	199	397	596

Residential Greywater

Greywater systems are an option for a decentralized non-potable wastewater reuse. Estimated residential greywater potential is provided in Table 9 with 25%, 50%, and 75% participation of South Coast residents. These estimates include greywater production from washing machings and showers of both single family and multi-family households.

Table 9. Residential greywater production from clothes washers and showers (AFY) based on district population.

	Residential Greywater (AFY)		
District	**25% Participation**	**50% Participation**	**75% Participation**
Goleta	475	950	1,426
La Cumbre	20	40	60
Santa Barbara	494	988	1,482
Montecito	57	114	171
Carpinteria	74	148	222
South Coast Total	1,120	2,240	3,361

Residential greywater production would vary depending on the efficiency of the appliances connected to the system as well as the behavior of the user (i.e. frequency of washer loads, duration of showers, etc.). These results were calculated assuming relatively efficient appliances to be conservative and also factor in the condition of residents targeting water use reduction (increasing efficiency) prior to, or alongside, water reuse.

Costs

Total costs of each source encompass financial expenditures, energy requirements, and environmental impacts. Financial costs are either variable (dependent on the amount of water produced) or fixed costs (paid regardless of water production), as components of full system costs. Energy requirements are indicated on a marginal basis (per unit of production). Environmental impacts include greenhouse gas emissions and aquatic ecological effects.

Financial

All financial costs in this report summarize the regional total (or range, where appropriate) of costs paid by districts using a specific source. A comprehensive outline of cost ranges broken down by district can be found in Appendices J and K.

Variable Costs

The financial costs associated with water production greatly vary by source. Variable costs of production will change for each source by the quantity of water extracted from that source in a given year. Variable costs are limited to O&M supplies (such as filter membranes), chemical costs for treatment, energy costs for treatment, and testing costs. Table 10 includes the annual variable costs by source:

Table 10. Variable cost ranges of each source on the South Coast. Variable costs include variable O&M supplies, Table A purchase costs (SWP only), and treatment plant costs. All variable costs are measured in $/AF. South Coast ranges include the lowest and highest observed costs from any district using that water source, given available data.

Source	South Coast
Groundwater	
Variable O&M ($/AF)	$60 - 752
Associated Treatment Plant Costs (avg $/AF)	$352 - 410
Desalination (3,125 AFY)	
Variable O&M ($/AF)	$581
Desalination (7,500 AFY)	
Variable O&M ($/AF)	$541
Recycled (Tertiary)*	**Goleta only*
Variable O&M ($/AF)	$119 - 210
State Water Project (Table A)	
Variable Purchase Costs ($/AF)	$273 - 341
Associated Treatment Plant Costs (avg $/AF)	$130 - 137
Cachuma Surface Water	
Associated Treatment Plant Costs (avg $/AF)	$130 - 137
Gibraltar Surface Water	
Associated Treatment Plant Costs (avg $/AF)	$137
Jameson Surface Water	
Associated Treatment Plant Costs (avg $/AF)	$352

Groundwater has the greatest range in variable O&M costs ($60-752/AF) (Table 10). Including the associated costs of treatment ($352-410/AF), groundwater is among the highest overall variable cost of production. The amount of pumping needed to extract groundwater for treatment depends on a district's well capacity and underlying basin geology. Given the variability of basin characteristics along the South Coast, some districts will face greater upfront energy and supply costs than others. Additionally, the range of treatment costs associated with groundwater also depends on water quality, which often deteriorate with greater pumping depths, thus increasing variable treatment costs.

Desalination has relatively high variable costs compared to most other South Coast sources. Looking at both production levels, there is an evident economy of scale: at 7,500 AFY, variable O&M costs are $541/AF; while at 3,125 AFY, variable O&M costs are $581/AF. Variable costs for desalination primarily include costs for treatment and membranes.

Among current sources, SWP and recycled water have some of the lowest variable cost ranges. These variable purchase costs for SWP are the unit prices of Table A deliveries, which vary annually. Between 2008 and 2016, variable purchase costs for SWP spanned $273-341/AF, excluding variable purchase costs of market exchanges and ID #1 exchanges. Another SWP variable cost is treatment. For SWP deliveries and exchanges, associated WTP costs span $130-137/AF, since all SWP water is delivered to Lake Cachuma and can be assumed to have the same treatment costs as Cachuma withdrawals.

For recycled water, the variable costs include only the tertiary treatment required for redistribution after meeting the NPDES discharge standards in Goleta ($119-210/AF). Although Santa Barbara's recycled program is not included in this financial analysis, budget reports from the City include costs of supplies and services for its reclaimed water program. These data put the range of marginal variable O&M costs between $314-321/AF from 2011 to 2015. The range among recycled water variable O&M costs may be due in part to the different tertiary treatment technologies used by the two districts with reclaimed water programs.

Surface water sources (Cachuma, Gibraltar, and Jameson) all have negligible variable O&M supply costs. Their associated treatment plant costs are the only variable expenditures for surface water. The water treatment plants by surface water body are as follows: all Gibraltar water for Santa Barbara is treated through Cater; all Jameson and Doulton water for Montecito is treated at Bella Vista; all Cachuma deliveries for Goleta are treated at Corona del Mar, while Cachuma deliveries for Santa Barbara, Montecito, and Carpinteria pass through Cater. Thus, Cachuma deliveries' treatment costs include two WTPs, giving the associated treatment costs a greater range than supplies from other local surface bodies. Since 2007, the average annual variable treatment costs of Jameson and Doulton is $352/AF, and Cachuma water at Corona del Mar in Goleta is $130/AF. At Cater, treatment costs for Gibraltar and other districts receiving Cachuma deliveries are $137/AF. Thus, the average annual variable costs of surface water treatment are: $130-137/AF for Cachuma; $137/AF for Gibraltar; and $352/AF for Jameson and Doulton.

Overall variable costs for different sources are displayed in Figure 9.

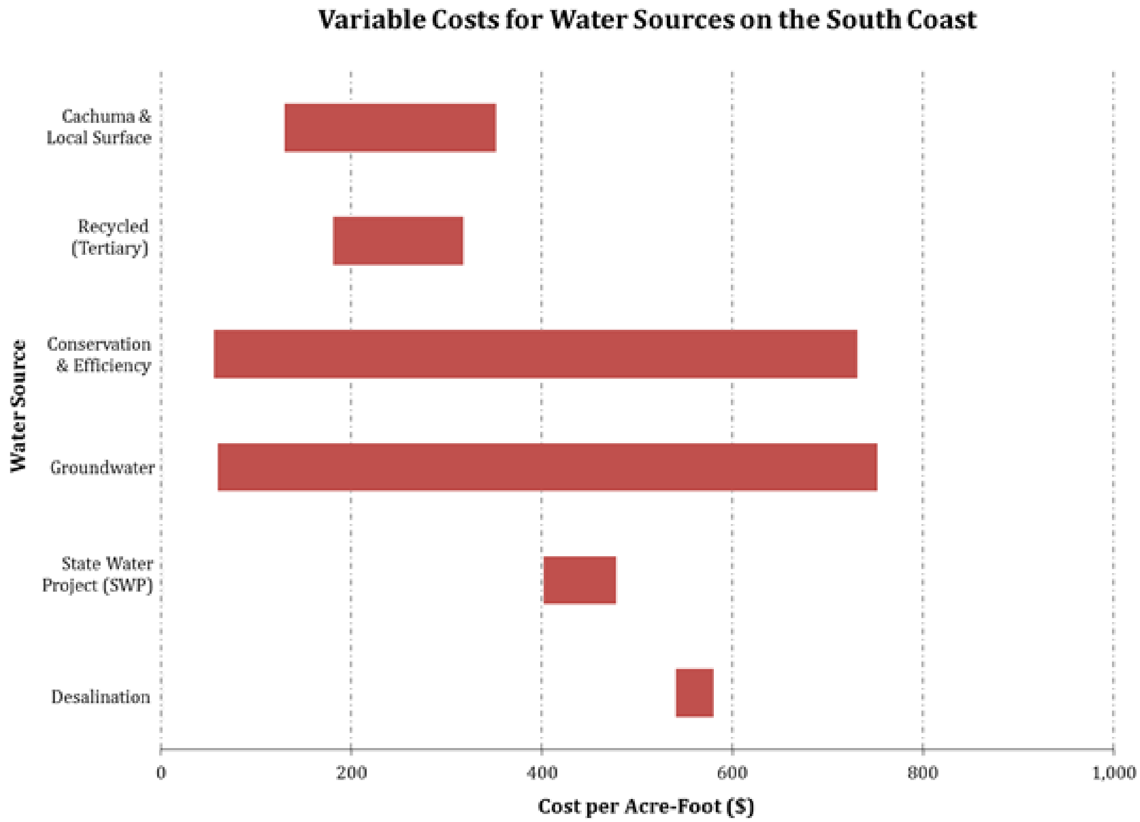

Figure 9. Comparisons of variable cost ranges ($/AF) for the following sources: recycled, Cachuma and local surface (including Jameson and Gibraltar), SWP, conservation & efficiency measures, groundwater, and desalination. South Coast ranges include the lowest and highest observed costs from any district using that water source, for data available since 2007. Desalination includes both 3,125 AFY and 7,500 AFY production capacities. Conservation and efficiency includes all programs within the Santa Barbara model with a benefit-cost ratio greater than 1.0.

Surface water (Cachuma, Jameson, Gibraltar, and other local surface bodies) systems are largely gravity-fed on the South Coast, so the primary cost variance associated with surface sources is treatment. Recycled (tertiary) refers to the variable costs observed at the Goleta WWTP.

The greatest variable cost range among current sources are groundwater and conservation/efficiency. In years where less groundwater is pumped, marginal variable costs are much greater. These variable costs do not necessarily have a linear relationship with the amount of water produced.

Another relatively large range of variable costs include conservation and efficiency measures, which encompass a broad range of programs, from cheap low-hanging fruit to more expensive options. Included in this range are all programs in the Santa Barbara model with a benefit-cost ratio greater than 1.0. Across all financially beneficial programs (i.e., those with a benefit-cost ratio greater than one to the utility), water demand could be reduced by 23 AFY to over 700 AFY (depending on the program).

Using Santa Barbara's water rates, this shows a financial cost to districts of $56/AF - $1,970/AF of saved water, which is among the least expensive sources given Santa Barbara is able to avoid paying to produce more expensive sources.

The smallest variable cost range is from desalination. These variable cost values are bid costs, rather than observed data points. Once the desalination plant is running, there may be a wider range of observed values. Additionally, desalination only exists in one district. The ranges occurring for other sources due to differing technologies, efficiencies, and treatment requirements do not exist.

As can be seen in Figure 9, South Coast water sources have wide and often overlapping variable cost ranges. Therefore, there are not major variable cost differences between sources. However, this analysis is only one piece of the larger picture, since water districts are paying much more than these variable costs for their water supplies. Additional fixed costs are examined below.

Fixed Costs

Fixed costs are costs incurred regardless of the amount of water extracted or produced from a source. Such costs include agency fees, debt service, capital costs paid in full upfront, and O&M equipment capital. Table 11 highlights the ranges of fixed costs by water source along the South Coast:

Table 11. Fixed costs of water sources on the South Coast. Fixed costs include upfront capital, fixed O&M costs (such as equipment), debt service, and agency fees. All fixed costs are measured in $/year. The South Coast ranges include the lowest and highest observed costs from any district using that water source, for data available since 2007.

Source	South Coast
Groundwater	
Upfront Capital Costs ($)	$90,956
Fixed O&M Costs ($/year)	$14,913 - 1,234,777
Debt Service ($/year)	$441,800 - 688,010
Desalination (3,125 AFY)	
Fixed O&M Costs ($/year)	$1,068,484
Debt Service ($/year)	$3,254,270
Desalination (7,500 AFY)	
Fixed O&M Costs ($/year)	$1,492,363
Debt Service ($/year)	$5,029,326
Recycled (Tertiary)*	**Goleta only*
Upfront Capital Costs ($)	$49,750 - 290,150
Fixed O&M Costs ($/year)	$0 - 290,000
State Water Project (Table A)	
Agency Fees ($/year)	$762,618 - 5,211,442
Fixed O&M Costs ($/year)	$145,656 - 758,957
Debt Service ($/year)	$617,962 - 2,826,403
Cachuma Surface Water	
Agency Fees ($/year)	$0 - 1,631,941
Fixed O&M Costs ($/year)	$105,989 - 2,072,784
Debt Service ($/year)	$38,684 - 160,790
Gibraltar Surface Water	
Fixed O&M Costs ($/year)	$293,944 - 372,337
Jameson Surface Water	
Fixed O&M Costs ($/year)	$94,300 - 120,500
Rainwater Harvesting	
Upfront Capital Costs ($)	$2,900,000 - 53,000,000
Greywater	
Upfront Capital Costs ($)	$504,700 - 22,360,000
Demand Reduction (Program-level)	
Upfront Capital Costs ($)	$11,148 - 478,506
Annual Cost ($) (not itemized)	$204,700 - 2,228,112

In contrast to the variable costs shown in Figure 9, SWP has among the greatest fixed costs (Table 11). Annual SWP agency fees due to CCWA, DWR, and USBR from each district range from $762,618 - $5.21 million. Another fixed cost from each district participating in SWP is annual debt service ($617,962 - $2.83 million). These agency fees depend on external factors including climate and upstream users' needs, as well as each member district's demographics and water demand. While no SWP deliveries are actually guaranteed for each year, districts that participate in the SWP have access to infrastructure that allows participation in market exchanges. Although the fixed costs are relatively high for SWP, the potential deliveries and market accessibility may be cited as justification for those higher expenses.

Desalination's fixed costs are also among the highest costs on the South Coast. The loans needed to finance Santa Barbara's desalination plant revitalization project are $55 million for 3,125 AFY and an estimated additional $30 million to grow to 7,500 AFY. Under these loan terms, annual debt service for desalination is approximately $3.25 million for 3,125 AFY, or $5.03 million for 7,500 AFY. Additionally, there are fixed O&M costs for capital equipment: $1.07 million for 3,125 AFY, or $1.49 million for 7,500 AFY. Like variable costs, fixed costs for desalination have economies of scale.

Like variable groundwater costs shown above, the fixed costs for groundwater have high variability. Due to different hydrogeological conditions across the districts, some districts have annual debt service to pay off large capital costs associated with pumping and treating groundwater, while other districts pay for groundwater capital expenditures upfront and do not have debt. Similarly, districts' fixed O&M costs vary, depending on the depth of groundwater pumping. The capital equipment needed to pump and treat groundwater along the South Coast can range from $14,913-$1.23 million.

Conservation and efficiency programs led by the districts have estimated upfront capital costs ranging from $11,148-$478,506 plus an additional $204,700-$2.23 million in non-itemized costs annually, depending on the collection programs provided by a given district.

Other future potential sources are decentralized efforts: greywater, rainwater harvesting, and stormwater capture. Although these were without variable costs, implementing any of these systems throughout a water district would require more upfront capital. Using literature reviews of such systems in similar districts and models and surveys of the natural and manmade landscape, the estimated fixed cost ranges of establishing any of these decentralized efforts in a South Coast district are as follows:

- Rainwater harvesting: $2.9 - $53 million
- Greywater: $504,700 - $22.36 million

It is estimated that each source could last 20 years before needing to replace fixtures.

For stormwater capture cost estimates, precise data was unavailable. A wide range of stormwater capture system types exist, including several different infrastructure options. The choice of stormwater capture system and its associated costs are site-specific, especially when incorporating treatment costs of stormwater runoff. Goleta Water District provides estimated injection costs for surplus surface water in their

2011 Water Supply Management Plan.[278] Treatment costs are estimated at $67/AF and extraction costs at $177/AF. Goleta injection costs reflect injection done by gravity (not pressurized) at a capacity of 200 gallons per minute per well. It should be noted that these estimates are based on excess water coming from Cachuma and there would be additional treatment needed for water running over urban surfaces. This also does not account for the costs needed to capture and convey stormwater to the treatment facility and then to the injection well (treatment would likely occur at the wastewater treatment plant to avoid having to pump water uphill to the potable treatment plant). Goleta also estimates the cost of design and construction for either upgrades of existing structures or new injection wells to be $1,108,600, as stated in their 2015 Infrastructure Improvement Plan.[279]

Finally, recycled water's annual fixed costs are comprised of two components: fixed O&M equipment costs and capital costs. Since 2010, fixed O&M costs in Goleta have ranged $49,750 - $290,150. For upfront capital costs, Goleta has spent a total of $813,600, or an annual average of $135,600, between 2010 and 2015. In some years, no capital outlay was noted. The reported range of annual upfront capital costs is $0 - $290,000. While data limitations prevented Santa Barbara's recycled water program from being included in this financial analysis, it is worth noting that fixed O&M costs for Santa Barbara ranged $477,507 - $616,495 between 2011 and 2016. However, there is a much greater range of capital costs for recycled water programs. Due to a full tertiary system replacement between 2014 and 2015, Santa Barbara has spent $12.49 million upfront since 2010. Thus, the range of total fixed costs (in particular, capital outlay) by each district is expansive ($0 - $12.49 million). Tertiary treatment equipment also have varying lifespans: plant infrastructure lasts an estimated 33 years, purple pipes have approximately 15 year lifetimes, but membranes must be replaced every five years. Depending on recycled water technologies and the timing of system upgrades and equipment replacement, recycled water fixed costs have a large variance in any given year.

Full System Costs

To find overall full system costs of each water source on the South Coast, we can add variable and fixed costs (Table 10 and Table 11, respectively). Table 12 shows the cumulative range of costs by source on the South Coast.

Table 12. Full system costs for each water source along the South Coast, as well as potential future sources. Full system costs encompass variable ($/AF) and fixed ($/year) costs. All variable costs are highlighted in gray: variable O&M (e.g. supplies), Table A variable purchase costs (SWP), and associated WTP costs. Fixed costs include upfront capital, debt service, fixed O&M (e.g. machinery), and agency fees. South Coast ranges include the lowest and highest observed costs from any district using that water source, for data available since 2007. South Coast ranges include the lowest and highest observed costs from any district using that water source, for data available since 2007.

Source	South Coast
Groundwater	
Associated Treatment Plant Costs (avg $/AF)	$352 - 410
Variable O&M ($/AF)	$60 - 752
Upfront Capital Costs ($)	$90,956
Fixed O&M Costs ($/year)	$14,913 - 1,234,777
Debt Service ($/year)	$441,800 - 688,010
Lifespan (years)	20 - 40
Desalination (3,125 AFY)	
Variable O&M ($/AF)	$581
Fixed O&M Costs ($/year)	$1,068,484
Debt Service ($/year)	$3,254,270
Lifespan (years)	20
Desalination (7,500 AFY)	
Variable O&M ($/AF)	$541
Fixed O&M Costs ($/year)	$1,492,363
Debt Service ($/year)	$5,029,326
Lifespan (years)	20
Recycled (Tertiary)*	*Goleta only
Variable O&M ($/AF)	$119 - 210
Fixed O&M Costs ($/year)	$49,750 - 290,150
Upfront Capital Costs ($)	$0 - 290,000
Lifespan (years)	4 - 5 for membranes; 15 for pumps; 33.3 for infrastructure
State Water Project (Table A)	
Variable Purchase Costs ($/AF)	$273 - 341
Associated Treatment Plant Costs (avg $/AF)	$130 - 137
Agency Fees ($/year)	$762,618 - 5,211,442
Fixed O&M Costs ($/year)	$145,656 - 758,957
Debt Service ($/year)	$617,962 - 2,826,403

Source	South Coast
Cachuma Surface Water	
Associated Treatment Plant Costs (avg $/AF)	$130 - 137
Agency Fees ($/year)	$0 - 1,631,941
Fixed O&M Costs ($/year)*	$105,989 - 2,072,784
Debt Service ($/year)	$38,684 - 160,790
Gibraltar Surface Water	
Associated Treatment Plant Costs (avg $/AF)	$137
Fixed O&M Costs ($/year)	$293,944 - 372,337
Jameson Surface Water	
Associated Treatment Plant Costs (avg $/AF)	$352
Fixed O&M Costs ($/year)	$94,300 - 120,500
Rainwater Harvesting	
Upfront Capital Costs ($)	$2,900,000 - 53,000,000
Lifespan (years)	20
Greywater	
Upfront Capital Costs ($)	$504,700 - 22,360,000
Lifespan (years)	20
Demand Reduction (Program-level)	
Upfront Capital Costs ($)	$11,148 - 478,506
Annual Cost ($) (not itemized)	$204,700 - 2,228,112
Estimated Water Savings (AFY)	$23 - 711
Marginal Cost of Saved Water ($/AF)	$56 - 1,970
Lifespan (years)	depends on device/program

While some sources may have low variable costs, the associated fixed costs are significantly greater, and vice versa. Additionally, the reliability and productivity of different sources is a critical factor in water districts' decision-making: regardless of financial costs, access to very reliable water sources in this region is vital. Some of the lowest-cost sources, such as surface water, are among the first to deplete during droughts. External factors such as the state of endangered species living in these habitats further limit the extraction amount. Desalination, one of the more expensive sources, is much more reliable and has consistent production regardless of climate. Finally, SWP, which has very high fixed costs, allows participating districts to buy or sell supplemental exchange water, in addition to any Table A deliveries they may receive in a given year. Although some districts may see no Table A deliveries, market access and the potential for deliveries provides extra insurance to regions with scarce water.

There are also economies of scale to consider when determining the amount of water produced from different sources. For instance, it is less marginally expensive to produce 7,500 AFY of desalinated water ($1,410/AF) than 3,125 AFY ($1,964/AF).

Marginal full system costs across all sources can be compared in Figure 10.

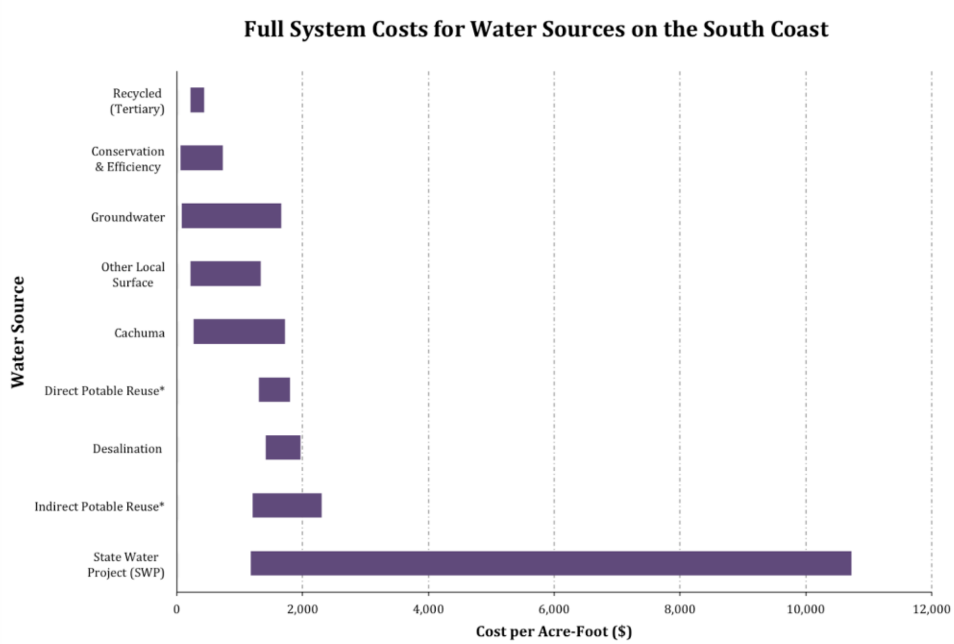

Figure 10. Relative comparisons of each source's marginal full system costs ($/AF). Full system costs comprise annual variable and fixed cost ranges. The full system costs are based on average water production over the years for which cost data are available. Direct potable reuse and indirect potable reuse are production and cost estimates from RMC Water and Environment's Long Term Supplemental Water Supply Alternatives Report (2015).[280] South Coast ranges include the lowest and highest observed marginal costs from any district using that water source.

Total marginal cost ranges for each source were calculated by finding each district's total payments for a source for each year with data (i.e., multiplying the production quantity by variable costs, then adding fixed costs) and dividing by that year's production quantity. The highest and lowest observed marginal costs along the South Coast are incorporated into the range (Figure 10).

Sources on the higher end of marginal full system costs have greater fixed costs, so their full system marginal costs appear greater in years with less production. Among the lower marginal full system costs of water production are recycled (tertiary) and conservation/efficiency.

Groundwater may have relatively low marginal system costs, but it also has a wider cost range. In years with less groundwater production, or with more capital costs to upgrade equipment, groundwater can be more than twice as expensive as the cheapest sources. Groundwater, Cachuma, and other local surface can be considered low- to mid-range full system cost options.

DPR and IPR are included in this graph as potential future sources, should the regulatory environment for potable reuse accommodate it. RMC Water and Environment's 2015 study for the County estimated costs for DPR and IPR programs along the South Coast, although costs were not broken down into fixed and variable costs, so they were not included in previous figures.[281] Desalination has a relatively high marginal cost of full system production, incorporating both 3,125 AFY and 7,500 AFY capacities as itemized in the construction bid for Santa Barbara.

Finally, SWP water has both the largest variance and the highest potential costs. Sources that have high marginal cost variability, including SWP and groundwater, tend to be used by more districts, among which different natural environments and consumer demand exist. Smaller districts, which will need less water from a source, may appear to have a greater marginal cost of production for that same source than a larger district, which will withdraw more water. Additionally, SWP allocations, which have the greatest marginal cost variance, are much more influenced by external circumstances than other sources. The amount of Table A allocations actually delivered to a district in a given year will depend on climate, the district's demographics, available alternative sources, and other SWP users' needs. While some years may receive SWP deliveries of over 70% of their allocation, other years may see deliveries under 10%. Regardless of actual deliveries, the high costs of agency fees and debt service are paid annually.

Energy

Energy requirements constitute a significant variable cost component for each water source. These requirements vary considerably between sources, based on the technology required to extract and treat water. Figure 11 illustrates these different average requirements.

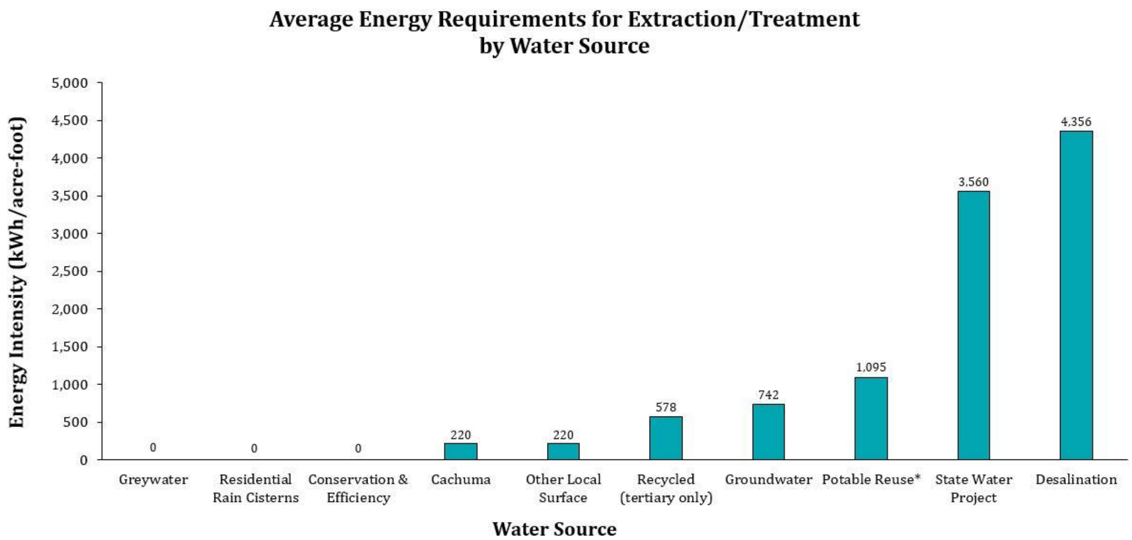

Figure 11. Average energy requirements (kWh/AF) for extraction and treatment of current and potential water sources on the South Coast.

Energy requirements for extraction and treatment of each source utilized on the South Coast are widely varied. Energy is not required for decentralized systems (greywater, rainwater harvesting, and conservation/efficiency) from the district perspective. Water from Cachuma and local surface sources is delivered by gravity to their respective potable treatment plants, where 220 kWh/AF is required for treatment (Figure 11).

Recycled water (tertiary only) refers to the energy required to treat wastewater beyond secondary NPDES permit treatment requirements to be used for non-potable applications. Groundwater energy requirements are dependent on well capacity and resulting treatment based on water quality, which is variable between basins and wells. On average, groundwater on the South Coast requires 742 kWh/AF (Figure 11). Potable reuse requires advanced treatment to convert wastewater to drinking water quality standards, and therefore requires about double the tertiary treatment energy requirement (Figure 11).

State Water deliveries yield a total energy demand of about 16 times that required for Cachuma and local surface waters, 3,560 kWh/AF. The most energy-intensive water source on the South Coast is desalination. The energy requirements for desalination shown in Figure 11 are the average between the current (3,500 AFY) and potential expanded (7,500 AFY) capacity of the Charles E. Meyer Desalination Facility. The relatively large energy requirement for desalination leaves this source the most vulnerable to fluctuations in energy prices, followed by the State Water Project and potable reuse.

This vulnerability to energy prices is particularly important given the context of anticipated increases in Southern California Edison customers' rates. On November 12, 2013, Southern California Edison announced a cumulative $841 million (or 12.4%)

increase in rates, planned between 2015 and 2017.[282] These price increases will be reflected in water prices across the South Coast, depending on the energy intensity of each water source. For example, desalination will experience the largest price increases as a result of increasing energy rates since it is the most energy intensive source on the South Coast.

Environmental

Greenhouse Gas Emissions

The greenhouse gas emissions of South Coast water sources are determined by the energy intensities of each source, the amount of water produced, and the energy source. The graph below compares total annual greenhouse gas emissions in an average year from each South Coast water source.

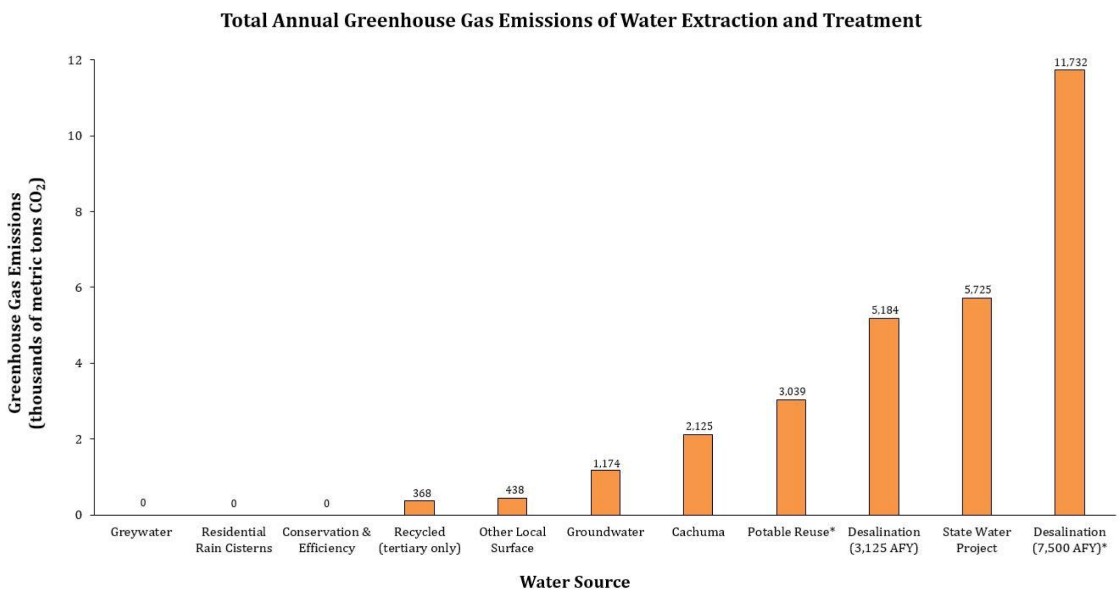

Figure 12. Total annual greenhouse gas emissions of water extraction and treatment, by South Coast water source. Asterisk on potable reuse and expanded desalination (7,500 AFY) denote that there are no current plans to implement either of these options. Note that these calculations are limited to the extraction and treatment processes of each water source, and do not include full life cycle processes. See Methods section for equation and data sources.

The three water sources on the left in Figure 12—greywater, residential rain cisterns, and conservation/efficiency—are decentralized sources. Without pumping or treatment infrastructure, these sources do not require energy for transportation or treatment, thereby emitting essentially no greenhouse gases. Recycled (tertiary), other local surface, groundwater, and Cachuma individually contribute approximately 400 - 2,000 metric tons of CO_2 emissions per year. Potable reuse, desalination, and SWP each contribute approximately 3,000-12,000 metric tons of CO_2 emissions per year.

Desalination is split into the two proposed production capacities—3,125 AFY and 7,500 AFY—to illustrate the additional greenhouse gas emissions that would result from an expansion. Increasing the production capacity would yield a decrease in marginal energy intensity (from 4,483.7 kWh/AF to 4,227.7 kWh/AF),[283] so the increase in greenhouse gas emissions is not linearly related to total water production.

These greenhouse gas emissions could potentially be offset through the California carbon offset market. In 2015, the average cost of carbon offsets in California was $12.77 per metric ton of CO_2 equivalent.[284] If, for example, the region were to offset greenhouse gas emissions produced by desalination extraction and treatment processes at the 7,500 AFY production capacity, this would cost approximately $149,817 per year.

The graph in Figure 12 incorporates total annual production volumes in the overall greenhouse gas emissions, but does not visualize the different productions between sources. Some sources are producing much more water than others, which may or may not be reflected by the total greenhouse gas emissions. In Figure 13, greenhouse gas emissions and water production are shown side-by-side.

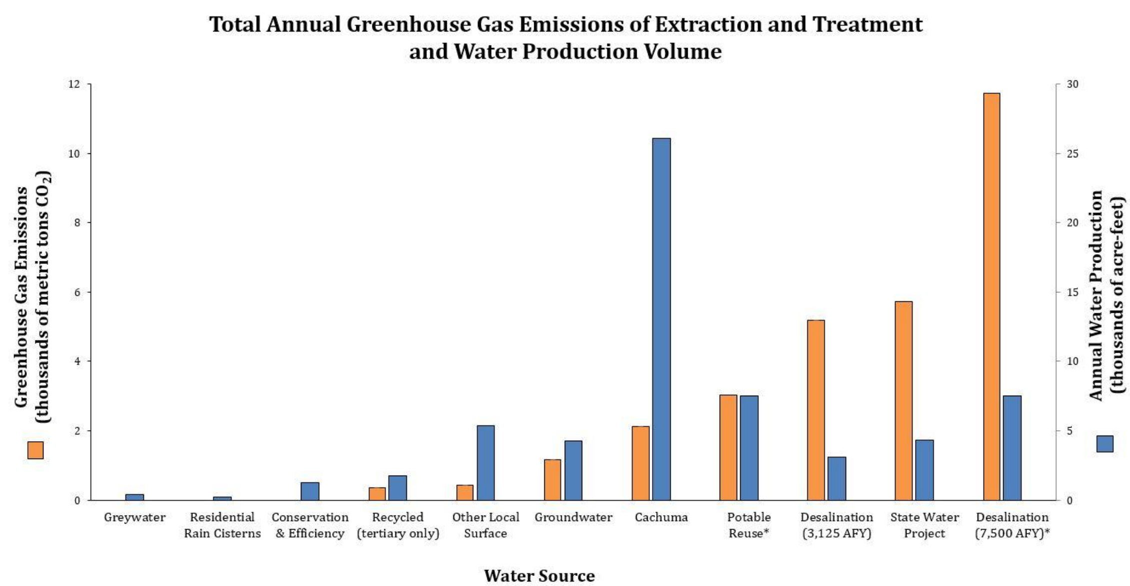

Figure 13. Total annual greenhouse gas emissions of extraction and treatment, and water production volume. Orange columns correspond to annual greenhouse gas emissions (metric tons CO_2). Blue columns correspond to annual water production (AFY). Asterisk on potable reuse and desalination (7,500 AFY) denote that there are no current plans to implement either of these options. Note that these calculations are limited to the extraction and treatment processes of each water source, and do not include full life cycle processes.

Figure 13 displays the disproportionate relationship between total annual water production and greenhouse gas emissions by water source along the South Coast. Cachuma, for example, produces more water in a given year than any other source, but still produces fewer total annual greenhouse gas emissions than potable reuse, desalination, and SWP. This can be explained by Cachuma's gravity-fed transport system and relatively low treatment requirements, which yield a low marginal energy consumption. Other local surface sources present a similar proportional relationship.

Figure 13 also illustrates the difference in greenhouse gas emissions between potable reuse and desalination at 7,500 AFY. The two sources yield the same annual water production (See Methods for calculations), but the extraction and treatment processes for desalination emit approximately 9,000 more metric tons of CO_2 per year.

Greenhouse gas emissions from South Coast water sources will vary depending on Southern California Edison's energy portfolio. As Southern California Edison transitions its portfolio towards renewable power, these total annual greenhouse gas emissions may decrease. However, these proportional relationships between greenhouse gas emissions by water sources will persist, as long as energy requirements do not change.

Ecosystem Impacts

Ecosystem impacts of water sources vary in magnitude. Below are the major ecosystem impacts associated with water supply sources on the South Coast. This discussion does not seek to include every possible ecosystem effect, rather it serves to provide discussion on the most notable of these influences.

Freshwater Ecosystem Impacts

State Water Project

The State Water Project is fed by water from the Sacramento-San Joaquin Delta, a 738,000-acre estuary that serves as a habitat for over 500 species of wildlife. Twenty of those species are listed as endangered, including the Delta smelt and the salt harvest Suisun Marsh mouse. The Delta also serves as an important migratory path for Chinook salmon.[285]

Historically, water exports from the Delta have threatened these species. In response, the State Water Resources Control Board imposed water quality objectives to protect the Bay-Delta ecosystem. However, in drought conditions, these standards are lowered in light of statewide water supply concerns.[286] By purchasing water from the State Water Project, the South Coast imposes environmental costs to endangered species in the Bay-Delta.

Lake Cachuma

Lake Cachuma supports a diverse habitat of animal and plant life. Most notably, the Lake is located along the Santa Ynez River, which serves as critical habitat for the Southern California steelhead trout. This fish species was designated as endangered in August 1997 by the National Marine Fisheries Service (NMFS). In 2000, NMFS released a biological opinion for the Bureau of Reclamation's operation and maintenance of the Cachuma Project.[287] In response, the Bureau of Reclamation, with COMB, developed a Fishery Management Plan (FMP) to ensure that ongoing operations at Cachuma would minimize the “take” of the steelhead trout.[288]

As part of the FMP, the Bureau of Reclamation is required to pump water down Hilton Creek to provide migratory habitat for the steelhead trout. In drought conditions, fish habitat is still protected. Currently, NMFS is preparing a new biological opinion for the steelhead. Additionally, the State Water Board is considering a new water rights order for Cachuma Project operations.[289]

According to a COMB official, the recent drought has negatively impacted the steelhead trout fishery. If the drought persists through the summer, water supply from Lake Cachuma will need to be "seriously curtailed."[290] It is unknown when the new biological opinion will be released, or the potential impact it will have on Cachuma deliveries.

Marine Ecosystem Impacts

Seawater Desalination

There are two major components of the Santa Barbara desalination facility that can have adverse impacts on the marine ecosystem: the seawater intake and the brine discharge system.

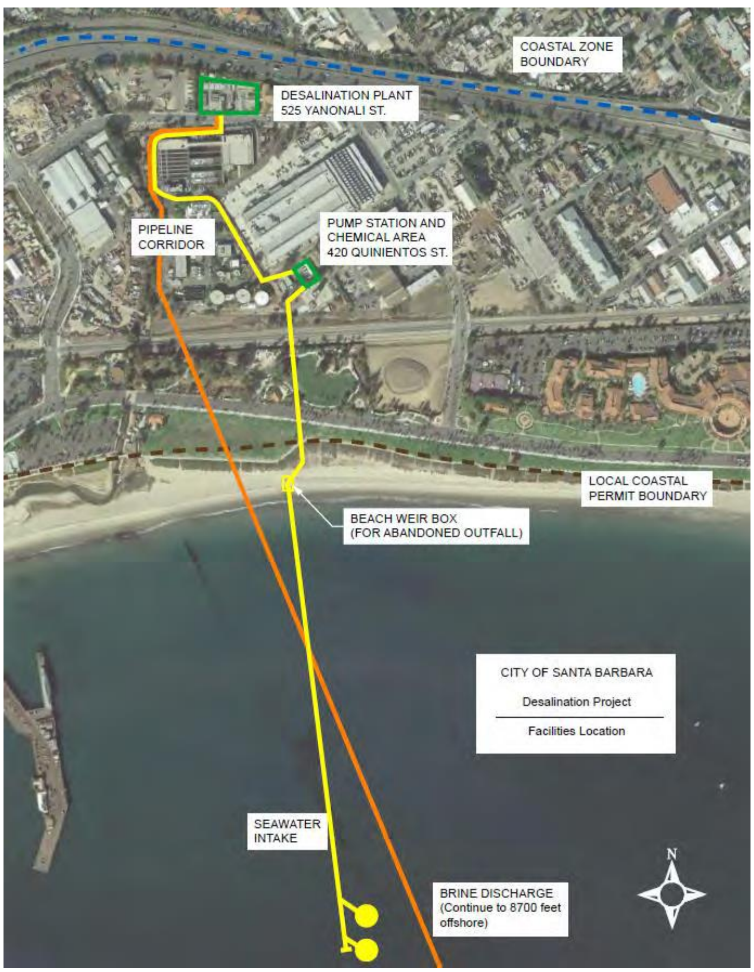

Figure 14. Charles E. Meyer Desalination Facility. (Source: City of Santa Barbara

The Charles E. Meyer Desalination Facility (Figure 14) is equipped with a screened open ocean intake. Open ocean intakes can kill aquatic organisms through impingement or entrainment. Impingement occurs when organisms are trapped against the screens by the force of the flowing water, and typically impacts larger organisms such as juvenile or adult fish, crabs, etc. Entrainment occurs when smaller organisms, such as plankton or fish larvae, pass through the screens and are drawn into the treatment facilities.[291]

One solution to reduce marine ecosystem impacts of desalination intakes is to switch from an open ocean intake to a subsurface intake, such as a vertical beach well, horizontal well, slant well, or infiltration gallery. A study conducted by Missimer et al. found that subsurface intakes for seawater reverse osmosis facilities improved the quality of the raw water, reduced the need for chemical treatments, minimized environmental impacts, decrease carbon emissions, and reduced the cost of treated water for customers.[292] The City of Santa Barbara is currently investigating the feasibility of a subsurface desalination intake.[293]

Brine discharge can also have significant impacts on the marine ecosystem. Increased salinity and the presence of pre- and post-treatment chemicals, such as anti-scalants and anti-foulants, in the discharge can have toxicological effects on aquatic organisms including fish, invertebrates, and algae. Since brine discharge is more saline than the receiving ocean waters, it may sink to the bottom. There, it can have deleterious impacts on benthic biota such as sea grasses, which are important primary producers in coastal ecosystems.[294]

The Santa Barbara desalination facility plans to mitigate the environmental consequences of the brine effluent by blending it with treated wastewater from the El Estero Wastewater Treatment Plant before discharging it into the ocean. The biological impacts of the brine discharge will depend on how much the City dilutes it with treated wastewater, the ambient salinity of the discharge site, and the resilience of the aquatic ecosystem.

Recycled Water

Similar to seawater desalination processes, recycling domestic wastewater results in brine discharges that may be harmful to coastal marine ecosystems. The concentrates produced by recycling wastewater from municipal sewage treatment facilities often differ from those produced by desalinated seawater, since the constituents found in the feedwater is significantly different. For example, concentrates from wastewater treatment processes may contain excreted hormones, pharmaceuticals, or other emerging contaminants.[295] The impacts of these concentrates on coastal marine ecosystems has not yet been fully studied.

The byproducts from treating domestic wastewater along the South Coast would be discharged into the ocean regardless of whether the wastewater was reused or discarded. However, advanced treatment of wastewater results in a more concentrated brine byproducts than secondary treatment, thereby potentially creating more toxic effluent. This is a notable environmental concern for potable reuse.

One solution would be to blend the brine discharge with non-recycled treated wastewater, as the Santa Barbara desalination facility is planning to do. However, as conservation and efficiency increases and more wastewater is recycled, there will be less available for such blending.

Stormwater Capture

As stormwater runoff moves across the land surface of the South Coast, it picks up pollutants such as fertilizers and pesticides from agricultural lands, oil and grease from urban areas, and bacteria and nutrients from livestock and pet wastes.[296] Stormwater runoff eventually deposits these natural and man-made pollutants into the ocean, where they can cause significant ecological harm.

Any water source that collects stormwater before it reaches the ocean actually provides environmental benefits to marine communities. In this study, these sources include residential rain cisterns and general stormwater capture opportunities.

Conservation/Efficiency/Greywater

The expansion of conservation, efficiency, and greywater programs limit the South Coast's total wastewater effluent. As a result, they limit the total amount of urban pollutants that reach marine ecosystems. These avoided costs can also be considered environmental benefits for marine ecosystems.

Additional Considerations

Beyond water production, demand, and costs associated with each possible water supply, the water districts must consider other factors in determining their water supply portfolios. The reliability of each source's production at any time varies widely, depending on climate, geological, technical, and regulatory conditions. Water districts also make decisions for both immediate and long-term goals, and some supply options may be explored or expanded upon in the future as demand increases or legal obstacles are lifted. Finally, the limitations of our analyses include data availability and organization. As more production and financial records become available in future years, and if the data are reported in standardized terms, continuing these analyses will become easier.

Reliability

One of the most important factors of water decision-making is the reliability of supply sources. Most obviously, many South Coast water supplies are recharged through precipitation. These sources are therefore susceptible to precipitation variability. Normal seasonal variability should not impact long-term source reliability, but unanticipated drought conditions can lead to significant shortfalls in regional supplies. Cachuma and other local surface supplies, SWP, residential rain cisterns, and stormwater capture supplies all diminish significantly in drought conditions. If drought conditions persist, groundwater supplies can also be affected. Precipitation-related reliability is at the forefront of district managers' minds in the current climate, but drought is not the only risk factor for South Coast water sources.

In California, earthquakes also pose a serious infrastructure risk to water systems. Water sources with long conveyance systems, such as SWP, are the most vulnerable. However, any source that depends on pipeline infrastructure for extraction, conveyance, treatment, or delivery is vulnerable to seismic events. These include Cachuma and other local surface, groundwater, recycled, potable reuse, and desalination. The impact to the water system as a whole would depend on the magnitude of the seismic event, the specific infrastructure damages inflicted, and the region's capacity to repair damages quickly. Decentralized sources, such as greywater, residential rain cisterns, and conservation/efficiency, cannot provide potable water for the South Coast in earthquake scenarios, but can decrease overall potable demand on the system in times of need.

Water sources that rely on technical machinery, which essentially includes all of the South Coast's centralized sources, are also vulnerable to technical malfunctions. Technical failures can be costly and impactful to regional supplies, such as with Santa Barbara's 2014-15 tertiary replacement for recycled water.

Additionally, many coastal freshwater sources are vulnerable to sea level rise resulting from climate change. For example, groundwater basins may experience saltwater intrusion and coastal infrastructure such as desalination or potable reuse facilities may experience technical failures.

State Water in particular can be unreliable, with a host of factors besides weather affecting this large-scale system. Factors influencing State Water deliveries include floods and potential sea level rise in the Delta, protection of endangered species, and water quality concerns about salinity within the Delta.[297] However, the South Coast’s SWP connection also allows for a measure of flexibility. For example, during the current drought, districts have been able to purchase water from agencies in other parts of the state. SWP infrastructure also facilitates exchanges of Cachuma and State Water between South Coast districts and ID #1; these exchanges reduce costs for both parties to the transaction. Connection to State Water provides a degree of flexibility for South Coast districts, but availability of State Water itself can vary widely on an interannual basis.

Lastly, regulatory and legal obstacles can also prevent the South Coast from pursuing otherwise viable water sources. For example, the State of California has not yet authorized water agencies to implement potable reuse systems. Additionally, some water supplies provide habitat for species protected by the Endangered Species Act. The South Coast's heavy reliance on water from Lake Cachuma leaves it particularly vulnerable to the outcome of the upcoming biological opinion regarding the status of

Southern California steelhead trout in the lake. Changes in regulations can have serious ramifications for the South Coast's long-term water management plans.

Generally, the diversity of the South Coast's water supply portfolio makes it relatively resilient to risk. Individual districts with fewer supply options - such as La Cumbre, which relies solely on SWP and groundwater for its entire portfolio - are more susceptible to unforeseen water supply shortfalls than the region as a whole. Increased regional collaboration would augment the South Coast's resilience to climate, geological, technical, and regulatory risks.

Opportunities for Expansion

The South Coast has a diverse portfolio of water supply options with access to imported water, groundwater, and desalination, among other sources. With predicted uncertainties associated with climate change expected to impact supply production in the long- and short-term, there are several options for potential future expansion of the supply portfolio that should be considered to improve resilience to climate uncertainties. DPR, groundwater conjunctive use, recycled water, and regional market transfers may currently have barriers to be overcome before they can realistically be implemented, but these barriers should be weighed against the overall benefit to increased reliability of water production on the South Coast when making such decisions.

Potable Reuse

Direct or indirect potable reuse, if implemented on the South Coast, would begin to close the loop of the urban water cycle by reducing wastewater discharge that is lost to the ocean. However, the use of recycled water as a direct potable source is not currently legal in California, except in the case of pilot projects. The California Water Action Plan, adopted in 2014 by Governor Brown, lists the increased use of recycled water as one of many supply options needed to put California overall on a path to increased sustainable water management.[298] As of February 2016, the state plans to adopt regulations to assess the feasibility of direct potable reuse by the end of 2016 and continue to provide financial assistance to local water agencies using low-interest loans and Proposition 1 funds.[299] The 2015 RMC supply alternatives study estimates that once the regulatory framework has been developed, implementation of direct potable reuse could occur within the following 10 years.[300]

Groundwater Conjunctive Use

Conjunctive use of groundwater with surface water supplies can provide an effective way of optimizing supply and demand in the context of uncertainty and maximize resiliency.[301] This method of water management also provides additional sustainability to a supply portfolio by allowing the water purveyor to balance production from a given source according to ecological, economic, and physical conditions. Goleta Water District is at a particular advantage for conjunctive use due to the fact that it is adjudicated. Adjudications can costs tens of millions of dollars and take decades to finalize (the action initiating Goleta's Wright Judgment was filed in 1973 and the court decision was not finalized until 1989).[302] Still, conjunctive use is something that water districts with unreliable surface supplies should consider. Future state or county mechanisms may form to help streamline the adjudication process under the objectives of California's Sustainable Groundwater Management Act. Water districts should start by gaining a thorough understanding of their geohydrology in order to accurately determine natural and artificial water balance dynamics.

Recycled Water Demand

One limitation of recycled water is the cost of the purple piping network. Although actual costs vary by landscape, topography, and distance, a rough estimate for the cost of laying purple pipes in an urban environment is $1 million per linear mile.[303,304] Districts may be deterred from implementing or expanding recycled water programs by this high upfront infrastructure cost. However, as climate patterns make other sources less reliable or available, districts may reconsider the cost-benefit assessment of a recycled program to augment potable supply. Demand would also have to be sufficiently high to justify creating or extending the purple pipe network to more customers for non-potable use.

The South Coast Recycled Water Development Plan, contained within the County's 2013 IRWMP, explores the near-term (next 10 years) and long-term (next 20 to 30 years) opportunities for the potential expansion of recycled water use.[305] An estimated 16,038 AFY (14.32 MGD) and 17,158 AFY (15.32 MGD) are the maximum potentially available new recycled water supply in the near- and long-term, respectively, for the South Coast with majority of use for urban irrigation and commercial customers.[306] However, only 67 AFY of near-term demand is projected by the South Coast agencies with an additional 4,854 AFY in the long-term planning horizon, reaching a potential of 6,556 AFY including current recycled water demand.[307]

Since Goleta and Santa Barbara are the only districts that currently produce recycled water and have purple pipe infrastructure, near-term expansion (including only Goleta and Santa Barbara) would increase regional recycled water production to 1,703 AFY with a capital cost of about $19.8 million ($800/AF, not including O&M).[308] It should be noted that since the South Coast Recycled Water Development Plan study began in 2010, Goleta and Santa Barbara's recycled water production for FY 2016 (2,125 AF total) is already expected to exceed the near-term expected production.[309] Long-term additional expansion (not including current or near-term production) would cost an additional about $53.8 million with a 1,899 AFY increase in production ($2,100/AF, not including O&M).[310]

Benefits to the expansion of non-potable recycled water include augmentation of potable supply, improved wastewater and ocean water quality, enhanced water and wastewater efficiency and reliability, and adaption to climate change.[311] Public perception regarding public health and safety concerns, additional water quality constraints required from the agricultural sector, as well as customer viability (e.g. closing business or changing water/water quality demands based on economic/other factors) negatively impact the success and expansion of recycled water programs on the South Coast.[312]

This study does not include a cost-benefit analysis for recycled water expansion on the South Coast, which is an important element of the planning process that must be conducted by each district. It should be noted that the availability of non-potable recycled supply is reduced with increased conservation and efficiency measures and that with the anticipated legalization of IPR and DPR systems in California, wastewater would be a shared water source between the three potential systems.

Conservation and Efficiency Opportunities

Demand-side management through conservation and efficiency measures is an important element of water portfolios, especially during times of drought. Saved water from efficiency measures improves reliability of existing supplies and reduces vulnerability during droughts while lowering energy and financial costs of water treatment as well as new infrastructure.[313]

Many of the South Coast districts have maintained long-term conservation and efficiency programs and have implemented additional programs since the recent drought declaration in 2014. For example, following Goleta's Stage II drought declaration in September 2014, the Water Savings Devices Distribution Program,[314] Smart Landscape Rebate Program,[315] and Water Savings Incentive Program were implemented to help achieve the targeted 25% district-wide water use reduction.[316] During the last drought (1987-92), Goleta's water allocation policy reduced district-wide demand by 28.6%, while Santa Barbara's landscape irrigation restrictions reduced household water demand by 16%.[317] While South Coast districts have implemented participation-based conservation and efficiency programs as well as enforced state-mandated water use reductions, additional programs could be modeled after other districts or municipalities to potentially further decrease water consumption.

Case studies on conservation and efficiency include measures such as WaterSmart Software©, which provides home water reports to district customers using social norms as an impetus for water use behavior change.[318] A pilot study was conducted between 2012 and 2013 through East Bay Municipal Utility District distributing WaterSmart Software© reports to 10,000 homes found savings ranging from 4.6 to 6.6% per participating household, with higher water users at the start of the study observing greater use reductions than households that began with lower use.[319] Albuquerque Bernalillo County Water Utility Authority's low-flow toilet rebate program (1996 to March 2009) observed an average decrease in daily water demand by 37.98, 46.87, and 60.36 gallons for households receiving first, second, and third toilet rebates, respectively, with a decreasing marginal benefit for each additional low flow toilet installed per household.[320] In 2002, the EPA compiled a report of conservation and efficiency case studies throughout the United States. While this EPA study is dated, it could serve as a beneficial resource for water districts building conservation and efficiency programs from scratch.[321]

Although each district operates independently and responds to diverse consumer demands, we investigated the potential benefits of increasing conservation across the whole region to the levels of the lowest per capita consumption rates. As a local example of residential conservation and efficiency potential, we estimated what residential water use would be on the South Coast if each resident used 67.2 GPCD. (67.2 GPCD was Goleta's average residential water use for 2013, including single-family and multi-family. Total water district populations were obtained from the 2013 IRWMP.) At this rate, the South Coast would use 15,782 AFY, substantially less than the 22,702 AF that were actually used in 2013 by the residential customer class. This calculation is purely illustrative, and does not incorporate the feasibility of decreasing water use to this level across the South Coast. Mechanisms that South Coast water agencies have used, or currently use, to achieve greater efficiency include watering restrictions, rebate programs, and ordinance changes (e.g. plumbing code).

Beyond residential conservation and efficiency, the South Coast has additional opportunities to reduce water demand from commercial, industrial, and medical facilities. As a tourist destination, the South Coast has several hotels, golf courses, and commercial buildings. Water districts and managers of these facilities could incorporate successful case studies from across the country and capitalize on significant water demand reductions. Several resources for sharing best management practices exist, such as EPA's WaterSense program.[322]

An often-cited example of improved efficiency on a golf resort is California's Resort at Pelican Hill in Newport Beach. The resort's landscapers installed weather-based irrigation controllers, drip irrigation, high-efficiency rotating nozzles, and rainwater cisterns, as well as reduced turf and increased xeriscaping across the resort's 100 acres. From 2009-10, these changes resulted in a water savings of over 48 million gallons (18% of baseline consumption).[323] Other best management practices for hotels are cited in a case study from a Hyatt Regency hotel in Atlanta, Georgia. Between 2000 and 2013, the hotel reduced water consumption by 35% through improvements to the building's mechanical systems. Major retrofits included increasing the cycles of concentration for their cooling tower, installing air handler condensate recovery systems, and optimizing the energy efficiency of the chiller and boiler systems to reduce the amount of water evaporated from the cooling tower. Additional high-efficiency upgrades in guest rooms and public restrooms further reduced the hotel's water consumption.[324] Given the tourism industry on the South Coast, some of these best management practices may be applicable to local hotels and golf courses, especially as older mechanical equipment reaches the end of its lifetime.

Another relevant case study for reducing water demand in non-residential facilities along the South Coast is Providence St. Peter Hospital in Olympia, Washington. In addition to mechanical system efficiency upgrades similar to the Hyatt Regency case study above, this hospital also retrofitted some water-intensive medical devices with more efficient equipment, thereby eliminating single-pass devices. For instance, steam sterilizers were improved with thermostatic valves to reduce water needed to cool steam condensate, and x-ray equipment devices were added to reuse water. Overall, the Providence St. Peter Hospital saved 5.9 million gallons of water annually between 1999 and 2011.[325]

Considering the potential to save water with retrofits or new devices, medical clinics and laboratories along the South Coast could possibly benefit from adopting some of these strategies. Overall, the volume of best management practices and successful case studies of water-saving projects across the country may reduce individual facilities' utility bills and increase the region's water supply. However, since the usage, purpose, mechanical systems, and financial considerations for each facility widely vary, it is important that broad generalizations for local facilities are not painted. What may be logistically and financially feasible for one building does not necessarily make sense for its neighbor. More individualized cost-benefit analyses are needed to identify the potential for increased non-residential efficiency and conservation efforts on the South Coast.

It is important to note that when examining overall case studies of conservation and efficiency programs, this study has not fully investigated the transferability of these savings to the South Coast. An examination of non-price water conservation programs in seven western US cities (including Los Angeles and San Diego) found that non-price programs reduce demand by anywhere from 1.1 to 4% and effectiveness of programs declines with an increasing total number of programs in a given city.[326] Studies have indicated that in order to quantify the effectiveness of a program, accurate information must be collected about specific program activities, levels of effort, scope and coverage, and the exact periods of program duration corresponding with activities and levels of effort.[327] Participant behavior also impacts the success of conservation and efficiency programs and can result in a "rebound effect," whereby households respond to improved efficiency by changing behavior that increases overall water use.[328]

South Coast Conduit Market Transfers

The districts on the South Coast manage their water resources and deliveries with very distinct hydrogeological regimes, supply portfolios, customer demands, production costs, revenue streams, planning strategies, and governing bodies. Dissimilarities like these can create barriers for district managers to collaborate on centralized planning discussions. However, they also present an opportunity for developing water markets, where an agency with limited supplies, high demand, and sufficient capital could purchase water from another district with more robust supplies and lower demand, provided there is a mechanism through which these transactions can be delivered.

Local transfers such as these are on the rise; transfers within the same county have gone from under 20% of total water transfers from 1987-94 to nearly 50% during 2003-11.[329] For additional discussion of market transfer opportunities on the South Coast, see Appendix M.

Limitations of Analysis

The greatest factor limiting our analysis was data availability. While district data is all technically public, we had to rely on busy district staff members to fulfill our requests for information. In some cases, this meant that data was limited to what was readily available or already digitized. The date ranges for which we obtained data imposed limits on our ability to conduct historical analysis. For supply and demand data, this meant that we were unable to compare patterns between the late 1980's drought and the current one. Within the timeframe that we were able to analyze, differences in water accounting between districts made some comparisons difficult. For example, districts often grouped their consumer classes differently from one another. If more detailed data had been available, we could have grouped these classes more cleanly; the existing data forced us to aggregate classes as best we could.

A unique discrepancy came from the fact that some data was provided on a WY basis, some on a FY basis, and some on a calendar year basis. In some cases, we were able to account for these differences because we had monthly supply and demand data. However, for some sources, reliable aggregated supply numbers were reported only each FY. In a few cases, we had to compromise in order to use the most reliable numbers over a timeframe and year type that best represented the data.

Our conservation and efficiency analysis and discussion were also limited by data and time. This report includes only a few conservation and efficiency options to implement within homes. Future studies looking at the total potential demand reduction on the South Coast would also incorporate efforts in other facilities: commercial and industrial buildings, hotels, hospitals, public parks and recreational spaces, and within the districts' own buildings. Notably, the agricultural sector has been largely excluded from this report. A thorough knowledge of agricultural water use patterns and needs would be a useful supplement to this analysis. Communication and trust between agricultural stakeholders and data gatherers would be essential prerequisites to a study of this sort.

Our urban stormwater runoff estimates were calculated using the curve number method. This method is limited in that it uses empirically derived averages for curve numbers associated with soil classes and percent imperviousness associated with land use types. A sensitivity analysis was conducted to investigate the effect of curve number errors of five units higher and lower than those assumed in our calculations. We found that this error scenario changed the average runoff results by as much as 50% (see Appendix D). Field tests would help calibrate the curve numbers and refine our estimates.

Our financial analysis was mainly limited by the format of the data. Each district accounts for their costs in a distinct way, and in some cases accounting practices change over time within districts. For some districts or sources, costs are broken down neatly into fixed costs, variable costs, debt service, and capital costs. However, such straightforward accounting was the exception rather than the rule. For example, O&M costs generally have both fixed and variable components, but costs were not always broken down on this basis. This type of discrepancy forced us to make assumptions in some cases. Our analysis would have benefitted from having more itemized costs available, but districts may not necessarily even make these calculations if they are not useful to the organization. Given more data and resources, it would also have been useful to calculate costs over a longer time period. Due to data limitations for certain sources, we were unable conduct financial analyses for years prior to 2007.

Our investigation of ecosystem impacts by water source was limited by the unavailability of local quantitative data. First, it is difficult to estimate the extent to which ecosystems are impacted by South Coast water sources. For example, no studies currently exist examining the precise impacts of brine discharge on benthic biota in marine ecosystems in Central California. Since ocean currents, ambient salinity, and ecosystem resilience differ significantly from place to place, biological surveys conducted elsewhere cannot be effectively applied to the Santa Barbara marine ecosystem. Second, the costs of these ecosystem impacts have not been calculated. For example, loss of biodiversity along Santa Barbara's coastline resulting from brine discharge may impact local tourism, but the extent of such an impact is unknown. Since these types of data collection and research were outside the scope of our project, our assessment of ecosystem impacts was limited to a qualitative analysis.

Future Studies

The data collection efforts and findings of this report would benefit from future local studies. As noted above, further cost-benefit and feasibility analyses of non-residential conservation efforts, as well as extended residential conservation efforts, may highlight a greater water demand reduction than the few residential-focused programs included here. Such studies would require in-depth fieldwork and models of stormwater and rainwater capture potential and infrastructure and equipment upgrade costs.

Other recommended studies to supplement these findings include site identifications for injection wells to recharge groundwater basins. These studies would rely on detailed hydrogeological data and fieldwork, as well as site-specific cost estimates. Establishing more injection wells may be financially viable if districts decrease their reliance on surface waters.

Additionally, it is recommended that future studies be conducted to quantify the ecological impacts of South Coast water sources and the cost externalities of those impacts. Some research methods may include distributing surveys to measure contingent valuation of ecosystem services, conducting travel cost analysis to measure ecosystem values through tourism, and/or calculating potential public health impacts of water sources (i.e. the potential for stormwater capture systems to prevent coastal bacterial blooms, thereby reducing bacterial infections in beachgoers). Energy intensity can also be related to greenhouse gas emissions and local air quality. Ecosystem costs and benefits of each source cannot be economically assessed through a readily-accessible model, especially since these effects are site-specific. Some of these studies could further quantify the economic effect of alterations to local ecosystems on the tourism industry.

Conclusions

The data gathered for this study reveal many conclusions for the South Coast. This report's findings include: historical water supply trends; historical water demand summaries; water produced by potential future sources; water sources' financial costs; water sources' energy requirements; and various environmental impacts of water production.

Historical Water Supplies

On the South Coast of Santa Barbara County, Lake Cachuma has historically been the primary water source, providing approximately 62% percent of the total annual supply. However, Lake Cachuma and other local surface reservoirs face significant vulnerabilities, including drought, siltation, and an impending biological opinion for steelhead trout. As local surface supplies have decreased in the current drought, South Coast water districts have supplemented their water needs with imported water and increased groundwater production.

Historical Water Demand

Residential water consumption accounts for the majority of water demand on the South Coast. Agricultural demand appears to be outside the control of the water districts; agricultural water consumption increases when crop prices increase and rainfall decreases.

Lost Water and Potential Future Sources

In a given year, an average of approximately 14,600 AF of treated wastewater is discharged into the ocean from WWTPs across the South Coast. This water could be captured through a variety of different programs. IPR and/or DPR facilities could accompany each WWTP, yielding an additional 12,400 AFY in potable water supplies (after 15% is lost in the advanced treatment process). Furthermore, greywater systems and conservation and efficiency measures could decrease the amount of water sent to WWTPs, thereby reducing water demand and also reducing wastewater effluent. Greywater systems, if implemented across the South Coast, could reuse between 1,100 and 3,400 AFY. There is a vast array of conservation and efficiency programs that could further decrease water demand. Specific examples modeled in this study include washer rebate programs, which could alone yield about 1,250 AFY in water savings, and lawn conversions, which could alone yield about 350 to 2,400 AFY in water savings.

Overall, an average 74,100 AF of precipitation falls onto the South Coast each year. An estimated 200 to 600 AFY of this precipitation could be captured and used on-site through residential rain cisterns. Approximately 7,000 AFY of urban stormwater runs off of South Coast land surfaces and into the ocean in an average year. Captured stormwater could be recharged into groundwater aquifers through spreading basins, over unconfined portions of the aquifers, or via injection wells. If 10% of this water could be captured and added to groundwater supplies, it would yield an additional 700 AFY. LID expansion across the South Coast could help decrease stormwater runoff as well, though not all LID projects would result in additional aquifer recharge due to the lack of hydraulic connectivity throughout most of the developed region.

Lastly, the South Coast loses water each year through pipe leaks in its infrastructure. An estimated 900 to 2,700 AFY is lost at the household level, with an additional 800 to 4,000 AFY at the district level. Some of this water loss is inevitable, due to lack of resources for infrastructure replacement and maintenance. However, smart meters may help to identify some of these leaks and target pipe replacement efforts.

Financial Costs

Variable and full-system cost analyses tell two different stories for the cost of water on the South Coast. Variable cost analyses, which include costs that vary depending on how much water is produced from each source in a given year, yield wide and overlapping cost ranges without major cost differences between sources.

Full-system cost analyses, which include all of the costs that the districts are paying for each source in a given year (including fixed costs and debt service), yield different results. When these costs are accounted for, the two least expensive sources appear to be recycled (tertiary) and conservation/efficiency. The three most expensive water sources appear to be potable reuse, desalination, and SWP. Some years, SWP full-system costs can be up to five times as expensive as any other source.

Energy Requirements

Decentralized sources, such as greywater and residential rain cisterns, have the lowest energy requirements on the South Coast. Potable reuse, SWP, and desalination have the highest energy intensities of all sources, meaning that the most expensive water sources are also the most energy-intensive. These energy requirements have long-term cost and environmental implications.

Environmental Impacts

The energy intensities of South Coast water sources also translate to greenhouse gas emissions. Even when considering total water production volume, potable reuse, desalination, and SWP remain the highest greenhouse gas emitters (or potential emitters, since potable reuse and desalination have not yet been activated).

Different water sources also have significant marine and freshwater ecosystem impacts. For example, both desalination and potable reuse will impact coastal marine ecosystems through brine discharge. However, the biological extent and cost of these external impacts are currently unknown.

Recommendations

The South Coast of Santa Barbara County is in a unique position in that it has a diverse portfolio of water supply options. Local water agencies face a multitude of water management decisions and opportunities. Below are some of the major takeaways from the project:

I. **South Coast water agencies should explore the feasibility, costs, and benefits of potential future water sources outlined in this study.** With their differing demographics, infrastructure and natural water resources, some strategies may be more appropriate than others. For example, Santa Barbara may be particularly well-equipped to implement potable reuse, since they will already have reverse osmosis infrastructure within the desalination facility.

II. **Fixed costs should be transparent and factored into decision-making processes.** Fixed costs can have significant impacts on how a water source's full system costs compare to other sources. For example, SWP fixed costs make it the most expensive water supply option on the South Coast. While districts may not be able to avoid paying some of these fixed costs, such costs still play an important role. Fixed costs contribute to the price of water, and rate payers have an interest in the sources of these costs. Additionally, other water districts investigating alternative sources to their current supplies would benefit from full system cost data. Locally, this information can be used to inform South Coast districts' long-term planning, including contract renewals and infrastructure renovation.

III. **Local water agencies should note, for long-term planning purposes, that the most expensive water sources on the South Coast are particularly vulnerable to fluctuations in energy prices.** Since energy prices across Southern California are expected to rise through the next few years, water agencies should anticipate that the variable costs of these water sources will also rise. The energy-water nexus is generating more interest from researchers and planners, and will be a growing topic of consideration for water decision-makers statewide.

IV. **Identifying externalized environmental impacts of water decisions will enable water agencies to make more informed decisions.** Since these environmental externalities impose costs on the region as a whole, regional collaboration will be required to address solutions. For example, marine impacts from various sources may have direct consequences for the local tourism industry and influence a wide variety of stakeholders across district boundaries.

We recommend the identification and quantification of these costs to the greatest extent possible.

Regional Collaboration

There are untapped opportunities for collaboration between South Coast water agencies and increased public transparency. Individual agencies and the public can reap considerable benefits from regional knowledge-sharing and data management.

First, improved communication can highlight ***best practices*** within individual agencies. Despite having different natural resources and water demands, there are many similarities between South Coast water agencies. Improved data-sharing and collaborative regional planning would help identify which programs have been successful on the South Coast, and how other districts can implement similar programs. For example, Santa Barbara has a robust conservation management program. Neighboring water districts aiming to create or strengthen their conservation programs should use Santa Barbara's model as a foundation.

Second, data-sharing will allow districts to more easily identify opportunities for regional ***market transfers***, potentially through the South Coast conduit. Streamlining these types of transactions would decrease water costs for the region as a whole, and could save individual districts from investing in expensive infrastructure projects to supplement gaps in their own portfolios.

Third, streamlined data management and increased inter-agency communication can serve an important role in ***public transparency***. Water customers, who are key stakeholders in regional water decisions, can more easily engage with districts if water data is transparent and readily available. The public plays an important role in advocating for concerns that may not be reflected in cost decisions. Environmental externalities, for example, are often left unaddressed without noisy and engaged public advocates. Inevitably, increased public participation will yield more robust and responsible water decision-making.

We recommend the following two actions for knowledge-sharing and collaboration across South Coast water decision-makers:

I. ***Create common reporting standards across the South Coast.*** Unit measurements, year types (calendar, fiscal, or water year), and budget elements vary across the water sources and agencies. Common reporting standards would streamline regional communication and technical analysis.
II. ***Maintain the South Coast Regional Water Database.*** As a culmination of our data collection, we created an Excel-based regional water database to track historical water production, metered sales, rate structures, and other key programs across the South Coast. We recommend that South Coast water agencies maintain this regional water database. It can serve as a tool for inter-

agency communication and public transparency, as well as a resource for identifying opportunities for market transfers.

Water supply planning is influenced by a varied and often unpredictable set of elements. Weather and climate, financial constraints, economic conditions, and legal framework all come into play as water managers make supply choices. Diverse and resilient water portfolios can help mitigate some of the inevitable uncertainties that districts face. Several of the options outlined in this report have the potential to increase the supply and flexibility of South Coast portfolios, as could greater knowledge-sharing and cooperation between districts. While many water choices come down to financial comparisons, there are options for cost reductions on the South Coast. There is also room to consider the environmental impacts of these decisions, and limit externalities when possible. A range of water supply options are available to South Coast decision makers. These options, along with regional collaboration efforts, can enhance water portfolios, helping the South Coast manage its water resources in a changing climate.

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Appendix A: Rate Structures

Introduction

In order to better analyze water issues on the South Coast, it is important to address the cost of water for consumers, and not only for districts. Water rates and water rate structures can play a vital role in incentivizing (or discouraging) conservation. This section will provide an overview of rate structures throughout the region. The focus here is primarily on the ability of each structure to promote conservation. A more complete analysis of the rate structures would include information about how well the rates function in terms of meeting the budgetary needs of the districts, but such questions are beyond the scope of this project.

Increasing Block Rate Structure

Increasing block rate structures involve billing at higher rates as more water is used, with the increases occurring at set points, and uniform rates within each of these tiers. There may also be fixed fees in addition to the volumetric rates. Goleta Water District, City of Santa Barbara, Montecito Water District, Carpinteria Valley Water District, and La Cumbre Mutual Water Company all use increasing block rate structures. This type of rate is generally considered to be the most effective at incentivizing conservation and is used widely in California. However, these rates can be difficult to implement, and not all increasing block rates are necessarily effective, especially when customers have low price sensitivity.[1] While each district on the South Coast uses the same type of rate structure, their systems still differ from one another substantially.

Considerations for Rate-Setting

In setting rates, the utility must ensure that pricing will cover their costs. Beyond this, pricing may include consideration of externalities or future operations.[2] Prices that are too low result in excessive and/or inefficient water use.[3,4] When setting tiered rates, it is important that blocks are set to the most efficient width. One example of an effective block structure would be to delineate the first block based on efficient indoor use, the next on efficient landscape use, and then on less efficient or even wasteful use.[5] Smaller blocks send stronger price signals, and as do larger increases between blocks. High fixed charges can interfere with these price signals, although they are attractive because they provide stable income for utilities.[6]

Analysis of Districts in the Santa Barbara Area

Notes and Assumptions

The following section looks into the rate structures of local water districts, with a focus on single-family residential rates. There are several caveats with this analysis. First, these evaluations do not evaluate the rates' performances in terms of how well they provide income to the districts. In addition, in any comparisons of the districts, it is important to remember that they have inherent differences in supply sources, infrastructure, and customer bases – all these factors make perfect comparisons impossible and impractical. However, it is still useful to take a closer look at the rate structures on the South Coast.

Current Rate Overview

Tables listing each component of the current water rates (as of January 2016) provide a complete picture of water rates for each district (Tables 13-17). Graphical representations of tiered rates allow for an at-a-glance comparison of single-family residential rates (Figure 15). It is important to note that this figure includes only variable charges, not fixed charges, which are generally substantial.

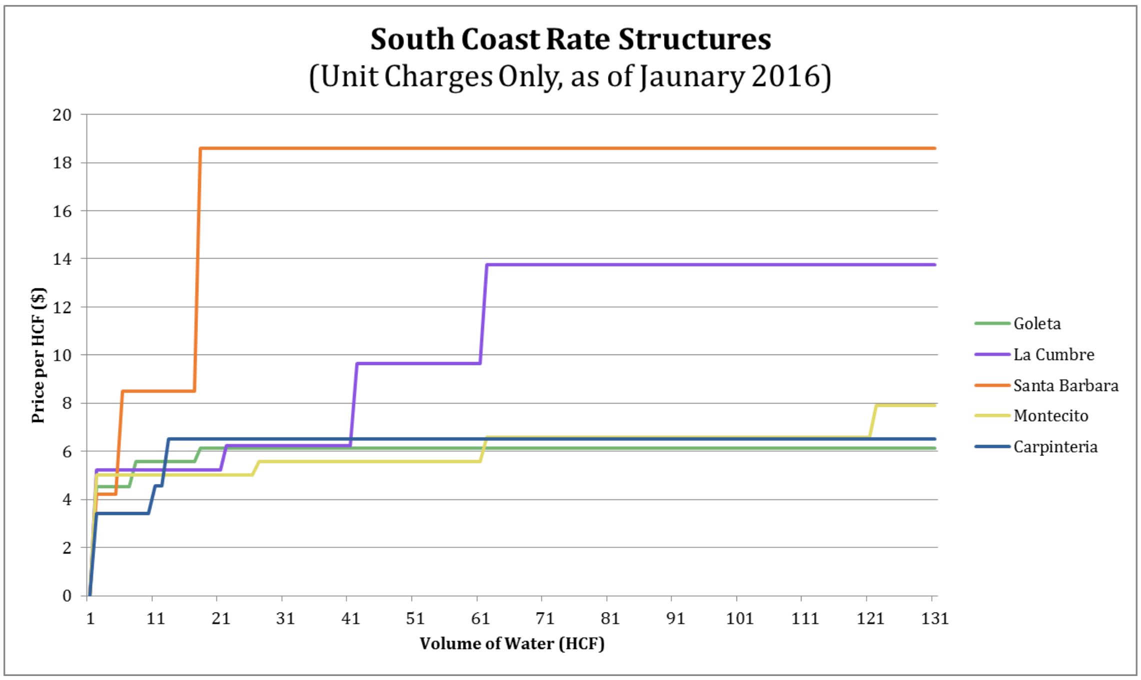

Figure 15. South Coast rate structures. This graph shows unit costs of water for single-family residences. Fixed costs are excluded from this graph. Since Carpinteria bases its rates on average use by account, this graph assumes a first tier amount of 9 HCF as an average base tier. As noted in the text, La Cumbre is the only district to bill bi-monthly. To accurately compare to other districts, tier widths for La Cumbre have been divided in half (assuming that use would be split evenly over each month in the billing period).

Goleta Water District: Goleta uses both fixed rates and unit rates in its billing. Goleta is unique in the region in that it uses tiers in its fixed rates as well as its variable rates. Fixed service fees are based on meter size, and residential customers in Goleta may fall into one of three tiers for fixed charges. Approximately 30% of the District's revenue comes from fixed rates.[7] The tiered fixed rate system can result in sudden large changes in the amount paid by customers, which creates an incentive for customers to stay in a lower fixed-rate tier. Unit costs in Goleta also have three tiers, separated in price by less than two dollars (Table 13). In other sectors, there are no tiers or allotments; water is billed at a uniform rate.

Table 13. Goleta Water District Rates, as of July 1, 2015.[8]

Goleta		
Water rates, or commodity charges, are billed according to the amount of water used by each type of customer, and are measured in HCF's (Hundres Cubic Feet, 1 HCF = 748 gallons). Fixed meter charges are based on the size of a customer's meter. (Effective July 1, 2015)		
Commodity Charges ($ / HCF)		
Single Family Residential	First 6 HCF each month	$4.52
	Next 10 HCF each month	$5.57
	All additional HCF each month	$6.12
Urban (includes Multi-Family Res., Commercial, Institutional, and Landscape Irrigation)		$5.25
Recreation Irrigation		$5.25
Urban Agriculture		$1.80
Goleta West Conduit		$1.35
Recycled		$3.26
Fixed Meter Charges ($ / Month)		
5/8" & 3/4" Meters (based on individual month's water use)	Ultra-Low Flow (6 HCF or less)	$14.14
	Low Flow (7-16 HCF)	$29.20
	All other 5/8" & 3/4" Meters	$44.40
1"		$68.16
1 1/2"		$127.57
2"		$198.85
3"		$424.58
4"		$757.23
6"		$1,672.04
8"		$2,860.09
10"		$4,523.38
Fire Line Charge		$9.44
Drought Surcharges per HCF*		
Stage 3		$2.60
*Drought surcharges apply uniformly to all customers except for use of recycled water that is subject to the Recycled Water Rates set forth above.		

La Cumbre Mutual Water Company: La Cumbre is the only local agency that bills bi-monthly. In order to compare with other districts, we divided their tier widths in half. Fixed rates are based on meter size, with some reductions for very low volume users. Per-unit costs are based on fixed tiers for residential and agricultural users. These tiers are quite wide (20 HCF on a monthly basis, or 40 HCF on a bimonthly basis), with the price increases between tiers ranging from about one dollar to four dollars (Table 14). Similar to Montecito, La Cumbre provides water to some higher-use customers with relatively large properties, who may be less price-sensitive than other customers in the region. Commercial users, schools, and golf courses have a base allocation calculated using average use, and an additional tier for purchase beyond that allocation.[9]

Table 14. La Cumbre Mutual Water Company Rates, effective July 1, 2015.[10]

La Cumbre		
Water Rates per Hundred Cubic Feet, HCF - (1 HCF = 748 gallons), per two months. (Effective July 1, 2015)		
Commodity Charges ($ / HCF)		
Single Family Residential	Tier 1 (0-40 HCF)	$5.24
	Tier 2 (41-80 HCF)	$6.25
	Tier 3 (81-120 HCF)	$9.66
	Tier 4 (>120 HCF)	$13.74
Commercial	Tier 1 (for 100% of 3 year average ('06-'08) on a bi-monthly average)	$5.24
	Tier 3 (for any usage above 3 year average)	$9.66
Multi-Family Residential	Tier 1 (for 0-18 HCF/Dwelling unit/billing period)	$5.24
	Tier 2 (for 19-60 HCF/Dwelling unit/billing period)	$6.25
	Tier 3 (for over 60 HCF/Dwelling unit/billing period)	$9.66
Schools & Golf Courses	Tier 1 (for 100% of 3 year average ('06-'08) on a bi-monthly average)	$5.24
	Tier 3 (for any usage above 3 year average)	$9.66
Agricultural	Tier 1 (for the first 40 HCF per bi-monthly billing period)	$5.24
	Tier 2 (for <= 870 HCF/agricultural acres/twelve month period	$3.92
	Tier 3 (for >870 HCF/agricultural acres/twelve month period)	$9.66
Bi-Monthly Meter Charges & Connection Charge		
"A" less than 50 HCF/Yr*		$14.00
"B" less than 100 HCF/Yr*		$28.00
3/4"		$42.00
1"		$70.00
1 1/2"		$140.00
2"		$224.00
3"		$420.00
4"		$700.00
Fire Sprinkler System (2" and under)		$29.40
Fire Sprinkler System (over 2")		$58.80
Private Fire Hydrant		$29.40
*This special bi-monthly charge is for 3/4" services that used less than the noted HCF for the previous year beginning on the last working day in December. (Effective Jan. 1, 2000)		
**Connection charge may be higher if job is determined by management to be significantly more costly to install than a typical installation.		

City of Santa Barbara: Santa Barbara uses increasing block rates for residential customers, and charges fixed rates based on meter size. The increases between tiers for the residential sector are quite steep, with an increase of about ten dollars between the second and third tiers (Table 15). Their third tier has by far the highest variable rates on the South Coast, theoretically providing the greatest conservation incentive. Santa Barbara's tiers are narrow in comparison to La Cumbre or Montecito. Nonresidential sectors are billed based on a simple budgeted allocation.

Table 15. City of Santa Barbara water rates, effective July 2015.[11]

Santa Barbara		
Water Rates per HCF (1 HCF = 748 gallons). (Effective July 2015)		
Commodity Charges ($ / HCF)		
Single Family Residential	First 4 HCF	$4.20
	Next 12 HCF	$8.51
	All other HCF	$18.59
Multi-Family Residential	First 4 HCF (per dwelling unit)	$4.20
	Next 4 HCF (per dwelling unit)	$8.51
	All other HCF	$18.59
Commercial / Industrial	100% of Monthly Water Budget	$6.53
	All other HCF	$15.24
Irrigation - Residential & Commercial	100% of Monthly Water Budget	$8.51
	All other HCF	$18.59
Irrigation - Recreation / Parks / Schools	100% of Monthly Water Budget	$3.70
	All other HCF	$18.59
Irrigation - Agriculture	100% of Monthly Water Budget	$2.43
	All other HCF	$18.59
Recycled Water	All HCF	$2.96
Outside City Limits	130% of corresponding in-City rates	
Monthly Meter Charges		
5/8"		$23.49
3/4"		$34.19
1"		$55.61
1 1/2"		$109.14
2"		$173.38
3"		$376.82
4"		$676.61
6"		$1,393.98
8"		$2,571.74
10"		$4,070.71

Montecito Water District: The Montecito Water District serves a unique set of customers, many of whom have large estates and high water use. The district uses fairly straightforward fixed meter charges and tiered rates for their customers. Compared to many other tiered structures, Montecito's rate structure has relatively flat tiers, with less than a three dollar increase from the first to fourth tier (Table 16). The tiers are also quite wide: first tier includes the first 25 HCF, the second includes the next 35 HCF, the third includes the next 60 HCF, and the fourth includes anything in excess of 60 HCF. Many of Goleta and Santa Barbara's customers would never use over 25 HCF per month; however, some of the high-volume users in Montecito certainly do fall into the higher tiers. In addition, many of Montecito's biggest water users are relatively price-insensitive. During the current drought, Montecito has turned to mandatory water allocations with steep fines for noncompliance in order to curb water use.[12] Commercial, industrial, and agricultural customers in Montecito have tiers based on allocations.

Table 16. Montecito Water District Rates (Fiscal Year 2015).[13]

Montecito		
As of July 2015		
Commodity Charges ($ / HCF)		
Single Family Residential	Block 1 (0-25 HCF)	$5.03
	Block 2 (26-60 HCF)	$5.57
	Block 3 (61-120 HCF)	$6.57
	Block 4 (121+ HCF)	$7.91
Multi-Family Residential/DU (DU=Dwelling Unit)	0-9 HCF/DU	$5.03
	10-30 HCF/DU	$5.57
	31+ HCF/DU	$6.57
Commercial	3 YR AVG Month Base Allotment	$5.57
	Over Base Allotment	$6.57
Institutional & Public Use	3 YR AVG Month Base Allotment	$5.57
	Over Base Allotment	$6.57
Agriculture	Domestic/DU (20 HCF/DU)	$5.03
	Ag 1 (=< 870 HCF/Acre/Year)	$2.80
	Ag 2 (> 870 HCF/Acre/Year)	$5.03
Monthly Meter Charges		
3/4"		$41.52
1"		$69.22
1 1/2"		$124.57
2"		$221.45
3"		$498.27
4"		$830.45
6"		$1,384.08

Carpinteria Valley Water District: Carpinteria's rates are structured somewhat differently than other local districts. First, their fixed costs are broken into multiple components. In addition, there are semi-variable charges for capital improvements and drought that apply per HCF of water used – users are charged these fees for at least 6 HCF, but no more than 100 HCF. Per-unit rates for all sectors are tiered in Carpinteria. However, unlike the other rates discussed so far, the tiers are determined using a base allocation. This allocation is calculated as the 5-year December through March average consumption per account, with a minimum allocation of 6 HCF per month (Table 17). The second tier is 20% of the width of the base allocation, and the third includes any additional use. In order to compare across districts, we considered the base amount to be 9 HCF (per recommendation by CVWD staff).

Table 17. Carpinteria Valley Water District rates, as of July 2015.[14]

Carpinteria				
As of July 2015				
Commodity Charges ($ / HCF)		**Basic**	**Pressure Zone I: Connections served by Gobernador Reservoir**	**Pressure Zone II: Connections served by Shepard Mesa Tank**
Residential	BASE (5 year Dec. to March water consumption by acct/dwelling unit; 6 HCF Minimum	$3.40	$3.66	$3.84
	MID LEVEL (20% of BASE volume)	$4.55	$4.81	$4.99
	PEAK (all consumption in excess of BASE + MID LEVEL)	$6.50	$6.76	$6.94
Commercial, Industrial & Public Authority	BASE	$3.40	$3.66	$3.84
	MID LEVEL	$4.55	$4.81	$4.99
	PEAK	$6.50	$6.76	$6.94
Agricultural/Irrigation	TIER 1 (100% of 5 year average monthly consumption or pre-defined water need based on land use activity)	$1.92	$2.18	$2.36
	TIER 2 (20% of TIER 1)	$2.25	$2.51	$2.69
	TIER 3 (all consumption in excess of TIER 1 + TIER 2)	$2.50	$2.76	$2.94
Residential Equiv. Charge ($/month)		$24.66	$24.66	$24.66
Monthly Meter Charges	**Basic Service Charge**	**SWP Service Charge**	**Drought Surcharge**	**Total Service Charge**
5/8"	$5.63	$30.00	$2.25	$37.88
3/4"	$5.63	$30.00	$2.25	$37.88
1"	$9.38	$50.00	$3.75	$63.13
1 1/2"	$18.75	$100.00	$7.50	$126.25
2"	$30.00	$160.00	$12.00	$202.00
3"	$60.00	$320.00	$24.00	$404.00
4"	$93.75	$500.00	$37.50	$631.25
6"	$187.50	$1,000.00	$75.00	$1,262.50

Customer Payments Across Districts

Price differences were also analyzed from the perspective of residential bills. Figure 16 illustrates how a resident's bill would change depending on water use in each district. This allows one to see how the price of water differs across the districts. Although this comprises only one facet of a complex issue, it provides a useful overview of South Coast water pricing overall.

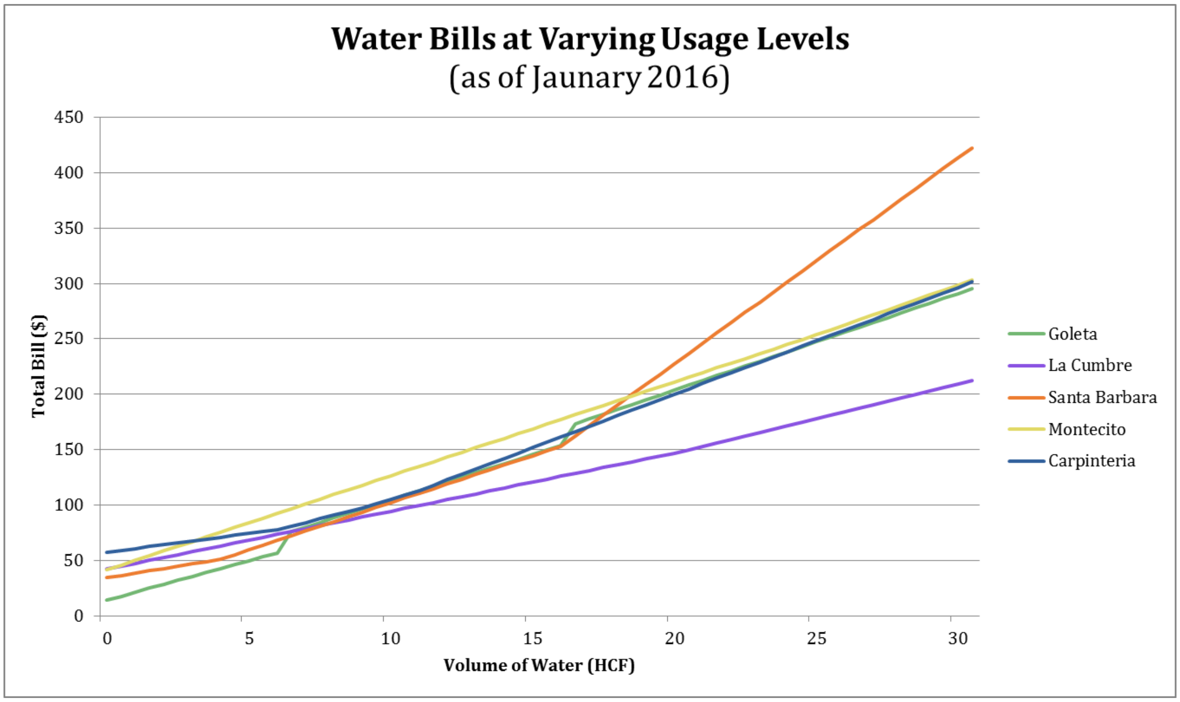

Figure 16. Monthly water bills by district on the South Coast. Amount billed is shown across a range of usage levels, from 0-30 hundred cubic feet (HCF). Calculations assumed a single-family home with a ¾" meter, and excluded sewer rates and effects of household size. Rate data was obtained from each water district's website.

Payments were calculated based on the rate structures of each district. For the sake of simplicity, several assumptions have been made. First, only single-family homes were considered, at a 3/4" meter size. Additionally, units were kept in hundred cubic feet (HCF), both because customers are billed in HCF and to eliminate the additional step of calculating gallons per capita per day (GPCD). While GPCD can be a more useful measure of water use than HCF, using GPCD would require incorporating household size into the calculations. The areas being examined have different household sizes, and household size has an extremely large impact on HCF used per month. Therefore, to keep these convoluting factors out of the analysis, bills were calculated based solely on HCF used, regardless of the number of people in a household. Sewer rates were also excluded from this project. The result is that one can compare the price that customers in each district would pay for the same amount of water.

Four out of the five South Coast water providers have changed their water rates in response to the drought, resulting in some substantial changes to customers' water payments. Overall, bills now increase more steeply as water use increases. This provides both an additional conservation incentive and more reliable revenue to districts which are now selling less water and seeing greater costs associated with the drought. Figure 17 illustrates the increases in customer bills (similar to Figure 16), broken down by district.

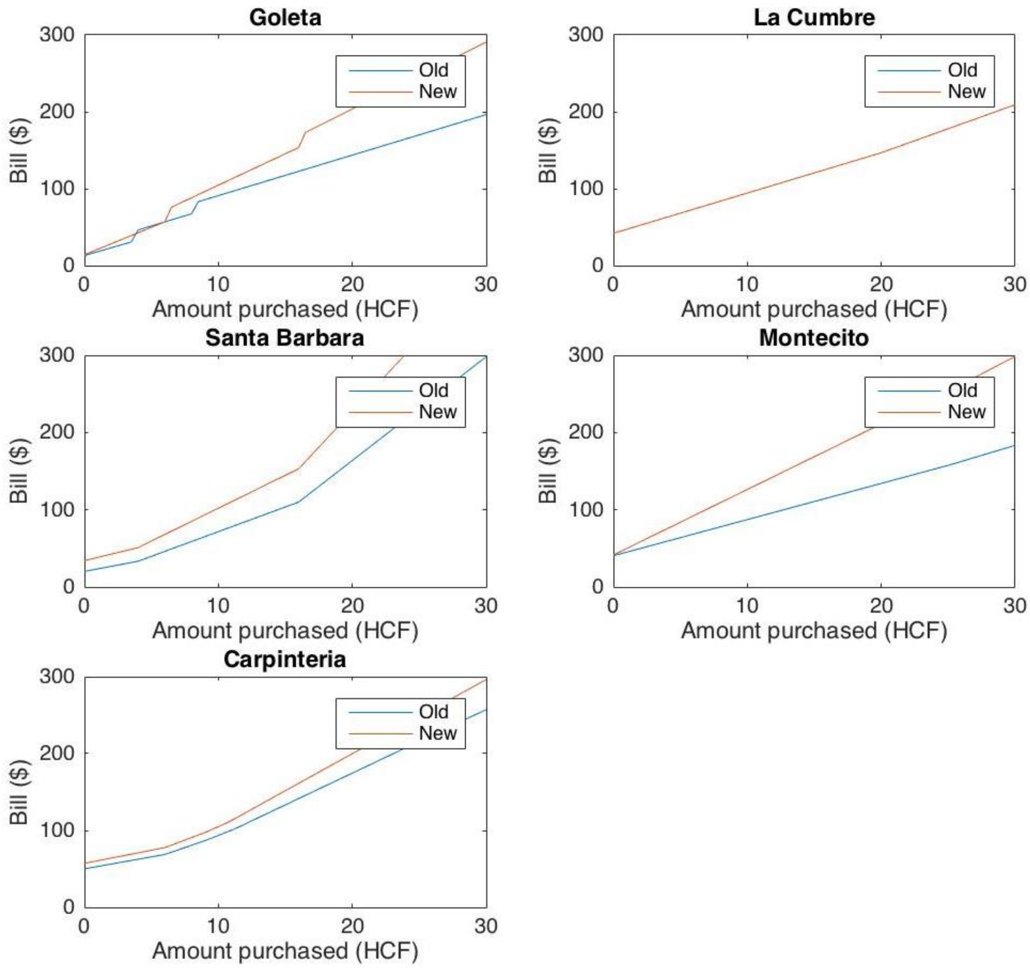

Figure 17. Monthly water bills by district on the South Coast, comparing "old" rates (prior to summer 2015) and "new" rates (July 2015 or later). Amount billed is shown across a range of usage levels, from 0-30 hundred cubic feet (HCF). Calculations assumed a single-family home with a ¾" meter, and excluded sewer rates and effects of household size. Rate data was obtained from each water district's website. Note that only one line appears on the La Cumbre graph because their rates did not change.

Goleta customers see large jumps in their water bills based on the tiered fixed rates both before and after the drought. Notably, Goleta has increased the size of the first fixed tier from 4 to 6 HCF. The result is that for some low water users, bills have increased, and for others, bills have decreased. As with most other districts, newer rates result in water becoming more expensive more quickly.

La Cumbre is the only water provider whose rates have not changed due to the drought.

Santa Barbara's rates have kept the same overall structure, with the tiers remaining at the same width, but the variable rates increasing. The kinks created by the rate increases are clearly visible in the graph. High water users in Santa Barbara will see extremely steep increases in their bills once they reach the third tier.

Before the current drought, Montecito had a rate structure that made water relatively inexpensive for high water users. In response to the drought, Montecito has raised their rates, but maintains extremely wide tiers (most of which are beyond the extent of this figure).

Carpinteria's rates have changed relatively little, but follow the same general trends as the other districts. As previously stated, this graph was produced using a base water allocation of 9 HCF, and would differ depending on that base allocation. The second tier was narrowed in response to the drought, from 25% of the base allocation to 20%.

Average Cost per HCF Analysis

The next analysis was of average cost of water per HCF at differing levels of use (Figure 18). This is useful for visualizing the way rates incentivize conservation.[15] If, after a certain point, the average cost per unit begins to increase, this sends a strong price signal to the consumer that using more water may not be in their best financial interest (although, depending on the role of water in maintaining their property values, this may not always be the case). If the average cost of water continues to fall as more water is purchased, this provides less of a conservation incentive.

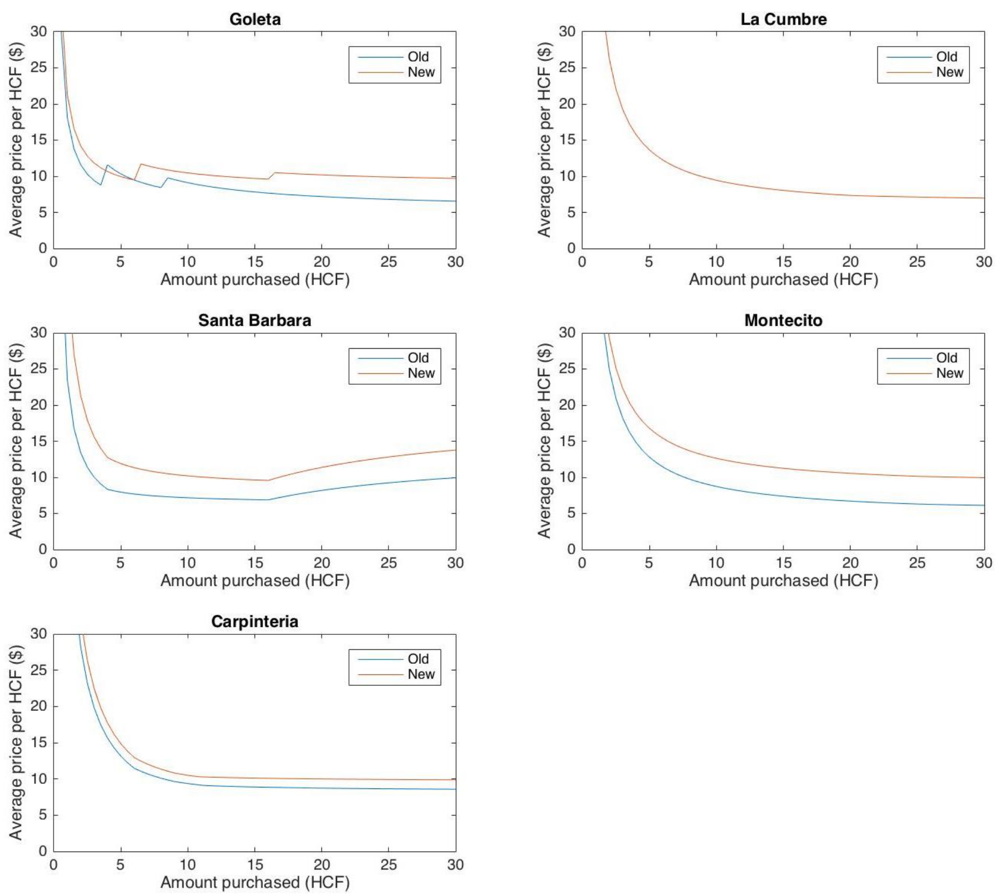

Figure 18. Average cost per HCF of water in each district, based on monthly usage. Cost is shown across a range of usage levels, from 0-20 HCF. Calculations assumed a single-family home with a ¾" meter, and

excluded sewer rates and effects of household size. Rate data was obtained from each water district's website.

As Goleta residents purchase more water, the average cost per HCF decreases, with the exceptions occurring at the thresholds of the fixed-rate tiers. Therefore, for users who are already in the highest tier, incentive to conserve could be reduced. Average price overall has increased in response to the drought.

Residential customers in La Cumbre, Montecito, and Carpinteria also see a decrease in the average cost of water as they purchase more across all tiers. Price overall has increased with new rates in Montecito and Carpinteria, but the general trends of average price per HCF remain.

Santa Barbara provides the exception to the pattern set by the other water districts. In tiers 1 and 2, the purchase of additional water decreases the average cost per unit overall. However, once the third tier is reached, the average cost of water begins to increase. This provides a strong price signal to the customer.[16]

Conclusion

Water rate structures vary on the south coast of Santa Barbara County, and they also vary in their ability to incentivize conservation. Fixed charges are often high, and price increases between tiers are often relatively low. Reevaluation of these elements could help some districts send stronger price signals for conservation. However, there are no one-size-fits-all solutions. The customer bases of these districts are dissimilar, including agricultural interests, water-conscious residents, and wealthy residents who respond poorly to price signals. Additionally, the districts get water from many sources with varying costs. Despite these complicating factors, this elementary look at rate structures would seem to indicate that districts are responding to the drought in a way that will increase conservation incentives and better reflect the cost of water supply.

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[1] Western Resource Advocates. 2004. "Water Rate Structures in Colorado: How Colorado Cities Compare in Using this Important Water Use Efficiency Tool." Western Resource Advocates, Colorado Environmental Coalition, Western Colorado Congress. http://www.westernresourceadvocates.org/media/pdf/Colorado%20Water%20Rate%20Structures.pdf

[2] U.S. Environmental Protection Agency. 2012. "Pricing Structures [Data & Tools]." http://water.epa.gov/infrastructure/sustain/pricing_structures.cfm

[3] Western Resource Advocates. 2015. Water Rate Structures. http://www.westernresourceadvocates.org/water/rates.php

[4] U.S. Environmental Protection Agency. 2012. "Pricing Structures [Data & Tools]." http://water.epa.gov/infrastructure/sustain/pricing_structures.cfm

[5] U.S. Environmental Protection Agency. 2012. "Pricing Structures [Data & Tools]." http://water.epa.gov/infrastructure/sustain/pricing_structures.cfm

[6] U.S. Environmental Protection Agency. 2012. "Pricing Structures [Data & Tools]." http://water.epa.gov/infrastructure/sustain/pricing_structures.cfm

[7] Goleta Water District. 2014. "Fiscal Year 2014-15 Final Budget." http://www.goletawater.com/rates-bills-and-budget/water-rates-and-meter-

charges/http://www.goletawater.com/assets/documents/finance/FY2014-15_BUDGET_FINAL%20-%20Web.pdf

[8] Goleta Water District. 2015. "Current Water Rates and Meter Charges."

[9] A note on La Cumbre's tier numbers for commercial, schools, and golf course accounts: while only two tiers were listed on the website, they were labeled as "Tier 1" and "Tier 3." This may be the product of a typographical error, here they are referred to as the first and second tiers.

[10] La Cumbre Mutual Water Company. 2015. "Water Rates and Charges." http://lacumbrewater.com/

[11] City of Santa Barbara. 2016. "Water & Wastewater Rates." http://www.santabarbaraca.gov/gov/depts/pw/resources/rates/wtrsewer/default.asp

[12] Montecito Water District. 2014. "Drought Program Summary." http://www.montecitowater.com/drought-program.htm

[13] Montecito Water District. (n.d.) "Billing Information." http://www.montecitowater.com/billing.htm

[14] Carpinteria Valley Water District. 2015. "Rates & Fees." http://www.cvwd.net/customer_service/billing/rates.htm

[15] Western Resource Advocates. 2004. "Water Rate Structures in Colorado: How Colorado Cities Compare in Using this Important Water Use Efficiency Tool." Western Resource Advocates, Colorado Environmental Coalition, Western Colorado Congress.

[16] Western Resource Advocates. 2004. "Water Rate Structures in Colorado: How Colorado Cities Compare in Using this Important Water Use Efficiency Tool." Western Resource Advocates, Colorado Environmental Coalition, Western Colorado Congress.

Appendix B: Greywater Analysis

Table 18. Water demand and usage assumptions for greywater produced from washers. Source: Pacific Institute's WECalc.

Clothes Washers

Water Use

Date range	*Type*	*gals/load*	*Source*	*Notes/explanation*
pre-1980s	All	56	7	
1980-1990	All	51	7	
1990-1998	All	41	7	
1998-2001	Conventional	41	7	
1998-2001	High Efficiency	27	7	
2001-2007	Conventional	39.2	1	Data is for "typical" clothes washer.
2001-2007	High Efficiency	24.2	3	Gals/load for this date range was assumed to be the same as gals/load in 2003.
2007-present	Conventional	31.1	2	
2007-present	High Efficiency/ENERGY STAR	14.4	2	
Don't know		40.9	4	Mean volume per load in Mayer et al. (1999).

Rinse type water use

	Rinse type	*Additional water use*	*Source*	*Notes/explanation*
	Single	0		We assume that water use of washing machine is based on 1 rinse cylce, and that the washing machine drum is filled up once to wash, once to rinse, once for second rinse.
	Double	50% more water used		

Utilization

	Loads/capita/day		*Source*	
	0.37		4	Calculated from reported 15 gallons of water per capita per day used for clothes washers, and average 40.9 gallons per load.

Clothes Washer Sources:

1. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE). (2001). Energy Conservation Program for Consumer Products: Clothes Washer Energy Conservation Standards; Final Rule. Retrieved July 2009 from http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/clwshr_rule.pdf.
2. ENERGY STAR. (2009). Lifecyle cost estimate for ENERGY STAR qualified residential clothes washer(s). http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerClothesWasher.xls
3. Gleick, Peter, Dana Haasz, Christine Henges-Jeck, Veena Srinivasan, Gary Wolff, Katherine Kao Cushing, Amardip Mann. (2003). Waste Not, Want Not: The Potential for Urban Water Conservation in CaliforniaDana Haasz, Christine Henges-Jeck, Veena Srinivasan, Gary Wolff, Katherine Kao Cushing, Amardip Mann.
4. Mayer P. W., W. B. DeOreo, E. M. Opitz, J. C. Kiefer, W. Y. Davis, B. Dziegielewski, and J. O. Nelson. (1999). Residential end uses of water. American Water Works Association. Summary available at http://www.aquacraft.com/Publications/resident.htm.
5. NexTag product search engine. Retrieved July 2009 from http://www.nextag.com/serv/main/buyer/OutPDir.jsp?search=energy+star+clothes+washer&psort=1.
6. Pers.comm., P.J. Biermayer, Lawrence Berkeley National Laboratory.
7. Vickers, Amy. (2001). Handbook of Water Use and Conservation. Water Plow Press, Amherst Massachusetts.

Table 19. Water demand and usage assumptions for greywater produced from showers. Source: Pacific Institute's WECalc.

Shower

Flow Rate

Year/type	*Rated flow (gal/min) Range*	*Actual flow* (gal/min) Range*	*Default assumption (VALUE USED IN CALCULATOR)*	*Source*	*Notes/explanation*
pre-1980	5.0-8.0	4.3	4.3	5	
1980-1993	2.75, 3.0, 4.0	1.8, 2.0, 2.7	2.2	5	We use an average of actual flow rates in Vickers (2001) for this date range.
1994-present (standard)	2.5	1.7	1.7	5	Assumes actual flow rate hasn't changed since 2001.
Average		2.2	2.2	4	Assumes average hasn't changed since 1999.
"low flow" (in suggestions)			1.3		Here we define a low flow showerhead as 2gpm, and apply a 66% throttle factor.

*Assumes a throttle factor of 66%. *Sources* : 5, 9.

Waiting for hot water

	avg gal/shower		*Source*
(5.21 gals/day/house)*(2.8persons/house)*(0.75shower/day/person)=		2.5	3
	avg mins/shower		
	(2.5 gals/shower)*(1 min/2.2 gal)=	1.1	4, 3

Temperature

Degrees (F)	*Source*
105.0	2

Frequency

showers/week	*Source*
4.7	4

Duration

mins	*Source*
8.2	4

Shower Sources:

1. ENERGY STAR Qualified Homes 2011: Savings & Cost Estimate Summary.
2. Koomey, Jonathan G., Camilla Dunha, and James D. Lutz. (1994). The Effect of Efficiency Standards on Water Use and Water Heating Energy Use in the U.S.: A Detailed End-use Treatment. Energy Analysis Program, Energy and Environment Division, Lawrence Berkeley Laboratory, Berkeley. Retrieved August 28, 2009 from http://enduse.lbl.gov/info/lbnl-35475.pdf.
3. Lutz, James. (2005). Estimating Energy and Water Losses in Residential Hot Water Distribution Systems. Lawrence Berkeley National Laboratory, University of California. Paper LBNL 57199. Retrieved August 28, 2009 from http://repositories.cdlib.org/cgi/viewcontent.cgi?article=3697&context=lbnl.
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5. Vickers, Amy. (2001). Handbook of Water Use and Conservation. Water Plow Press, Amherst Massachusetts.
6. Consumer Reports. Retrieved July 2009 from consumerreports.org.
7. ENERGY STAR. 2009. ENERGY STAR Qualified Homes 2011 Savings & Cost Estimate Summary. Retrieved July 2009 from http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/2011_Savings_Cost_Summary.pdf.
8. The Home Depot. Retrieved July 2009 from homedepot.com.
9. Brown and Caldwell Consultants. 1984. Residential Water Conservation Projects; Summary Report. Prepared for U.S. Department of Housing and Urban Development, Office of Policy Development and Research. Report HUD-PDR-903. Washington, D.C.

Table 20. Full estimated greywater production from South Coast residents (single family and multi-family households). Population data from Santa Barbara County.

Greywater (Full Participation) District Supply - estimated volume of greywater produced (AFY)						
	Goleta	**La Cumbre**	**Santa Barbara**	**Montecito**	**Carpinteria**	**South Coast**
Shower	909	38	945	109	141	2,143
Shower warm-up	122	5	127	15	19	287
Shower total	1,031	43	1,072	123	160	2,430
Clothes Washer Total	870	37	904	104	135	2,050
Greywater Supply Total	**1,901**	**80**	**1,976**	**228**	**296**	**4,480**

City of Santa Barbara
Water Resources Division
Building & Safety Division

Community Development & Public Works Departments
630 Garden Street
805-564-5485
805-564-5460

Graywater Fact Sheet

Based on 2013 California Plumbing Code Chapter 16

There is keen interest on the part of many Santa Barbara citizens in re-using household washwater for irrigation. This practice can save water and offer many other ecological benefits. Santa Barbara is a world leader in graywater innovation and policy. The rules below are based on the graywater section of the California Plumbing Code, which was inspired in large part by the experience and suggestions from Santa Barbara residents.

General Rules

These new regulations apply to residential buildings.

- **Kitchen sink, toilets, and diaper-soiled water are not included in the definition of graywater.** (It may be possible to reuse water from these sources but this would be governed by wastewater, not graywater codes)
- **No ponding, spray, or exposed runoff of graywater is allowed.**
- **All systems must have an air-gap or suitable backflow prevention** to protect the potable water system.
- **Not for root crops or edible portions of food crops.**

When a Permit is Not Required:

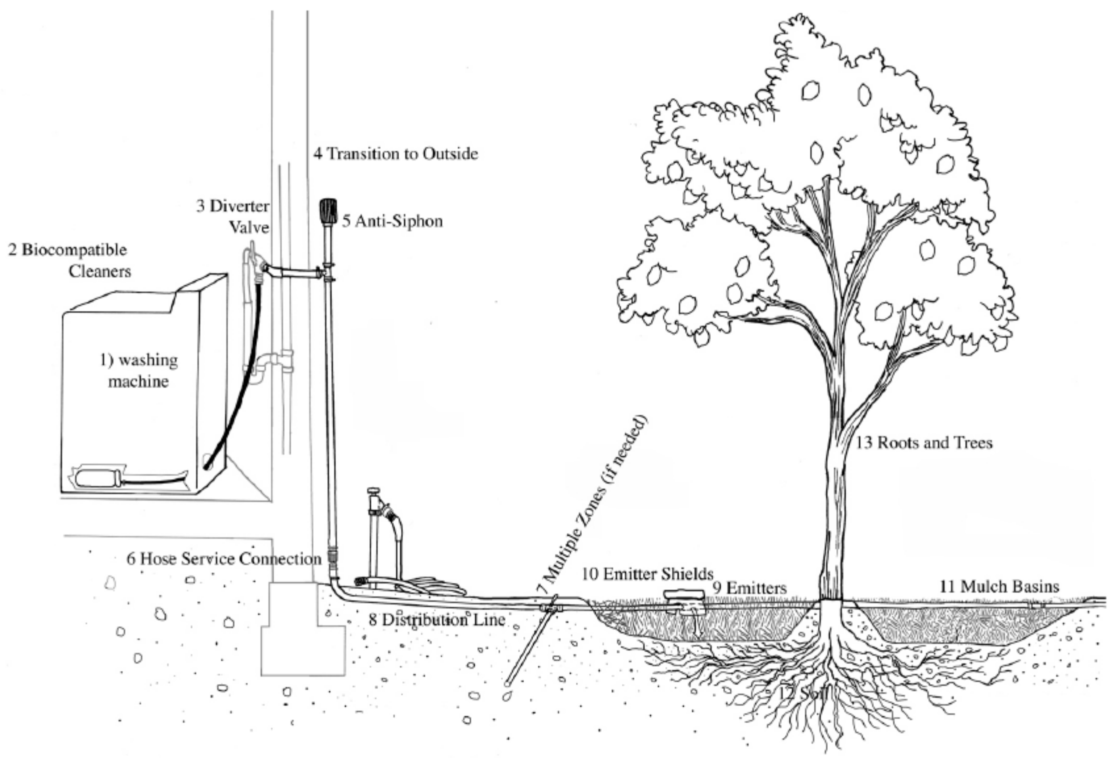
One type of Graywater System DOES NOT require a City building permit; clothes washer only systems. Eleven conditions apply to this type of system:

1. **The design shall allow the user to direct the flow to the irrigation or disposal field or the building sewer.** The direction control of the graywater shall be clearly labeled and readily accessible to the user.
2. **The installation, change, alteration or repair of the system does not include a potable water connection or a pump** (other than the washer pump) and does not affect other building, plumbing, electrical or mechanical components including structural features, egress, fire-life safety, sanitation, potable water supply piping or accessibility.
3. **The graywater shall be contained on the site where it is generated**.
4. **Graywater shall be directed to and contained within an irrigation or disposal field**. (Note: mulch basins are an acceptable type of disposal field.)
5. **Ponding or runoff is prohibited** and shall be considered a nuisance.
6. **Graywater may be released above the ground surface provided at least two (2) inches (51 mm) of mulch, rock, or soil, or a solid shield covers the release point**. Other methods which provide equivalent separation are also acceptable.
7. **Graywater systems shall be designed to minimize contact with humans and domestic pets.**

8. **Water used to wash diapers or similarly soiled or infectious garments shall not be used** and shall be diverted to the building sewer.
9. **Graywater shall not contain hazardous chemicals** derived from activities such as cleaning car parts, washing greasy or oily rags, or disposing of waste solutions from home photo labs or similar hobbyist or home occupational activities.
10. **Exemption from construction permit requirements of this code shall not be deemed to grant authorization for any graywater system to be installed in a manner that violates other provisions of this code** or any other laws or ordinances of the Enforcing Agency.
11. **An operation and maintenance manual shall be provided.** Directions shall indicate the manual is to remain with the building throughout the life of the system and indicate that upon change of ownership or occupancy, the new owner or tenant shall be notified the structure contains a graywater system.

For sample plans for a Laundry to Landscape system, visit www.SantaBarbaraCA.gov/Graywater

Elements of a Laundry to Landscape Graywater System



Drawing used with permission from OasisDesign.net

<u>**These Graywater Systems DO Require Permits**</u>

1. Simple System — Up to 250 gpd of discharge, not including a clothes washer system. All other aspects of the code apply.

2. Complex System — Over 250 gpd of discharge. All other aspects of the code apply.

Appendix C: Conservation and Efficiency

Conservation Programs

Table 21. Input and results from the City of Santa Barbara's Long-term Conservation Program for 2014-2040.[1,2] All programs included have a benefit-cost ratio greater than 1.0 for the utility. All programs are currently implemented by the City of Santa Barbara, with the exception of full AMI (smart meter) implementation (as of March 2016).

				Lifetime savings - present value ($)		Lifetime costs - present value ($)		Benefit:cost ratio			
Program	Customer classes affected	Average [annual] water savings (mgd)	Average annual water savings (AFY)	Utility	Community	Utility	Community	Utility	Community	Cost of Savings per Unit Volume ($/mg)	Cost of Savings per Unit Volume ($/AF)
Full AMI [smart meter] Implementation - Online water use software and leak detection customer notification	SF, MF, BUS, IND, IRR	0	532	$15,529,795	$25,080,767	$4,448,235	$4,448,235	3.5	5.6	949	309
Washer Rebates for HE Machines	SF	0	26	$936,117	$2,141,254	$381,297	$1,087,401	2.5	2	1,670	544
Washer Rebates for HE Machines	MF	0	23	$820,087	$1,875,851	$143,956	$410,540	5.7	4.6	720	235
Irrigation (Landscape) Water Budgets	IRR	0	170	$3,641,382	$3,641,382	$257,193	$257,193	14.2	14.2	172	56
Irrigation Water Surveys	BUS, IND, IRR	0	27	$578,788	$578,788	$533,712	$1,217,959	1.1	0.5	2,242	731
CII Water Check Up Level 1	BUS	0	38	$1,194,004	$2,263,036	$266,312	$497,887	4.5	5.6	797	260
Free Nozzle Program	SF, MF, BUS, IND, IRR	1	711	$13,751,119	$13,751,119	$1,584,157	$1,584,157	8.7	8.7	253	82

Table 22. Input and results produced from Goleta Water District's 2013 Technical Conservation Program Analysis.[3] As of March 2016, none of the 3 programs have been implemented except for the following individual programs: Water Savings Devices Distribution Program,[4] Smart Landscape Rebate Program,[5] and Water Savings Incentive Program.[6]

	Program	Customer Class	Implementation Through 2020	Benefit Cost Ratio
Program 1	Low Flow Showerhead Distribution	SF	700 Showerheads	6
	Low Flow Showerhead Distribution	MF	700 Showerheads	6
	Ultra High Efficiency Toilet (UHET, 0.8 gpf) Rebate	SF	420 UHET Rebates	7.6
	Ultra High Efficiency Toilet (UHET, 0.8 gpf) Rebate	MF	280 UHET Rebates	7.6
	High Efficiency Toilet (HET, 1.28 gpf) Rebate	Commercial	70 HET Rebates	13.5
	High Efficiency Urinal Rebate	Commercial	70 HE Urinal Rebates	5.6
	Water Efficient Ice Machines Rebate	Commercial	70 Ice Machine Rebates	12.9
	Smart Landscape Rebate Program	All	350 Landscape Rebates	7.8
	Large Landscape Water Budgets	Landscape Irrigation	210 Water Budgets	30
	Large Landscape Water Surveys - Mixed Use Accts	Commercial	28 Landscape Surveys	2.1
Program 2	Ultra High Efficiency Toilet (UHET, 0.8 gpf) On-Bill Single Financing	SF	420 UHETs	18.4
	Ultra High Efficiency Toilet (UHET, 0.8 gpf) On-Bill Financing	MF	280 UHETs	18.4
	FreeSprinklerNozzles.com Nozzle Distribution	SF	1400 Nozzles	2.3
	FreeSprinklerNozzles.com Nozzle Distribution	Commercial	700 Nozzles	2.3
	FreeSprinklerNozzles.com Nozzle Distribution	Irrigation	700 Nozzles	2.3
	Smart Landscape Rebate Program	All	350 Landscape Rebates	7.8
Program 3	Connectionless Food Steamer Rebate	Commercial	70 Food Steamer Rebates	12.2
	Dry Vacuum Pump Rebate	Commercial	70 Vacuum Pump Rebates	12.9
	Large Landscape Water Surveys - Mixed Use Accts	Commercial	28 Landscape Surveys	2.1
	FreeSprinklerNozzles.com Nozzle Distribution	Commercial	700 Nozzles	2.3
	FreeSprinklerNozzles.com Nozzle Distribution	Irrigation	700 Nozzles	2.3
	Smart Landscape Rebate Program	All	350 Landscape Rebates	7.8

Table 23. Input and results produced from Goleta Water District's 2013 Technical Conservation Program Analysis.[7] As of March 2016, none of the 3 programs have been implemented except for the following individual programs: Water Savings Devices Distribution Program,[8] Smart Landscape Rebate Program,[9] and Water Savings Incentive Program.[10]

	Complete Benefit : Cost Ratio - Without Personnel	Complete Benefit : Cost Ratio - Including Personnel	Annual Programmatic Water Savings by 2020 (AF)	Annual Implementation Costs ($)	Annual Implementation Costs - Including Personnel ($)	Annual Implementation Costs per AF - Without Personnel ($/AF)	Annual Implementation Costs per AF - Including Personnel ($/AF)
Program 1	10.5	2	485	$76,100	$392,600	$58	$298
Program 2	8.3	2.1	461	$51,000	$204,700	$88	$355
Program 3	8.4	2.4	374	$60,600	$214,300	$79	$280

Washer Rebates for High Efficiency Machines – Single- and Multi-Family

To calculate potential water savings related to washer rebates for high efficiency machines, output from City of Santa Barbara's Long-Term Conservation Program for 2014 – 2040[11,12] was used as a proxy for the other South Coast districts. The following specifications from the Santa Barbara model were applied across the South Coast: program lifespan of 12 years, 24% of SF homes will have participated in the rebate program in 12 years, and 26% of MF will have participated in the rebate program in 12 years.

Table 24. Simplified output for washer rebate program for high efficiency machines for single- and multi-family customers from the City of Santa Barbara's Long-term Conservation Program for 2014-2040.[13,14]

Customer classes affected	Average [annual] water savings (mgd)	Average annual water savings (AFY)	Average annual water savings after 12 years (AFY)	Utility BCR	Cost of Savings per Unit Volume ($/mg)	Cost of Savings per Unit Volume ($/AF)
SF	0.02	25.94	311	2.46	$1,670	$544
MF	0.02	22.72	273	5.7	$720	$235

A weighted average based on the specifications of the Santa Barbara model were applied to the remaining South Coast districts. Results are included in Tables 5 and 6.

$$End\ of\ Program\ Annual\ Water\ Savings\ (AF) = \left(\frac{Other\ District\ Participation}{Santa\ Barbara\ Participation}\right) \times Santa\ Barbara's\ Annual\ Water\ Savings\ at\ End\ of\ Program$$

Table 25. Results for potential washer rebate programs for high efficiency machines for all South Coast water districts.

District	# SF accounts	# MF Accounts	24% SF accounts	26% MF accounts
Goleta	13,342	1,578	3,264	403
La Cumbre	1,298	71	318	18
Santa Barbara	16,920	6,126	4,139	1,563
Montecito	4,204	74	1,028	19
Carpinteria	3,078	314	753	80

Table 26. Results for potential washer rebate programs for high efficiency machines for all South Coast water districts.

	End of Program Annual Water Savings (AFY)	
District	**Single-Family**	**Muti-family**
Goleta	245	70
La Cumbre	24	3
Santa Barbara	311	273
Montecito	77	3
Carpinteria	228	14
South Coast Total	**886**	**363**

Lawn Conversions – Single Family

In order to estimate potential water savings from turfgrass conversions for all South Coast water districts, a survey was first completed in ArcGIS using aerial imagery and the Santa Barbara County parcel shapefile[15] to measure the average turf area of a single-family parcel within each water district's service area (See Appendix F for GIS survey results). A turf conservation adjustment proportion was applied to each district equal to actual State-mandated conservation percentages observed during the recent drought to account for the age of the aerial imagery.[16] Scenarios of 25%, 50%, and 75% participation of all single-family homes converting turfgrass to artificial turf, climate appropriate landscape, or permeable hardscape were explored (no further assumptions were made regarding participant's alternative landscape decisions).

Table 27. Summary of statistical significance associated with sample size of ArcGIS turf area survey and results from the survey. [17,18]

District	# SF accounts	Sample Size	Confidence Interval (%)	Margin of Error (%)
Goleta	13,342	96	95	10
La Cumbre	1,298	90		
Santa Barbara	16,920	96		
Montecito	4,204	95		
Carpinteria	3,078	95		

Table 28. Summary of statistical significance associated with sample size of ArcGIS turf area survey and results from the survey. [19,20]

District	# SF accounts	Average Total Turf Area (acres)	Turf Conservation Adjustment	Average Turf Area per SF residence (acres)	Total Participating Area (acres) - 25% Participation	Total Participating Area (acres) - 50% Participation	Total Participating Area (acres) - 75% Participation
Goleta	13,342	373	0.27	0.021	71	142	213
La Cumbre	1,298	94	0.37	0.044	14	29	43
Santa Barbara	16,920	384	0.35	0.012	50	99	149
Montecito	4,204	305	0.45	0.037	39	77	116
Carpinteria	3,078	69	0.21	0.025	19	38	58

A literature review was conducted to determine the average expected water savings for turf replacement and removal programs in California and a range of values was applied to the total participating acreage on the South Coast.[21]

Table 29. Average reported observed water savings for turf removal programs from 9 surveyed California water agencies.[22]

	Average Expected Water Savings			
	Minimum	**Maximum**	**Southern California**	**Mean**
gal/ft^2/year	13	70	45	31
AF/acre/year	2	9	6	4

Table 30. Average expected water savings from turf removal programs for each South Coast water district, demonstrating 25%, single-family parcel participation, based on average reported observed savings for turf removal programs from 9 surveyed California water agencies.[23]

	Average Annual Water Savings (AFY, 25% participation)			
District	**Minimum**	**Maximum**	**Southern California**	**Mean**
Goleta	128	665	427	294
La Cumbre	26	134	86	59
Santa Barbara	89	464	298	205
Montecito	70	360	232	160
Carpinteria	35	180	116	80
South Coast Total	**348**	**1,803**	**1,159**	**798**

Table 31. Average expected water savings from turf removal programs for each South Coast water district, demonstrating 50% single-family parcel participation, based on average reported observed savings for turf removal programs from 9 surveyed California water agencies.[24]

	Average Annual Water Savings (AFY, 50% participation)			
District	**Minimum**	**Maximum**	**Southern California**	**Mean**
Goleta	256	1,330	855	589
La Cumbre	52	268	172	119
Santa Barbara	179	927	596	411
Montecito	139	721	463	319
Carpinteria	69	360	231	159
South Coast Total	**695**	**3,606**	**2,318**	**1,597**

Table 32. Average expected water savings from turf removal programs for each South Coast water district, demonstrating 75% single-family parcel participation, based on average reported observed savings for turf removal programs from 9 surveyed California water agencies.[25]

	Average Annual Water Savings (AFY, 75% participation)			
District	**Minimum**	**Maximum**	**Southern California**	**Mean**
Goleta	385	1,995	1,282	883
La Cumbre	78	402	259	178
Santa Barbara	268	1,391	894	616
Montecito	209	1,081	695	479
Carpinteria	104	540	347	239
South Coast Total	**1,043**	**5,408**	**3,477**	**2,395**

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[1] City of Santa Barbara. October 2010. "City of Santa Barbara Water Conservation Technical Analysis." http://www.water.ca.gov/irwm/grants/docs/Archives/Prop84/Submitted_Applications/P84_Round2_Implementation/Cachuma%20RCD%20(201312340020)/Attachment%203.%20(cont)%20-%20Att03_IG2_WorkPlan_App03_01_2of4.pdf

[2] City of Santa Barbara Public Works staff. Personal Communication. January 25, 2016.

[3] Goleta Water District. June 2013. "Technical Report on Optimizing the Goleta Water District Conservation Program." http://www.goletawater.com/assets/documents/conservation/GWD%20Water%20Conservation%20Final%20Report%2011%20June%202013_web.pdf

[4] Goleta Water District. November 2014. "Water Savings Device Distribution Program." Board of Directors Agenda Letter. http://www.goletawater.com/meetingdocs/document-gate.php?f=agendas/Item_4_Nov._11_2014..pdf

[5] Goleta Water District. July 2015. "Smart Landscape Rebate Program." Board of Directors Agenda Letter. http://www.goletawater.com/meetingdocs/document-gate.php?f=agendas/Item_2_July_14_2015.pdf

[6] Goleta Water District. December 2014. "Water Savings Incentive Program." Board of Directors Agenda Letter. http://www.goletawater.com/meetingdocs/document-gate.php?f=agendas/Item_3_Dec._9_2014.pdf

[7] Goleta Water District. June 2013. "Technical Report on Optimizing the Goleta Water District Conservation Program." http://www.goletawater.com/assets/documents/conservation/GWD%20Water%20Conservation%20Final%20Report%2011%20June%202013_web.pdf

[8] Goleta Water District. November 2014. "Water Savings Device Distribution Program." Board of Directors Agenda Letter. http://www.goletawater.com/meetingdocs/document-gate.php?f=agendas/Item_4_Nov._11_2014..pdf

[9] Goleta Water District. July 2015. "Smart Landscape Rebate Program." Board of Directors Agenda Letter. http://www.goletawater.com/meetingdocs/document-gate.php?f=agendas/Item_2_July_14_2015.pdf

[10] Goleta Water District. December 2014. "Water Savings Incentive Program." Board of Directors Agenda Letter. http://www.goletawater.com/meetingdocs/document-gate.php?f=agendas/Item_3_Dec._9_2014.pdf

[11] City of Santa Barbara. October 2010. “City of Santa Barbara Water Conservation Technical Analysis.” http://www.water.ca.gov/irwm/grants/docs/Archives/Prop84/Submitted_Applications/P84_Round2_Implementation/Cachuma%20RCD%20(201312340020)/Attachment%203.%20(cont)%20-%20Att03_IG2_WorkPlan_App03_01_2of4.pdf

[12] City of Santa Barbara Public Works staff. Personal Communication. January 25, 2016.

[13] City of Santa Barbara. October 2010. “City of Santa Barbara Water Conservation Technical Analysis.” http://www.water.ca.gov/irwm/grants/docs/Archives/Prop84/Submitted_Applications/P84_Round2_Implementation/Cachuma%20RCD%20(201312340020)/Attachment%203.%20(cont)%20-%20Att03_IG2_WorkPlan_App03_01_2of4.pdf

[14] City of Santa Barbara Public Works staff. Personal Communication. January 25, 2016.

[15] See Appendix F for GIS survey results

[16] See Appendix F for GIS survey results

[17] See Appendix F for GIS survey results

[18] See Appendix F for GIS survey results

[19] See Appendix F for GIS survey results

[20] See Appendix F for GIS survey results

[21] Briana Seapy. March 2015. “Turf Removal and Replacement: Lessons Learned.” California Urban Water Conservation Council. http://cuwcc.org/Portals/0/Document%20Library/Resources/Publications/Council%20Reports/Turf%20Removal%20_%20Replacement%20-%20Lessons%20Learned.pdf

[22] Briana Seapy. March 2015. “Turf Removal and Replacement: Lessons Learned.” California Urban Water Conservation Council. http://cuwcc.org/Portals/0/Document%20Library/Resources/Publications/Council%20Reports/Turf%20Removal%20_%20Replacement%20-%20Lessons%20Learned.pdf

[23] Briana Seapy. March 2015. “Turf Removal and Replacement: Lessons Learned.” California Urban Water Conservation Council. http://cuwcc.org/Portals/0/Document%20Library/Resources/Publications/Council%20Reports/Turf%20Removal%20_%20Replacement%20-%20Lessons%20Learned.pdf

[24] Briana Seapy. March 2015. “Turf Removal and Replacement: Lessons Learned.” California Urban Water Conservation Council. http://cuwcc.org/Portals/0/Document%20Library/Resources/Publications/Council%20Reports/Turf%20Removal%20_%20Replacement%20-%20Lessons%20Learned.pdf

[25] Briana Seapy. March 2015. “Turf Removal and Replacement: Lessons Learned.” California Urban Water Conservation Council. http://cuwcc.org/Portals/0/Document%20Library/Resources/Publications/Council%20Reports/Turf%20Removal%20_%20Replacement%20-%20Lessons%20Learned.pdf

Appendix D: Precipitation and Stormwater Analysis

Table 33. Daily precipitation intensity distribution between 1996 and 2015 water years. Data source: CIMIS Station SB107

Daily Precipitation at CIMIS Station SB107 1996 - 2015 WY							
Precipitation Rate (decimal in/day)	*Precipitation Rate (in/day)*	*Event Frequency (# of days/yr)*	*% of Total Precipitation Days*	*Cumulative*	*Precipitation within Rate Bin (in/yr)*	*% of Total Precipitation Inches*	*Cumulative*
0.13	less than or equal to 1/8	94.1	70.17%	70.17%	3.348	10.29%	10.29%
0.25	1/4	11.2	8.35%	78.52%	2.141	6.58%	16.87%
0.38	3/8	5.6	4.18%	82.70%	1.725	5.30%	22.17%
0.50	1/2	3.7	2.76%	85.46%	1.643	5.05%	27.22%
0.63	5/8	4.7	3.50%	88.96%	2.682	8.24%	35.46%
0.75	3/4	2.9	2.16%	91.13%	2.023	6.22%	41.67%
0.88	7/8	1.3	0.97%	92.10%	1.076	3.31%	44.98%
1.00	1	2.2	1.64%	93.74%	2.073	6.37%	51.35%
1.13	1 1/8	1.5	1.12%	94.85%	1.602	4.92%	56.27%
1.25	1 1/4	1.2	0.89%	95.75%	1.435	4.41%	60.68%
1.38	1 3/8	0.7	0.52%	96.27%	0.921	2.83%	63.51%
1.50	1 1/2	0	0.00%	96.27%	0	0.00%	63.51%
1.63	1 5/8	0.9	0.67%	96.94%	1.414	4.34%	67.86%
1.75	1 3/4	0.3	0.22%	97.17%	0.499	1.53%	69.39%
1.88	1 7/8	0.4	0.30%	97.46%	0.718	2.21%	71.60%
2.00	2	0.3	0.22%	97.69%	0.574	1.76%	73.36%
2.13	2 1/8	0.4	0.30%	97.99%	0.832	2.56%	75.92%
2.25	2 1/4	0.3	0.22%	98.21%	0.666	2.05%	77.96%
2.38	2 3/8	0.4	0.30%	98.51%	0.932	2.86%	80.83%
2.50	2 1/2	0.1	0.07%	98.58%	0.239	0.73%	81.56%
2.63	2 5/8	0.4	0.30%	98.88%	1.024	3.15%	84.71%
2.75	2 3/4	0.2	0.15%	99.03%	0.54	1.66%	86.37%
2.88	2 7/8	0.3	0.22%	99.25%	0.848	2.61%	88.97%
3.00	3	0.3	0.22%	99.48%	0.881	2.71%	91.68%
	greater than 3	0.7	0.52%	100.00%	2.708	8.32%	100.00%
	Total	134.1	100.00%		32.544	100.00%	

Table 34. Total annual precipitation volume falling within district boundaries. Daily precipitation data source: CIMIS Station SB107.

Annual Rainfall Volume (AFY) 1996 - 2015 WY						
Water Year	**Goleta**	**La Cumbre**	**Santa Barbara**	**Montecito**	**Carpinteria**	**South Coast Total**
1996	42,437	2,927	18,233	14,469	16,536	94,602
1997	41,929	2,892	18,015	14,296	16,338	93,470
1998	111,771	7,708	48,023	38,110	43,552	249,164
1999	26,535	1,830	11,401	9,048	10,340	59,153
2000	62,423	4,305	26,820	21,284	24,323	139,155
2001	19,865	1,370	8,535	6,773	7,741	44,284
2002	18,101	1,248	7,777	6,172	7,053	40,351
2003	55,028	3,795	23,643	18,762	21,442	122,670
2004	25,423	1,753	10,923	8,668	9,906	56,675
2005	51,813	3,573	22,262	17,667	20,189	115,504
2006	53,698	3,703	23,072	18,309	20,924	119,707
2007	17,618	1,215	7,569	6,007	6,865	39,274
2008	41,011	2,828	17,621	13,983	15,980	91,423
2009	25,641	1,768	11,017	8,743	9,991	57,160
2010	35,332	2,437	15,180	12,047	13,767	78,763
2011	58,580	4,040	25,169	19,974	22,826	130,589
2012	29,798	2,055	12,803	10,160	11,611	66,426
2013	29,363	2,025	12,616	10,012	11,441	65,456
2014	13,944	962	5,991	4,754	5,433	31,085
2015	27,381	1,888	11,764	9,336	10,669	61,038
1996 - 2015 Avg	39,384	2,716	16,922	13,429	15,346	87,797
2006-2015 Avg	33,236	2,292	14,280	11,332	12,951	74,092
Annual Min	13,944	962	5,991	4,754	5,433	31,085
Annual Max	111,771	7,708	48,023	38,110	43,552	249,164

Table 35. Calculated annual urban stormwater runoff and sensitivity analysis.

Annual Runoff Volume (AFY) 1996 - 2015 WY						
Water Year	**Goleta**	**La Cumbre**	**Santa Barbara**	**Montecito**	**Carpinteria**	**South Coast Total**
1996	6,033	287	2,835	1,689	1,822	12,665
1997	7,154	342	3,325	2,015	2,174	15,010
1998	22,962	1,128	10,498	6,567	7,133	48,288
1999	1,858	83	969	485	521	3,916
2000	13,436	668	6,108	3,867	4,215	28,294
2001	2,615	128	1,203	745	811	5,503
2002	956	42	519	243	260	2,021
2003	12,431	615	5,619	3,578	3,895	26,139
2004	5,441	285	2,389	1,613	1,789	11,516
2005	6,500	303	3,124	1,792	1,924	13,643
2006	8,208	392	3,816	2,311	2,490	17,217
2007	748	33	431	183	202	1,597
2008	9,059	456	4,052	2,633	2,885	19,085
2009	1,221	54	653	314	342	2,585
2010	2,667	120	1,357	707	758	5,609
2011	6,243	310	2,926	1,771	1,956	13,206
2012	2,097	91	1,108	541	575	4,412
2013	313	14	195	73	84	678
2014	374	16	192	98	102	783
2015	2,254	103	1,110	611	658	4,737
1996 - 2015 Avg	5,629	274	2,621	1,592	1,730	11,845
2006 - 2015 Avg	3,318	159	1,584	924	1,005	6,991
Annual Min	313	14	192	73	84	678
Annual Max	22,962	1,128	10,498	6,567	7,133	48,288

Runoff Sensitivity to Curve Number Error (+/- AFY from assumed CN)						
Change in CN	**Goleta**	**La Cumbre**	**Santa Barbara**	**Montecito**	**Carpinteria**	**South Coast Total**
CN +5 (10-yr Avg)	1,869	170	646	536	496	3,716
CN -5 (10-yr Avg)	-1,151	-100	-410	-342	-319	-2,322

Table 36. Percent of calculated runoff from total annual rainfall.

			Runoff/Rainfall % 1996 - 2015 WY			
Water Year	**Goleta**	**La Cumbre**	**Santa Barbara**	**Montecito**	**Carpinteria**	**South Coast Total**
1996	14.22%	9.80%	15.55%	11.67%	11.02%	13.39%
1997	17.06%	11.82%	18.45%	14.10%	13.30%	16.06%
1998	20.54%	14.63%	21.86%	17.23%	16.38%	19.38%
1999	7.00%	4.52%	8.50%	5.36%	5.04%	6.62%
2000	21.53%	15.52%	22.77%	18.17%	17.33%	20.33%
2001	13.16%	9.35%	14.10%	11.00%	10.48%	12.43%
2002	5.28%	3.35%	6.68%	3.94%	3.69%	5.01%
2003	22.59%	16.20%	23.77%	19.07%	18.17%	21.31%
2004	21.40%	16.26%	21.87%	18.60%	18.06%	20.32%
2005	12.54%	8.49%	14.03%	10.14%	9.53%	11.81%
2006	15.29%	10.58%	16.54%	12.62%	11.90%	14.38%
2007	4.24%	2.69%	5.70%	3.04%	2.95%	4.07%
2008	22.09%	16.13%	23.00%	18.83%	18.05%	20.88%
2009	4.76%	3.07%	5.93%	3.60%	3.42%	4.52%
2010	7.55%	4.91%	8.94%	5.87%	5.50%	7.12%
2011	10.66%	7.68%	11.63%	8.87%	8.57%	10.11%
2012	7.04%	4.45%	8.65%	5.32%	4.95%	6.64%
2013	1.07%	0.68%	1.54%	0.73%	0.73%	1.04%
2014	2.68%	1.68%	3.20%	2.07%	1.88%	2.52%
2015	8.23%	5.48%	9.44%	6.54%	6.17%	7.76%
1996 - 2015 Avg	11.95%	8.36%	13.11%	9.84%	9.36%	11.28%
2006-2015 Avg	8.36%	5.74%	9.46%	6.75%	6.41%	7.90%
Annual Min	1.07%	0.68%	1.54%	0.73%	0.73%	1.04%
Annual Max	22.59%	16.26%	23.77%	19.07%	18.17%	21.31%

Rooftop rainwater harvesting model constraints. NRDC source: "Capturing Rainwater from Rooftops: An Efficient Water Resource Management Strategy that Increases Supply and Reduces Pollution" (2011).

NRDC Constraints

- 250 gal / 500 sq. ft. of roof
- 80% capture efficiency
- Max 1" of rainfall per day
- No capture if temperature < 40 deg. F

Potential inflow = rainfall x roof area, up to system capacity

Outflow = outdoor irrigation

System balance = previous day's surplus + potential inflow – outflow

Actual daily inflow = 0 if system full, potential inflow if system not full

Project-specific Constraints

- 25% Participation
- Average SFR roof area by district (GIS survey)
- Number of SFR houses by district (SB County IRWMP 2013)
- 2004 – 2014 Santa Barbara daily rainfall (CIMIS)
- System capacity (based on average roof area and capture volume)
- Outdoor water usage (minimum monthly sales used as base, additional is assume irrigation, monthly value / # of days = avg. daily usage by month)

Soil Conservation Service (SCS) Curve Number Method. Runoff equations provided by California Environmental Protection Agency, Office of Environmental Health Hazard Assessment: "User's Guide for the California Impervious Surface Coefficients" (2010). Curve numbers provided by United States Department of Agriculture, Natural Resources Conservation Service, Conservation Engineering Division: "Urban Hydrology for Small Watersheds" (1986).

The Curve Number Method

Stormwater runoff estimates are calculated as follows:

$$S = (1000/CN) - 10$$

Where:

S = the potential abstraction (maximum potential retention of water by the soil after runoff begins)
CN = the CN for the given LUC and HSG

Once the potential abstraction has been calculated, it can be used in the following equation:

$$Q = (P - 0.2S)^2 / (P + 0.8S)$$

Where:

Q = depth of runoff (inches)
P = precipitation (inches)
S = the potential abstraction

Open Space Curve Number by hydrologic soil group (Good condition)			
A	B	C	D
39	61	74	80

To produce runoff, P must be greater than 0.2S. If P is less than or equal to 0.2S, then the runoff amount is essentially zero. When P is greater than 0.2S, multiplying the Q value by the area of the site gives the volume of runoff produced.

$$CN = [(CN_{OS}) \times (1 - ISC_i)] + [(98) \times (ISC_i)]$$

Where:

CN_{OS} = the runoff potential of the soil assuming the area is open space (OS), in good hydrologic condition, and that the soil is not frozen; the four CN_{OS} for HSGs A, B, C, and D (see text box above) are 39, 61, 74, and 80, respectively (National Engineering Handbook, 2004),

1-ISC = the percent of land use category *i* that is pervious,

98 = maximum potential runoff,

ISC = the percent of land use category *i* that is impervious.

Appendix E: Additional Low-Impact Development Information

Table 37. Top 10 areas with greatest potential for increased infiltration from LID. Ranked by subtracting open space curve number (CNos) from developed curve number (CN) per unit area.

Rank	Land Use Type	Underlying Soil Group	Average CN - CNos	Coverage (acres)
	GOLETA			
1	SUPERMARKETS	B	27.57	5.10
2	WHOLESALE LAUNDRY	B	26.75	1.05
3	BOWLING ALLEYS	B	25.88	2.25
4	HEAVY INDUSTRY	B	25.86	1.50
5	BED AND BREAKFAST	B	25.16	0.15
6	SERVICE STATIONS	B	25.01	5.25
7	AUTO SALES, REPAIR, STORAGE, CAR WASH, ETC	B	24.79	13.95
8	RETAIL STORES, SINGLE STORY	B	24.58	20.25
9	INDUSTRIAL CONDOS,PUDS	B	24.24	0.30
10	SHOPPING CENTERS (NEIGHBORHOOD)	B	24.23	17.85
	LA CUMBRE			
1	RESTAURANTS,BARS	B	29.60	0.43
2	RETAIL STORES, SINGLE STORY	B	29.60	0.14
3	AUTO SALES, REPAIR, STORAGE, CAR WASH, ETC	B	25.60	1.43
4	HOTELS	B	22.20	0.43
5	CHURCHES, RECTORY	B	16.38	3.15
6	OFFICE BUILDINGS, SINGLE STORY	B	16.10	0.57
7	RACE TRACKS, RIDING STABLES	B	15.58	1.43
8	SERVICE STATIONS	D	13.68	0.29
9	LIGHT MANUFACTURING	D	12.69	1.72
10	WAREHOUSING	D	12.30	1.29
	SANTA BARBARA			
1	RETAIL STORES, SINGLE STORY	A	37.84	1.11
2	AUTO SALES, REPAIR, STORAGE, CAR WASH, ETC	A	33.63	0.16
3	MOBILE HOME PARKS	A	29.12	1.74
4	LUMBER YARDS, MILLS	B	28.98	0.48
5	MINERAL PROCESSING	B	27.01	0.16
6	INDUSTRIAL CONDOS,PUDS	B	26.64	0.16
7	WHOLESALE LAUNDRY	B	26.00	2.38
8	WAREHOUSING	B	25.14	10.62
9	OPEN STORAGE, BULK PLANT	B	25.09	2.38
10	SHOPPING CENTERS (NEIGHBORHOOD)	B	25.00	11.42
	MONTECITO			
1	SERVICE STATIONS	B	23.87	0.58
2	SUPERMARKETS	B	23.03	0.58
3	STORE AND OFFICE COMBINATION	B	21.83	0.15
4	RETAIL STORES, SINGLE STORY	B	21.21	0.87
5	PARKING LOTS	B	17.02	0.15
6	COMMERCIAL (MISC)	B	15.73	0.29
7	CLUBS, LODGE HALLS	A	14.13	3.20
8	RIGHTS OF WAY,SEWER,LAND FILLS,ETC	A	14.04	0.73
9	RESTAURANTS,BARS	B	13.69	0.29
10	NURSERIES,GREENHOUSES	A	13.37	0.44
	CARPINTERIA			
1	SHOPPING CENTERS (NEIGHBORHOOD)	A	40.07	2.12
2	RETAIL STORES, SINGLE STORY	A	33.93	0.39
3	WAREHOUSING	A	32.76	4.05
4	PACKING PLANTS	A	32.13	2.51
5	OFFICE BUILDINGS, MULTI-STORY	A	27.87	15.05
6	STORE AND OFFICE COMBINATION	B	25.41	1.16
7	LIGHT MANUFACTURING	B	24.92	3.28
8	WAREHOUSING	B	24.59	4.63
9	RIVERS AND LAKES	A	23.90	0.39
10	MOBILE HOME PARKS	A	23.82	11.58

Tables from EPA (2007): Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices.

Table 1. Summary of LID Practices Employed in the Case Studies

Name	LID Techniques							
	Bioretention	Cluster Building	Reduced Impervious Area	Swales	Permeable Pavement	Vegetated Landscaping	Wetlands	Green Roofs
2nd Avenue SEA Street	✓		✓	✓				
Auburn Hills	✓		✓	✓		✓	✓	
Bellingham Parking Lot Retrofits	✓							
Central Park Commercial Redesigns	✓			✓				
Crown Street	✓		✓	✓				
Gap Creek			✓			✓		
Garden Valley	✓	✓		✓	✓		✓	
Kensington Estates		✓	✓		✓	✓	✓	
Laurel Springs	✓	✓	✓	✓				
Mill Creek		✓	✓	✓				
Poplar Street Apartments	✓			✓			✓	
Portland Downspout Disconnection*			✓					
Prairie Crossing	✓		✓	✓		✓		
Prairie Glen	✓	✓	✓	✓		✓	✓	
Somerset	✓			✓				
Tellabs Corporate Campus	✓			✓		✓	✓	
Toronto Green Roofs								✓

*Although impervious area stays the same, the disconnection program reduces directly connected impervious area.

-

Table 2. Summary of Cost Comparisons Between Conventional and LID Approaches[a]

Project	Conventional Development Cost	LID Cost	Cost Difference[b]	Percent Difference[b]
2nd Avenue SEA Street	$868,803	$651,548	$217,255	25%
Auburn Hills	$2,360,385	$1,598,989	$761,396	32%
Bellingham City Hall	$27,600	$5,600	$22,000	80%
Bellingham Bloedel Donovan Park	$52,800	$12,800	$40,000	76%
Gap Creek	$4,620,600	$3,942,100	$678,500	15%
Garden Valley	$324,400	$260,700	$63,700	20%
Kensington Estates	$765,700	$1,502,900	–$737,200	-96%
Laurel Springs	$1,654,021	$1,149,552	$504,469	30%
Mill Creek[c]	$12,510	$9,099	$3,411	27%
Prairie Glen	$1,004,848	$599,536	$405,312	40%
Somerset	$2,456,843	$1,671,461	$785,382	32%
Tellabs Corporate Campus	$3,162,160	$2,700,650	$461,510	15%

[a] The Central Park Commercial Redesigns, Crown Street, Poplar Street Apartments, Prairie Crossing, Portland Downspout Disconnection, and Toronto Green Roofs study results do not lend themselves to display in the format of this table.
[b] Negative values denote increased cost for the LID design over conventional development costs.
[c] Mill Creek costs are reported on a per-lot basis.

Table 3. Cost Comparison for 2nd Avenue SEA Street [15]

Item	Conventional Development Cost	SEA Street Cost	Cost Savings*	Percent Savings*	Percent of Total Savings*
Site preparation	$65,084	$88,173	–$23,089	–35%	–11%
Stormwater management	$372,988	$264,212	$108,776	29%	50%
Site paving and sidewalks	$287,646	$147,368	$140,278	49%	65%
Landscaping	$78,729	$113,034	–$34,305	–44%	–16%
Misc. (mobilization, etc.)	$64,356	$38,761	$25,595	40%	12%
Total	**$868,803**	**$651,548**	**$217,255**	—	—

* Negative values denote increased cost for the LID design over conventional development costs.

Table 4. Cost Comparison for Auburn Hills Subdivision [19]

Item	Conventional Development Cost	Auburn Hills LID Cost	Cost Savings*	Percent Savings*	Percent of Total Savings*
Site preparation	$699,250	$533,250	$166,000	24%	22%
Stormwater management	$664,276	$241,497	$422,779	64%	56%
Site paving and sidewalks	$771,859	$584,242	$187,617	24%	25%
Landscaping	$225,000	$240,000	–$15,000	-7%	-2%
Total	**$2,360,385**	**$1,598,989**	**$761,396**	—	—

* Negative values denote increased cost for the LID design over conventional development costs.

Table 5. Cost Comparison for Bellingham's Parking Lot Rain Garden Retrofits[22]

Project	Conventional Vault Cost	Rain Garden Cost	Cost Savings	Percent Savings
City Hall	$27,600	$5,600	$22,000	80%
Bloedel Donovan Park	$52,800	$12,800	$40,000	76%

Table 6. Site Information and Cost Additions/Reductions Using LID Versus Traditional Designs

Name	Total BMP Area (ft²)	Total Impervious Area Treated (ft²)	Percent of Impervious Area Treated	Cost Additions[a]	Cost Reductions[b]	Change in Cost After Redesign
Breezewood Station Alternative 1	4,800	64,165	98.4%	$36,696	$34,785	+ $1,911
Breezewood Station Alternative 2	3,500	38,775	59.5%	$24,449	$21,060	+ $3,389
Olive Garden	1,780	31,900	59.1%	$14,885	$11,065	+ $3,790
Kohl's, Best Buy, & Office Depot	14,400	354,238	56.3%	$89,433	$80,380	+ $9,053
First Virginia Bank	1,310	20,994	97.7%	$6,777	$1,148	+ $5,629
Chick-Fil-A[c]	1,326	28,908	82.2%	$6,846	$12,540	– $5,694

[a] Additional costs for curb, curb blocks, storm piping, inlets, underdrains, soil, mulch, and vegetation as a result of the redesign.
[b] Reduced cost for curb, storm piping, roof drain piping, and inlets as a result of the redesign.
[c] Cost reduction value includes the cost of a Stormceptor unit that is not needed as part of the redesign.

Table 7. Cost Comparison for Gap Creek Subdivision[37]

Total Cost of Conventional Design	Gap Creek LID Cost	Cost Savings	Percent Savings	Savings per Lot
$4,620,600	$3,942,100	$678,500	15%	$4,800

Table 8. Cost Comparison for Garden Valley Subdivision[39]

Item	Conventional Development Cost	Garden Valley LID Cost	Cost Savings*	Percent Savings*
Stormwater management	$214,000	$59,800	$154,200	72%
Site paving	$110,400	$200,900	–$90,500	–82%
Total	**$324,400**	**$260,700**	**$63,700**	—

* Negative values denote increased cost for the LID design over conventional development costs.

Table 9. Cost Comparison for Kensington Estates Subdivision[42]

Item	Conventional Development Cost	Kensington Estate LID Cost	Additional Cost
Stormwater management	$243,400	$925,400	$ 682,000
Site paving	$522,300	$577,500	$55,200
Total	**$765,700**	**$1,502,900**	**$737,200**

Table 10. Cost Comparison for Laurel Springs Subdivision[45]

Item	Conventional Development Cost	Laurel Springs LID Cost	Cost Savings	Percent Savings	Percent of Total Savings
Site preparation	$441,600	$342,000	$99,600	23%	20%
Stormwater management	$439,956	$136,797	$303,159	69%	60%
Site paving and sidewalks	$607,465	$515,755	$91,710	15%	18%
Landscaping	$165,000	$155,000	$10,000	6%	2%
Total	**$1,654,021**	**$1,149,552**	**$504,469**	—	—

Table 11. Cost Comparison for Mill Creek Subdivision[47]

Item	Conventional Development Cost per Lot	Mill Creek LID Cost per Lot	Cost Savings per Lot	Percent Savings per Lot	Percent of Total Savings
Site preparation	$2,045	$1,086	$959	47%	28%
Stormwater management	$4,535	$2,204	$2,331	51%	68%
Site paving and sidewalks	$5,930	$5,809	$121	2%	4%
Total	**$12,510**	**$9,099**	**$3,411**	—	—

Table 12. Cost Comparison for Prairie Crossing Subdivision[52]

Item	Cost Savings	Percent Savings
Reduced Road Width	$178,000	13%
Stormwater Management	$210,000	15%
Decreased Sidewalks	$648,000	47%
Reduced Curb and Gutter	$339,000	25%
Total	**$1,375,000**	—

Table 13. Cost Comparison for Prairie Glen Subdivision[55]

Item	Conventional Development Cost	Prairie Glen LID Cost	Cost Savings*	Percent Savings*	Percent of Total Savings*
Site preparation	$277,043	$188,785	$88,258	32%	22%
Stormwater management	$215,158	$114,364	$100,794	47%	25%
Site paving and sidewalks	$462,547	$242,707	$219,840	48%	54%
Landscaping	$50,100	$53,680	–$3,580	–7%	–1%
Total	**$1,004,848**	**$599,536**	**$405,312**	—	—

* Negative values denote increased cost for the LID design over conventional development costs.

Table 14. Cost Comparison for Somerset Subdivision

Conventional Development Cost	Somerset LID Cost	Cost Savings	Percent Savings	Savings per Lot
$2,456,843	$1,671,461	$785,382	32%	$4,000

Table 15. Cost Comparison for Tellabs Corporate Campus[61]

Item	Conventional Development Cost	Tellabs LID Cost	Cost Savings	Percent Savings	Percent of Total Savings
Site preparation	$2,178,500	$1,966,000	$212,500	10%	46%
Stormwater management	$480,910	$418,000	$62,910	13%	14%
Landscape development	$502,750	$316,650	$186,100	37%	40%
Total	**$3,162,160**	**$2,700,650**	**$461,510**	—	—

Appendix F: GIS Analysis and Results

Table 38. Results from South Coast GIS survey of roof area, turf area, and pool area on single family residential properties.

Single Family Residential Parcels	Goleta	La Cumbre	Santa Barbara	Montecito	Carpinteria
Total district area (acres)	29,000	4,900	93,091	13,500	15,494
Number of SFR parcels	12,797	1,339	21,339	4,583	2,184
Number of SFR units	16,645	1,442	22,360	3,999	2,602
Average parcel size (acres)	0.45	1.38	0.34	1.24	0.46
Average roof area per parcel (m^2)	357.52	563.75	284.88	545.63	369.73
Roof-to-parcel ratio	0.19	0.1	0.21	0.11	0.2
Estimated total roof area (acres)	1,130.54	186.53	1,502.19	617.92	199.53
Average turf area per parcel (m^2)	118.1	283.59	72.91	269.62	127.96
Turf-to-parcel ratio	0.06	0.05	0.05	0.05	0.07
Estimated total turf area (acres)	373.45	93.83	384.45	305.34	69.06
Turf conservation adjustment (2013)	0.27	0.37	0.35	0.45	0.21
Adjusted turf area (acres)	272.62	59.11	251.43	167.94	54.55
Average pool area per parcel (m^2)	6.09	13.82	4.57	15	6.57
Estimated total pool area (acres)	19.27	4.57	24.09	16.99	3.54

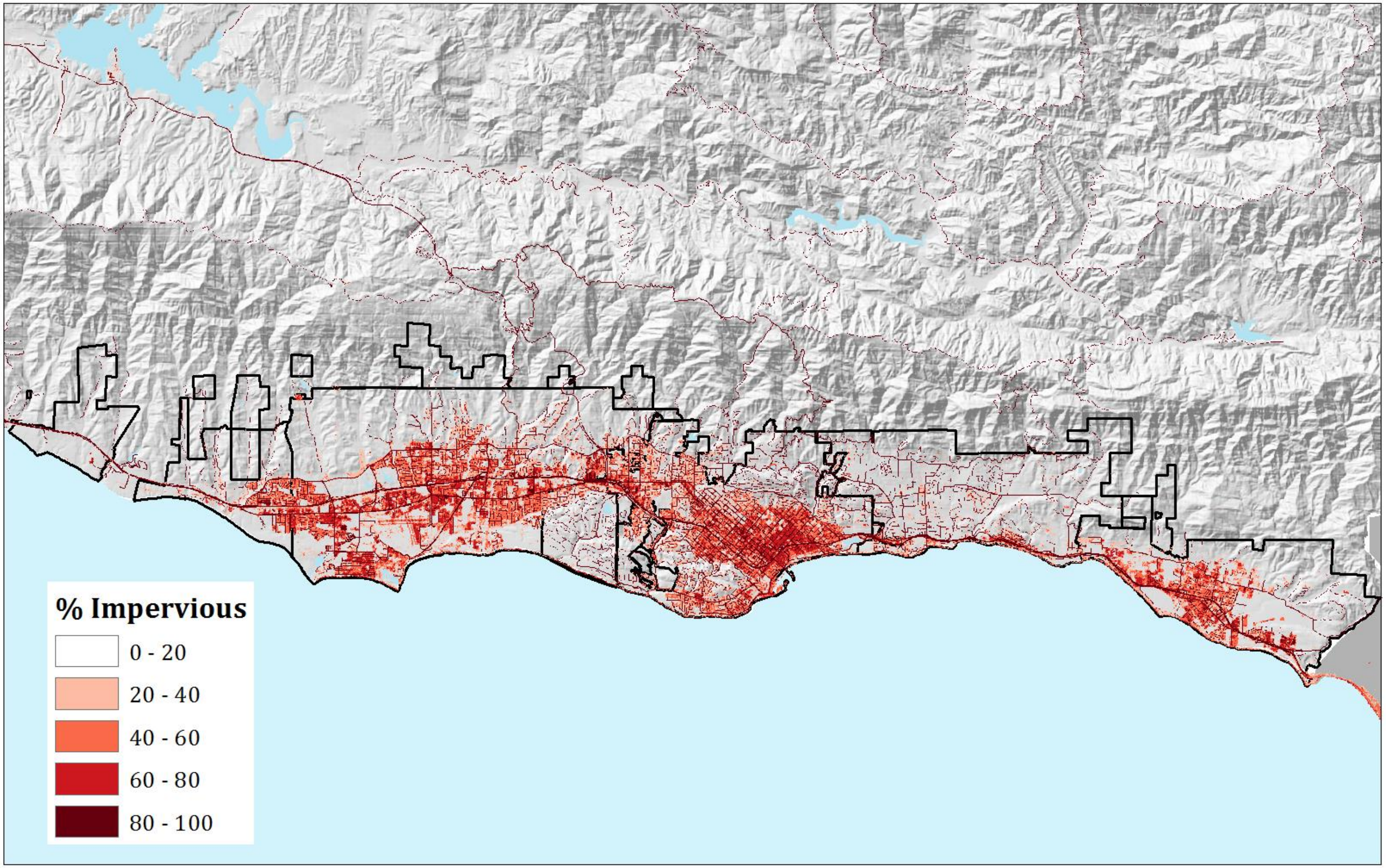

Figure 19. South Coast percent imperviousness. Data source: National Land Cover Database..

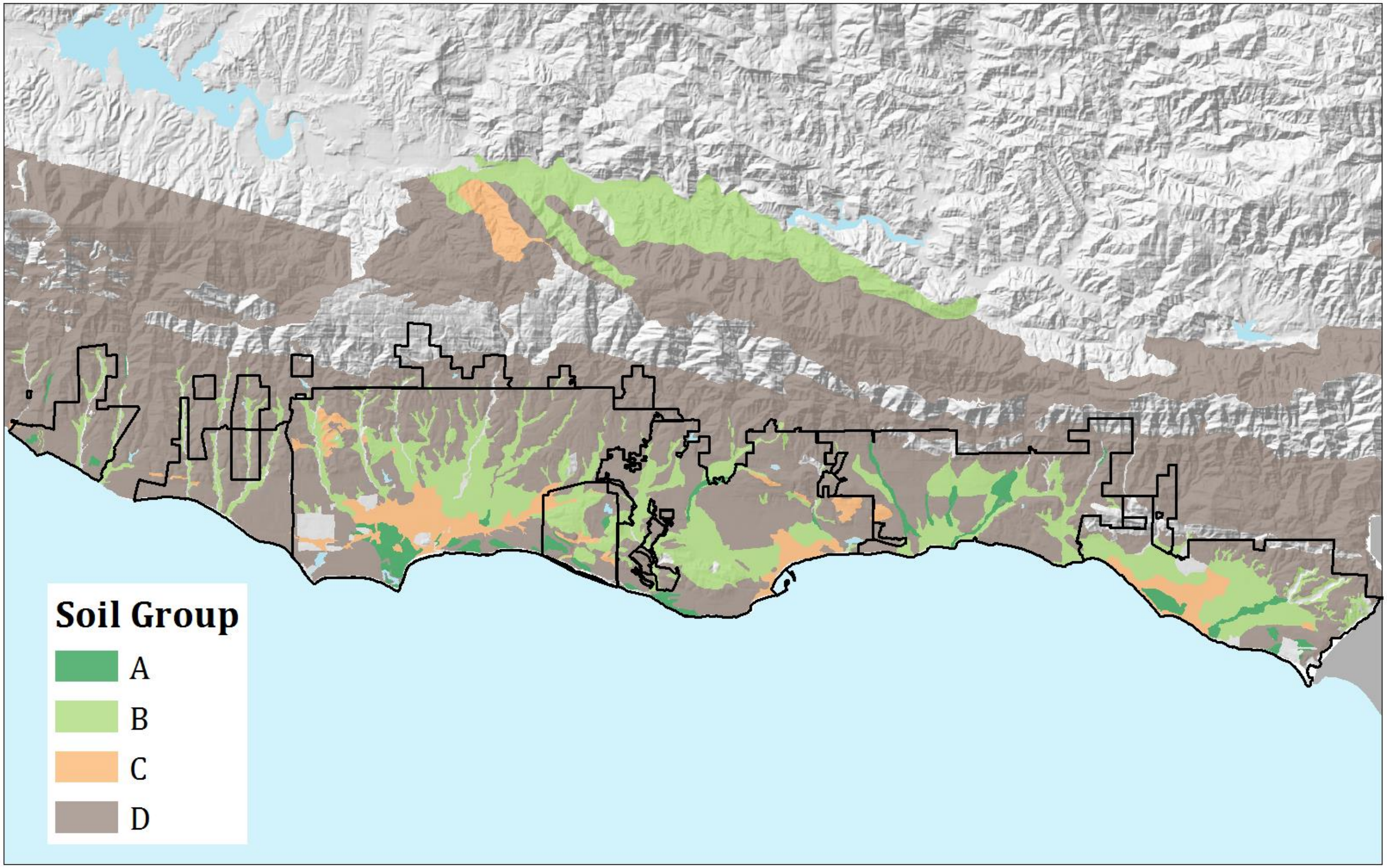

Figure 20. South Coast hydrologic soil group classifications. Data source: National resources Conservation Service's SSURGO database.

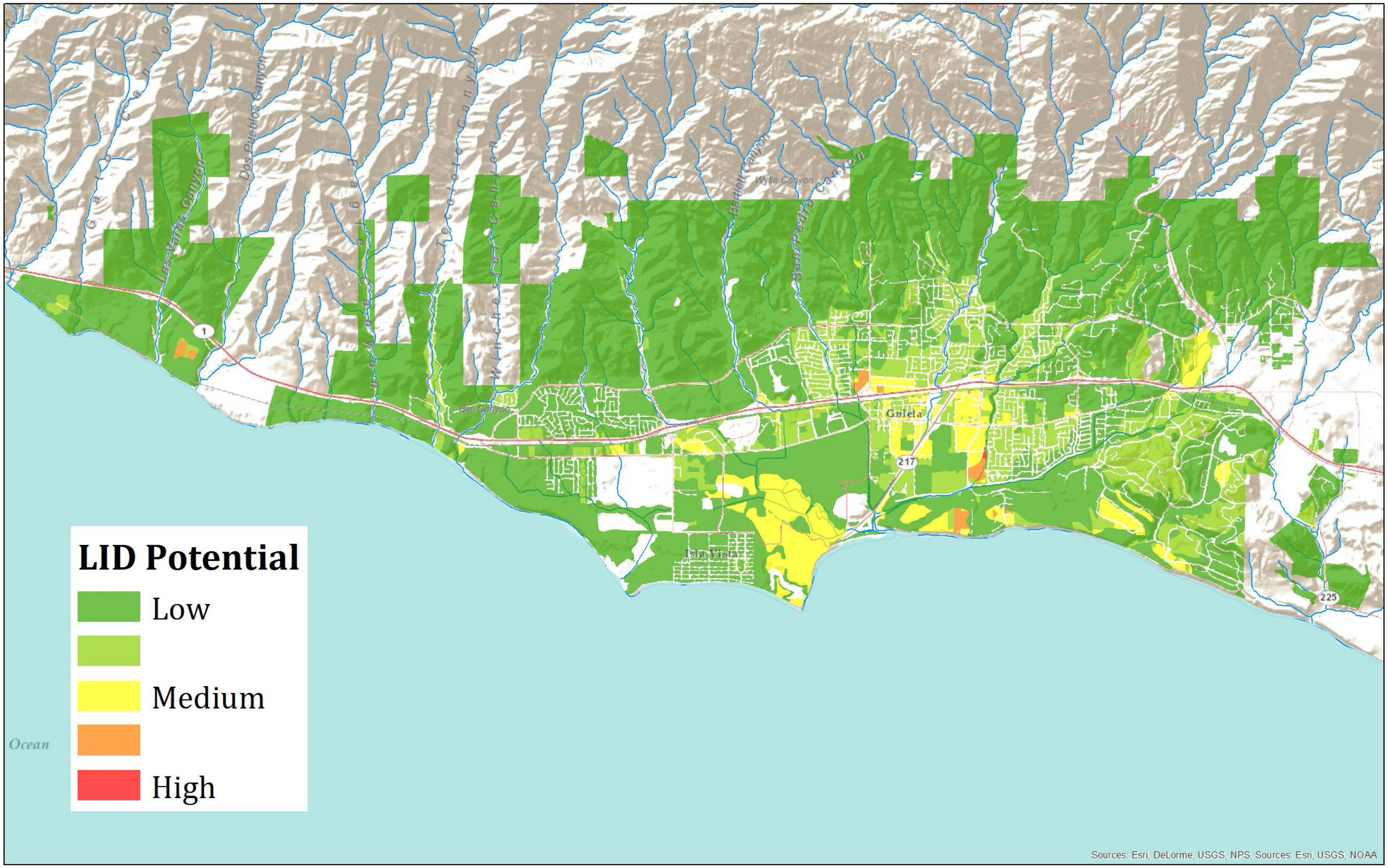

Figure 21. Goleta potential for reduced stormwater runoff from low-impact development using curve number method (preliminary results by Cody Wilgus).

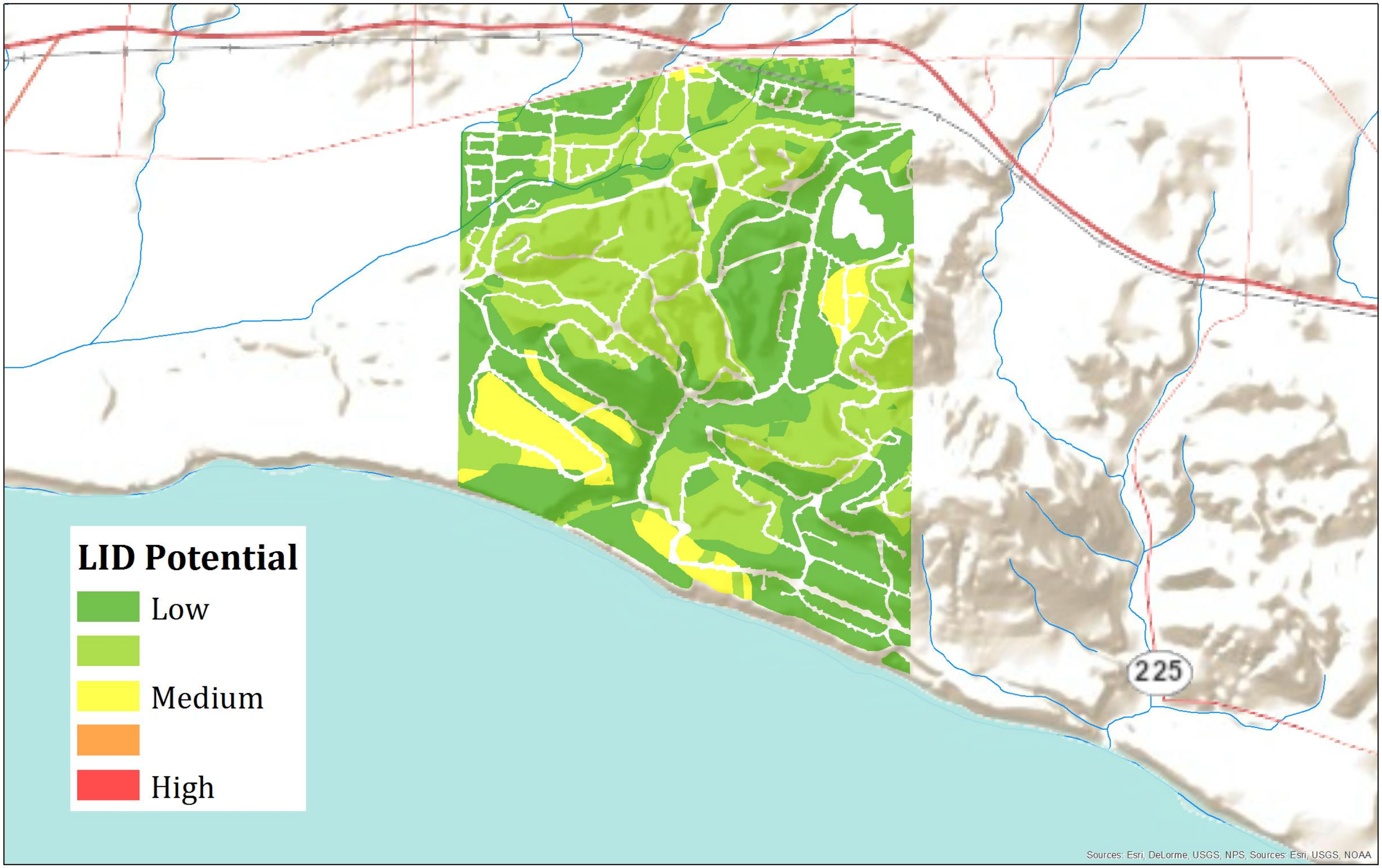

Figure 22. La Cumbre potential for reduced stormwater runoff from low-impact development using curve number method (preliminary results by Cody Wilgus).

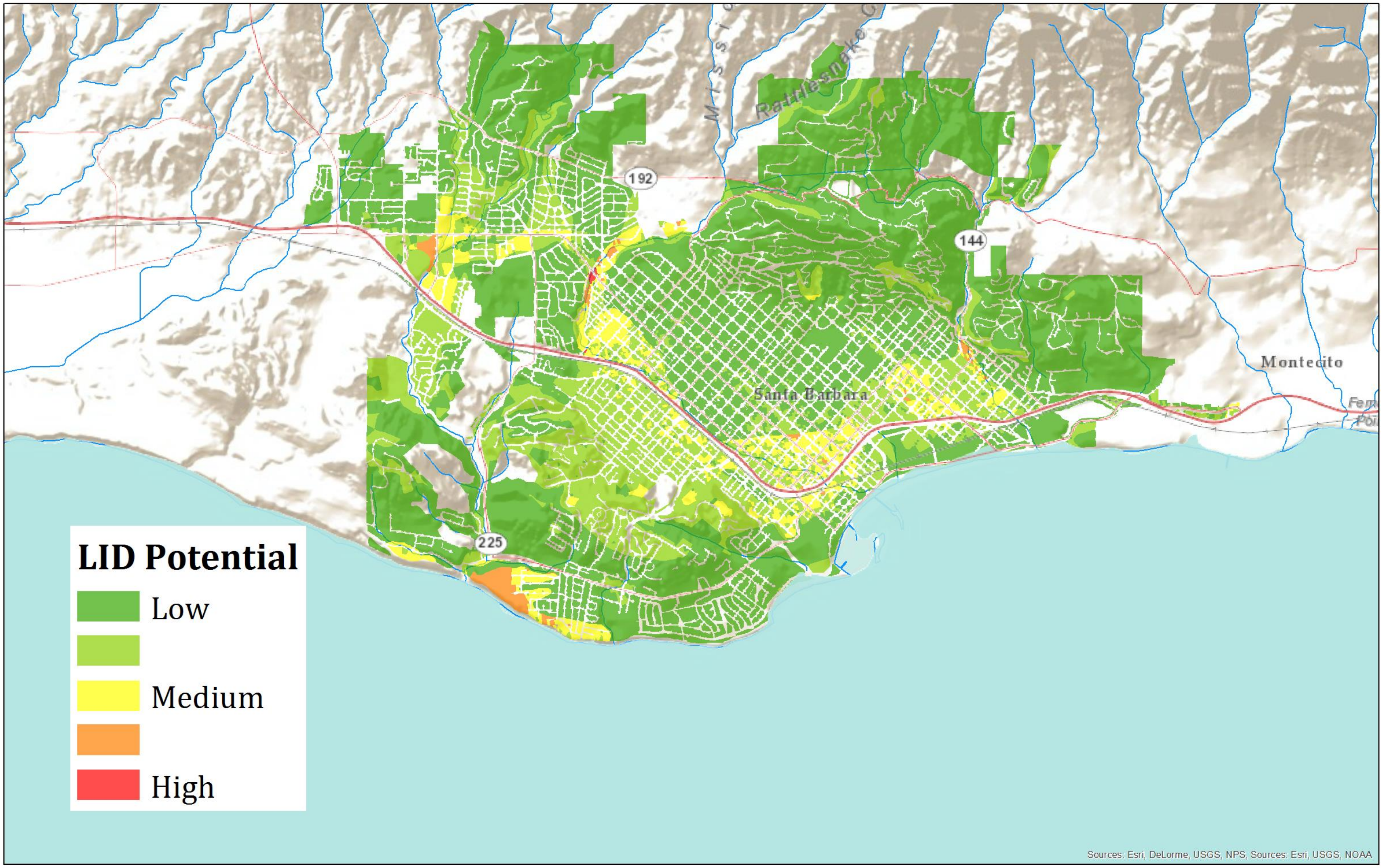

Figure 23. Santa Barbara potential for reduced stormwater runoff from low-impact development using curve number method (preliminary results by Cody Wilgus).

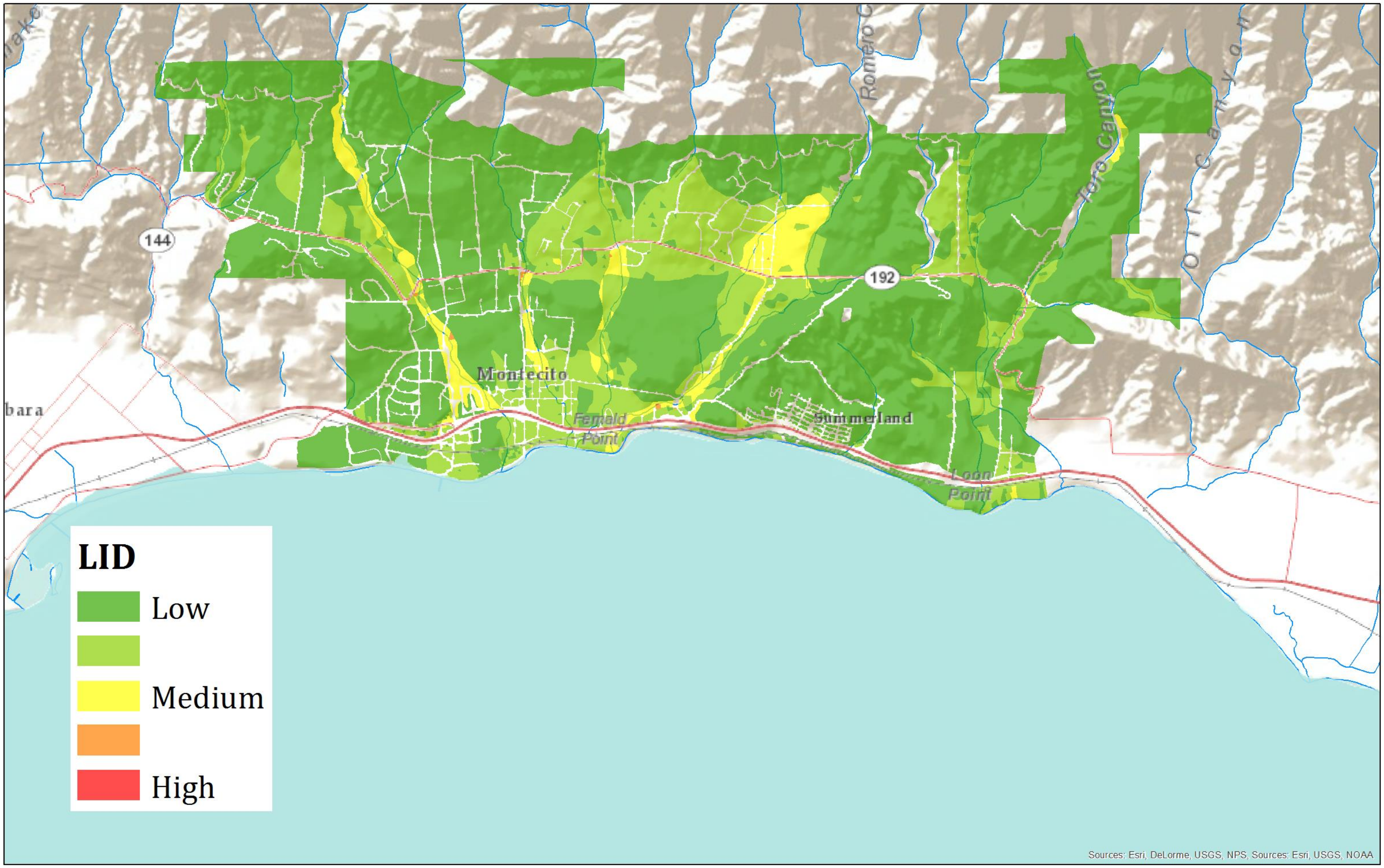

Figure 24. Montecito potential for reduced stormwater runoff from low-impact development using curve number method (preliminary results by Cody Wilgus).

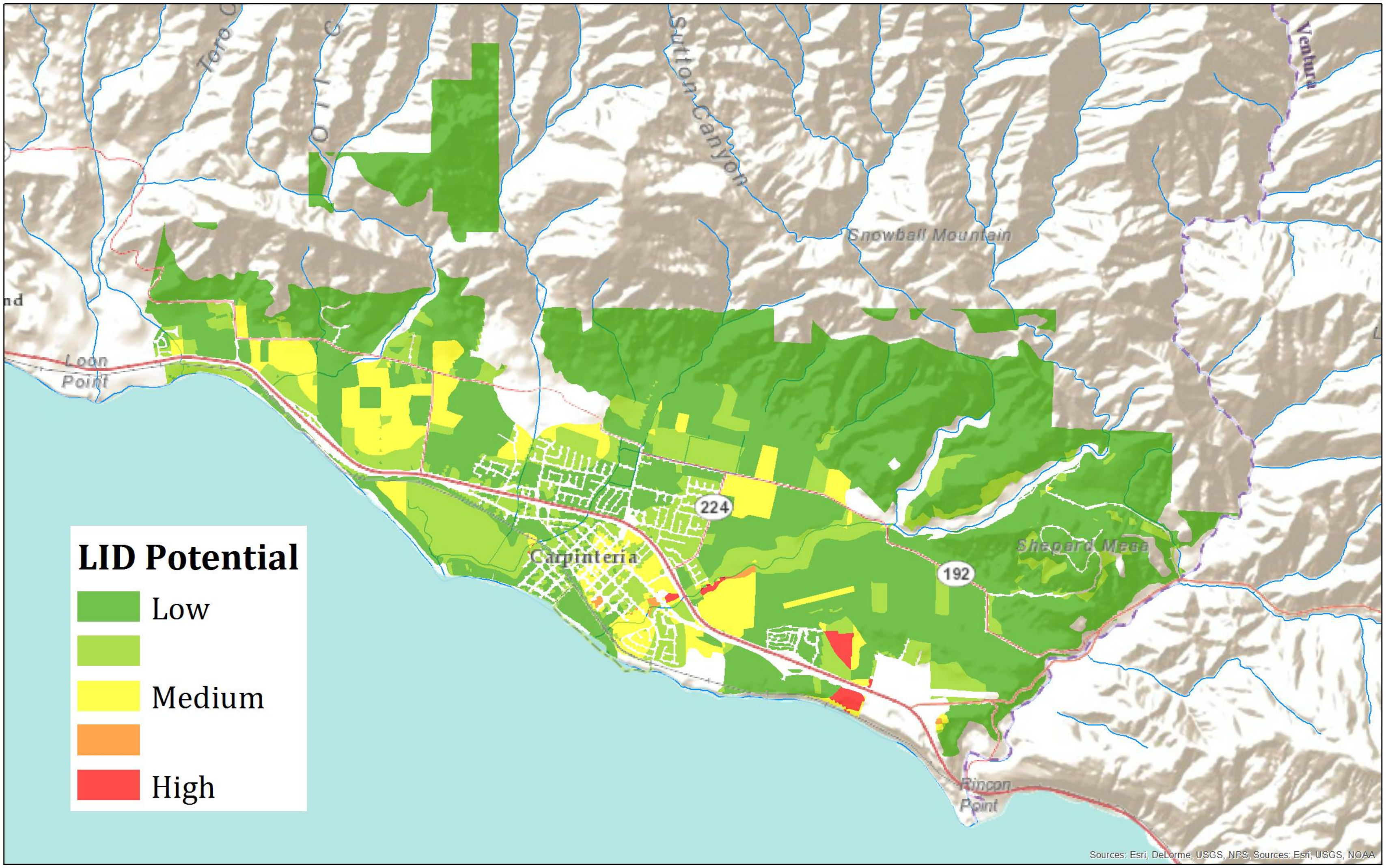

Figure 25. Carpinteria potential for reduced stormwater runoff from low-impact development using curve number method (preliminary results by Cody Wilgus).

Appendix G: State Water Project Breakdown

We were unable to obtain data on what portion of the district-reported State Water delivery numbers were actually exchange or carryover water. In order to estimate amount of water from each individual subcategory of State Water, we used the allocation percentages released by DWR in each year to determine whether the delivery amounts exceeded the allocation.[1] Where delivery amounts did exceed allocations, we assumed that the additional water delivered was either carryover or market water. This is merely a preliminary illustrative analysis. Hard data does exist on these delivery amounts, and should be available from CCWA or the districts themselves. However, we were not provided with this data, and so we conducted this brief analysis, with results below.

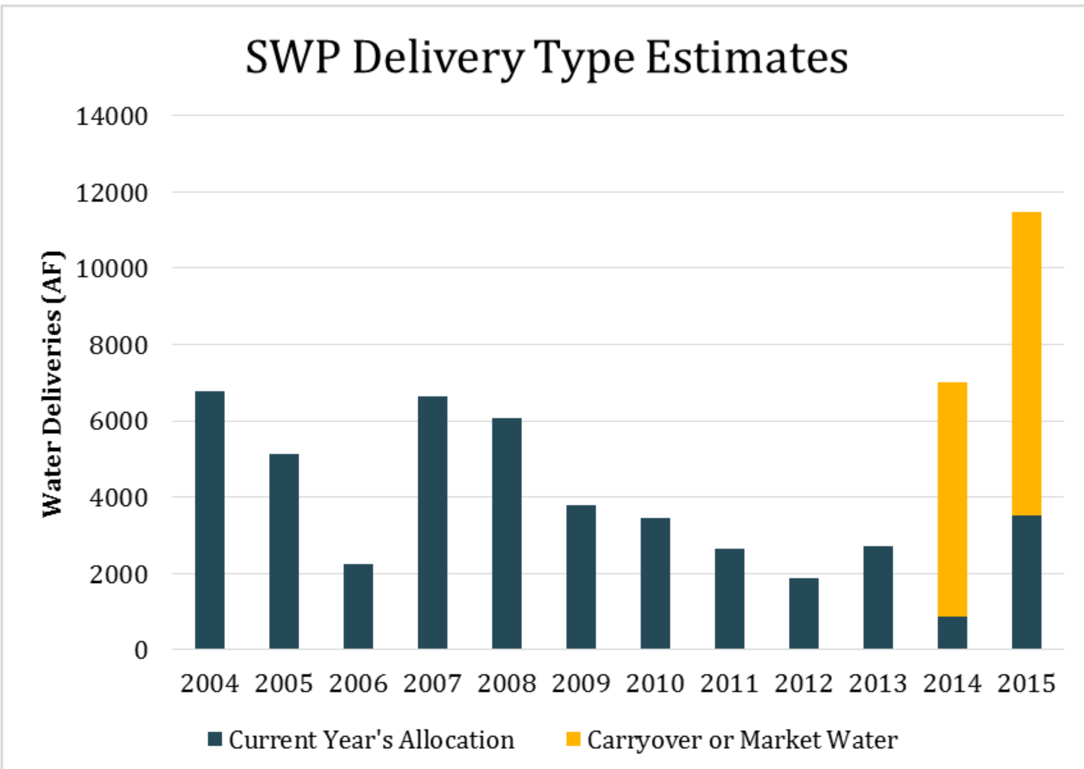

Figure 26. General estimates for the breakdown in State Water delivery types for the South Coast from 2004-2015.

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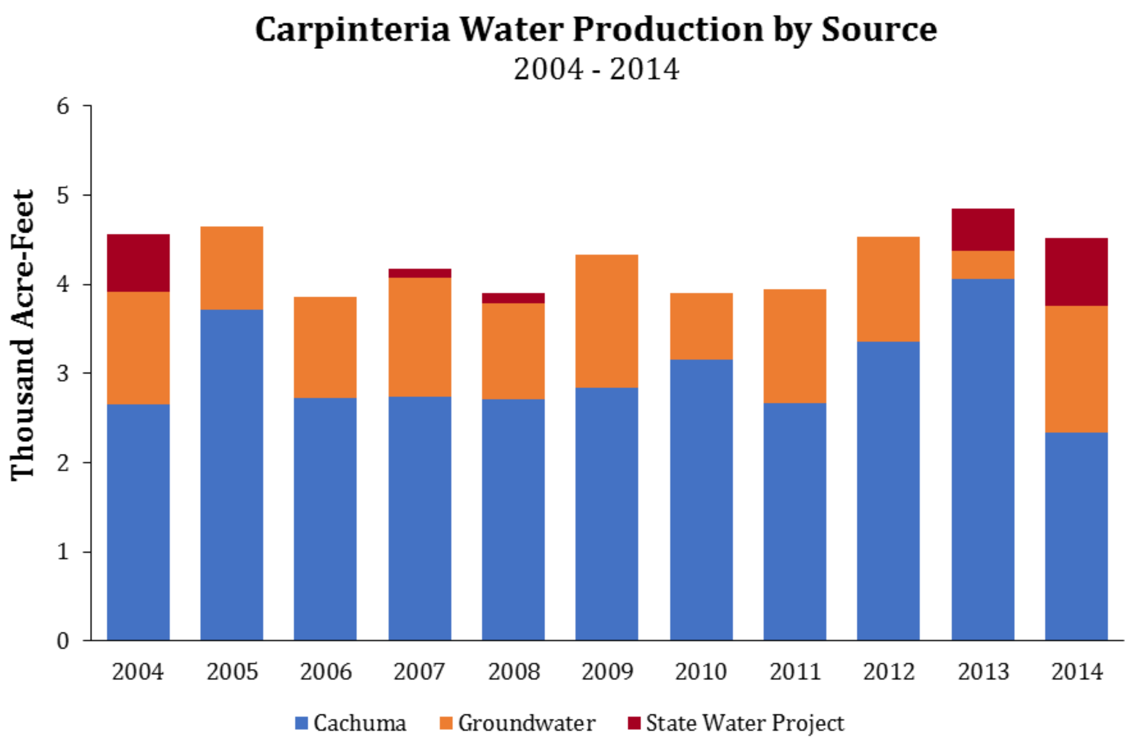
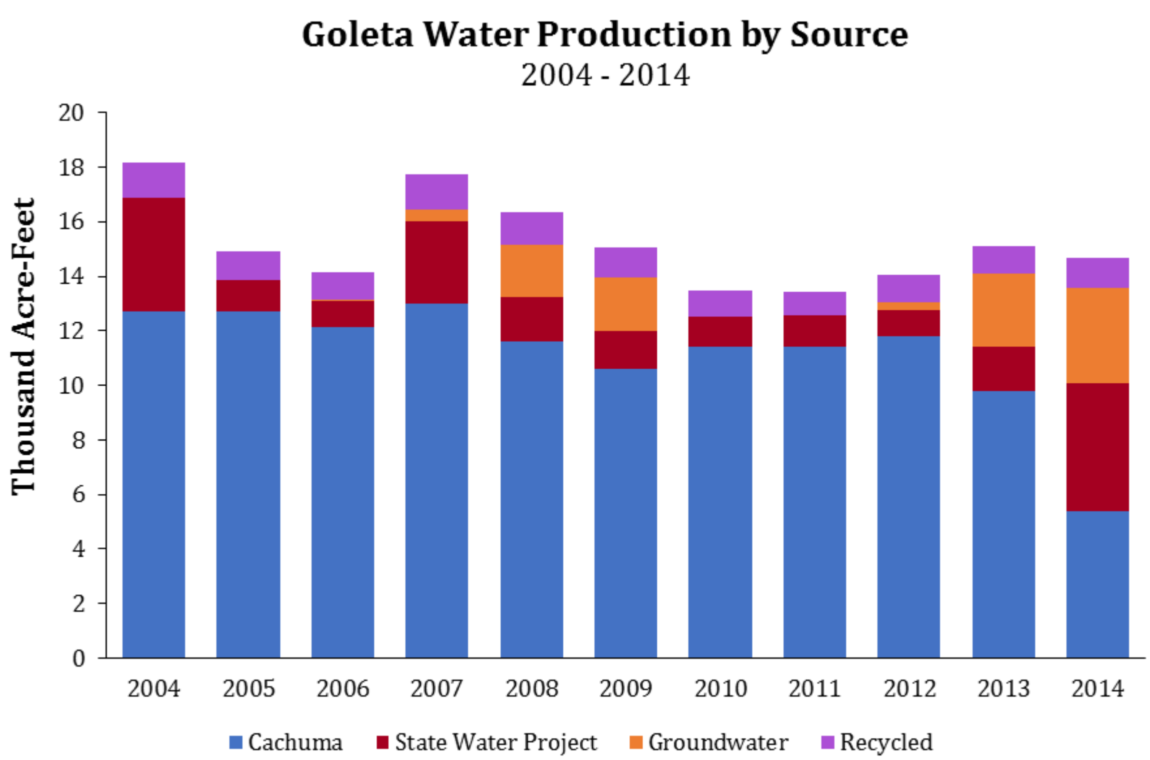
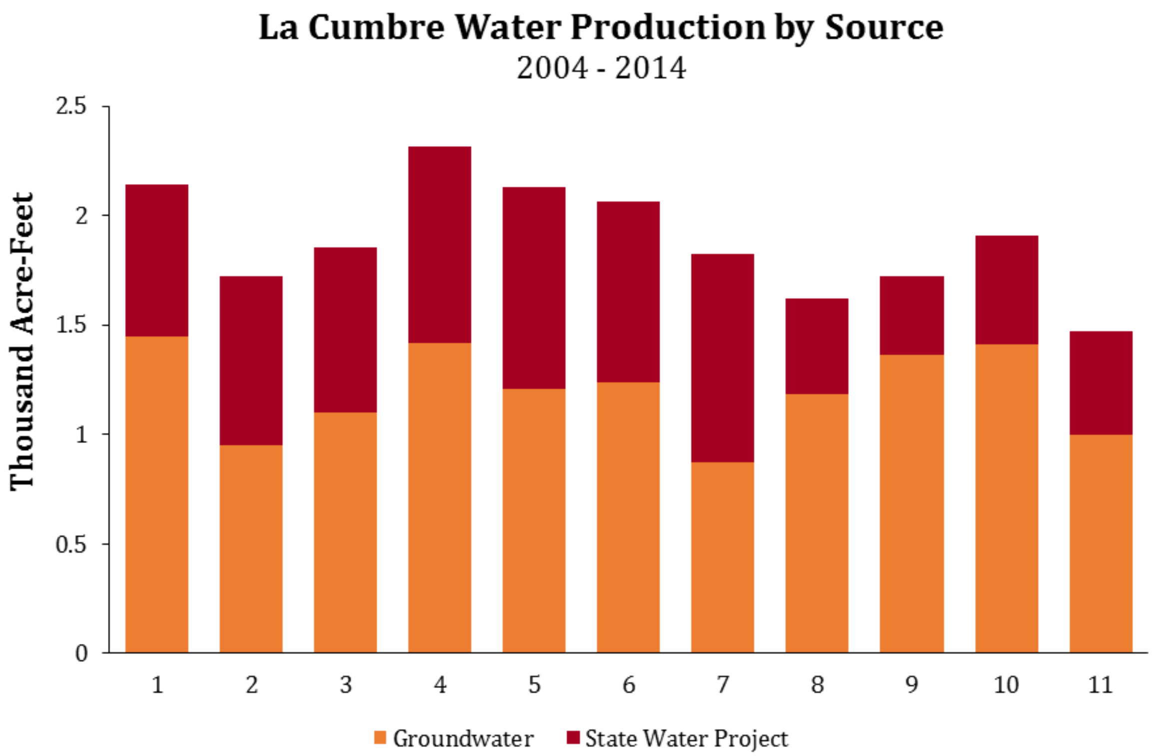
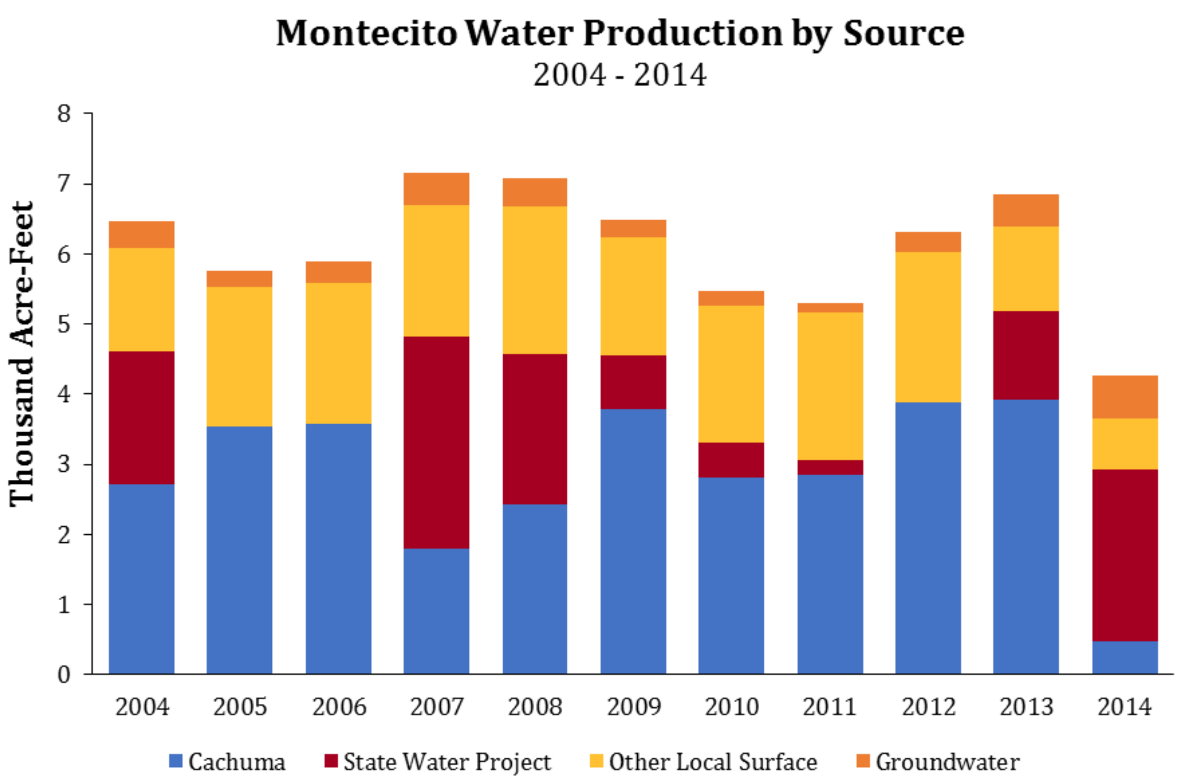
[1] California Department of Water Resources. 2016. "SWPAO – Notices to Contractors." http://www.water.ca.gov/swpao/notices.cfm

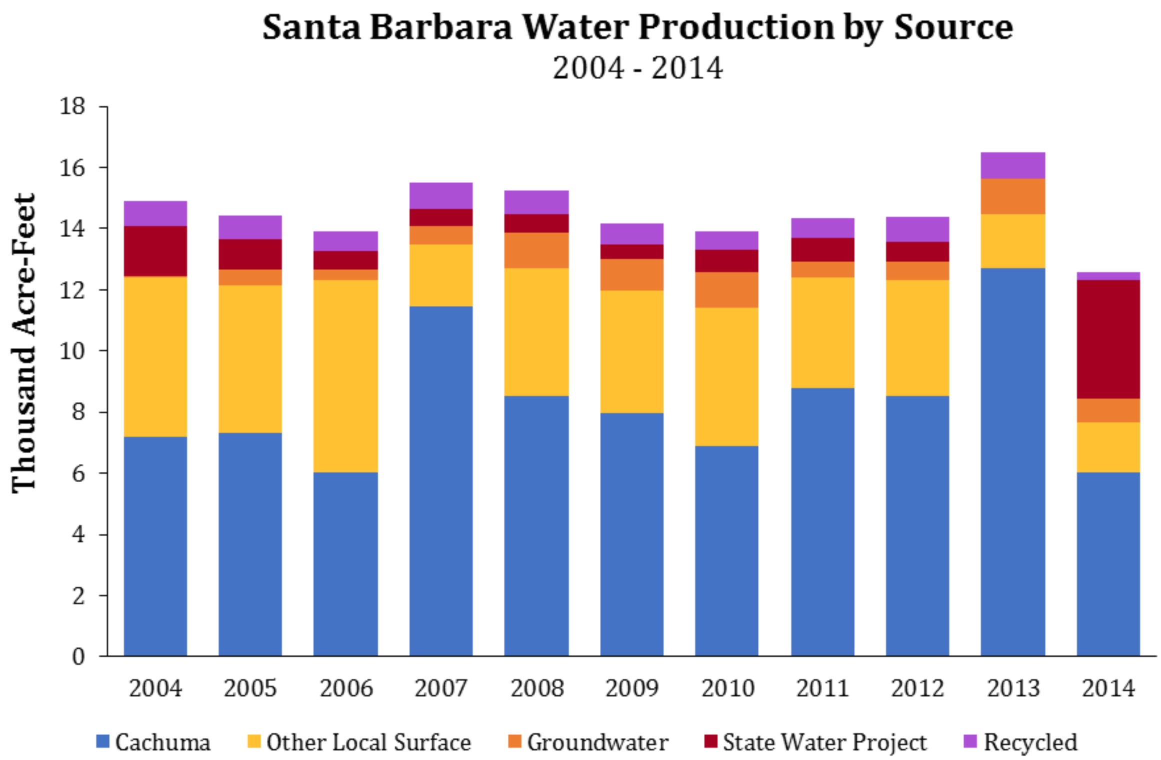
Appendix H: Water Production by District





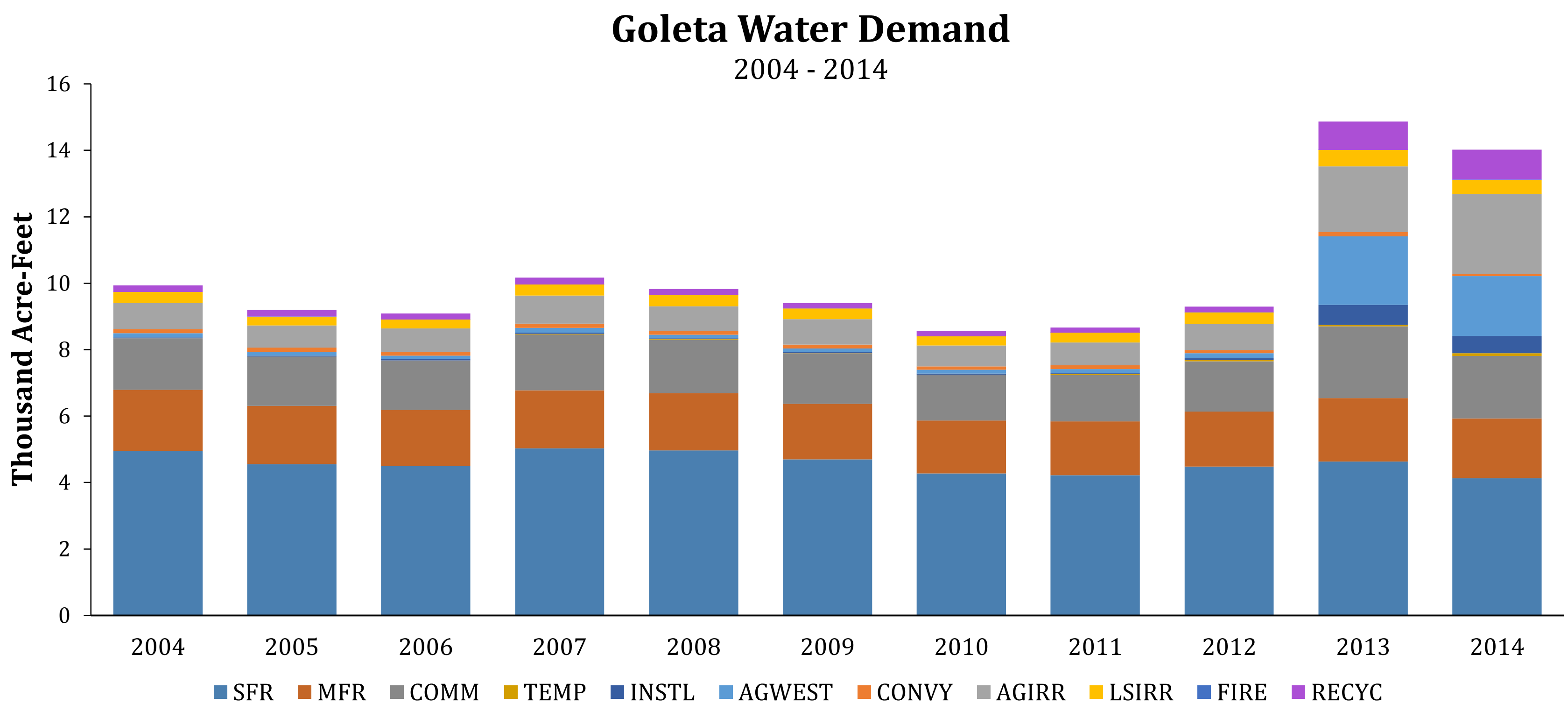

La Cumbre Water Production by Source
2004 - 2014
Thousand Acre-Feet
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
7
8
9
10
11
Groundwater
State Water Project


Montecito Water Production by Source
2004 - 2014
Thousand Acre-Feet
8
7
6
5
4
3
2
1
0
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Cachuma
State Water Project
Other Local Surface
Groundwater

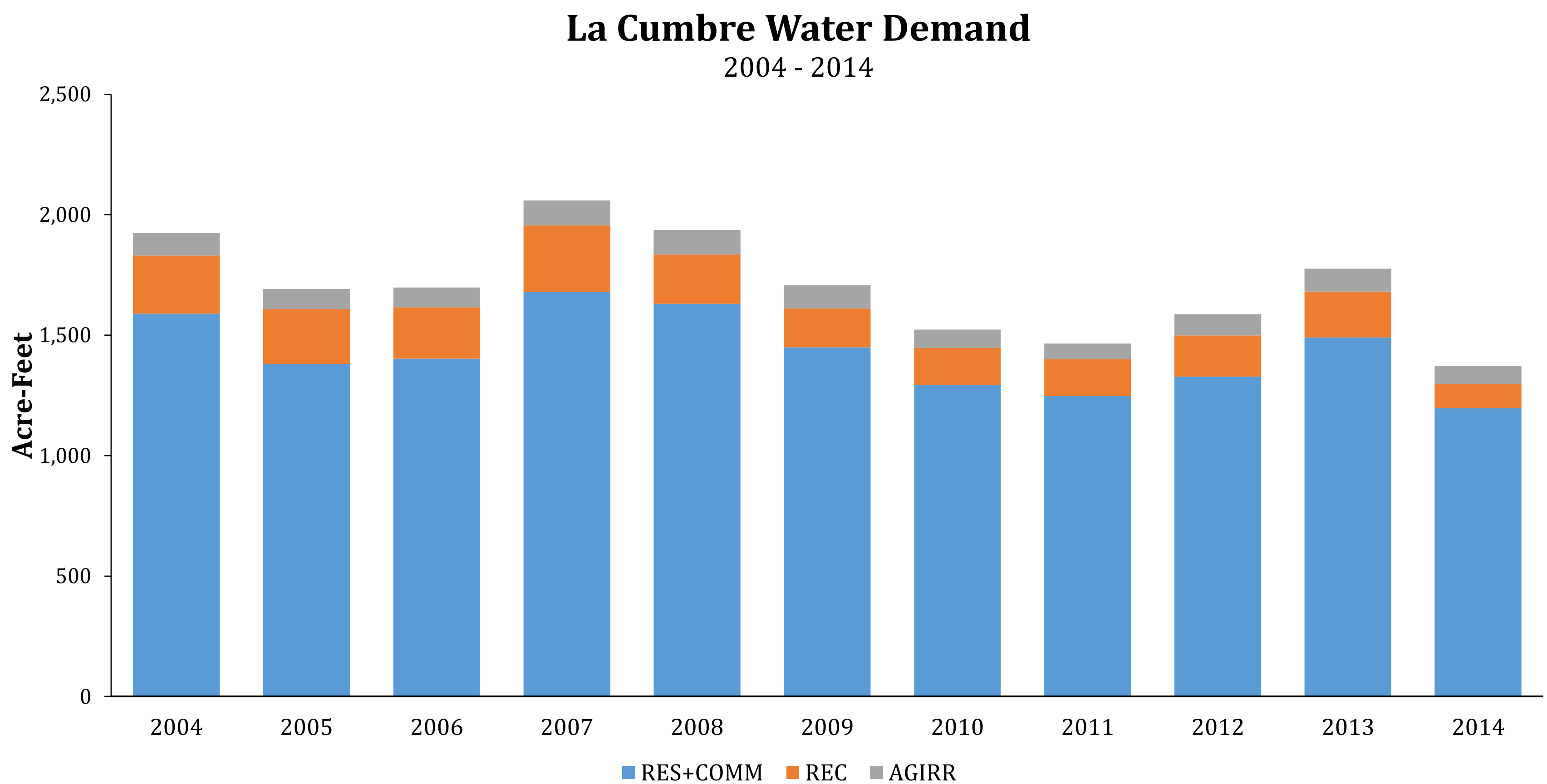


Santa Barbara Water Production by Source
2004 - 2014
Thousand Acre-Feet
0
2
4
6
8
10
12
14
16
18
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Cachuma
Other Local Surface
Groundwater
State Water Project
Recycled

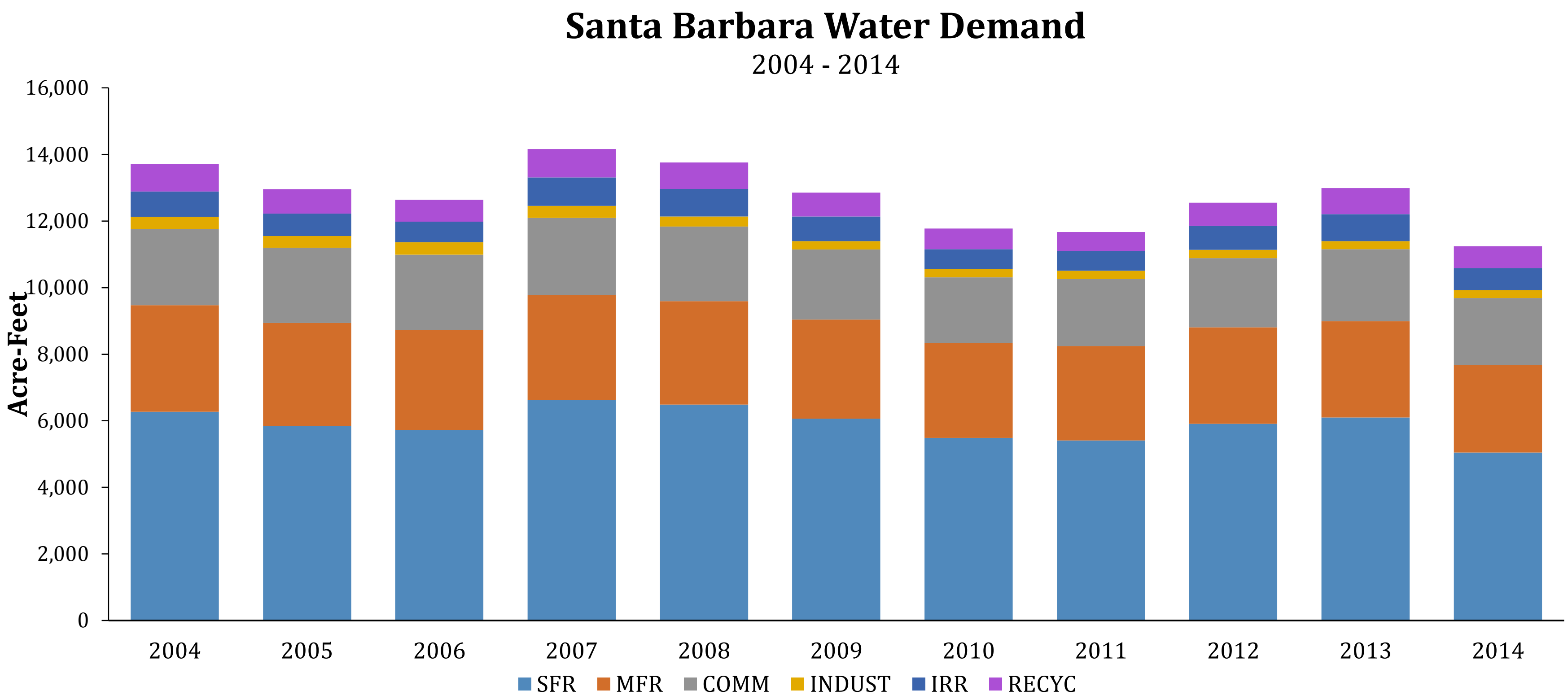
Appendix I: Water Demand by District



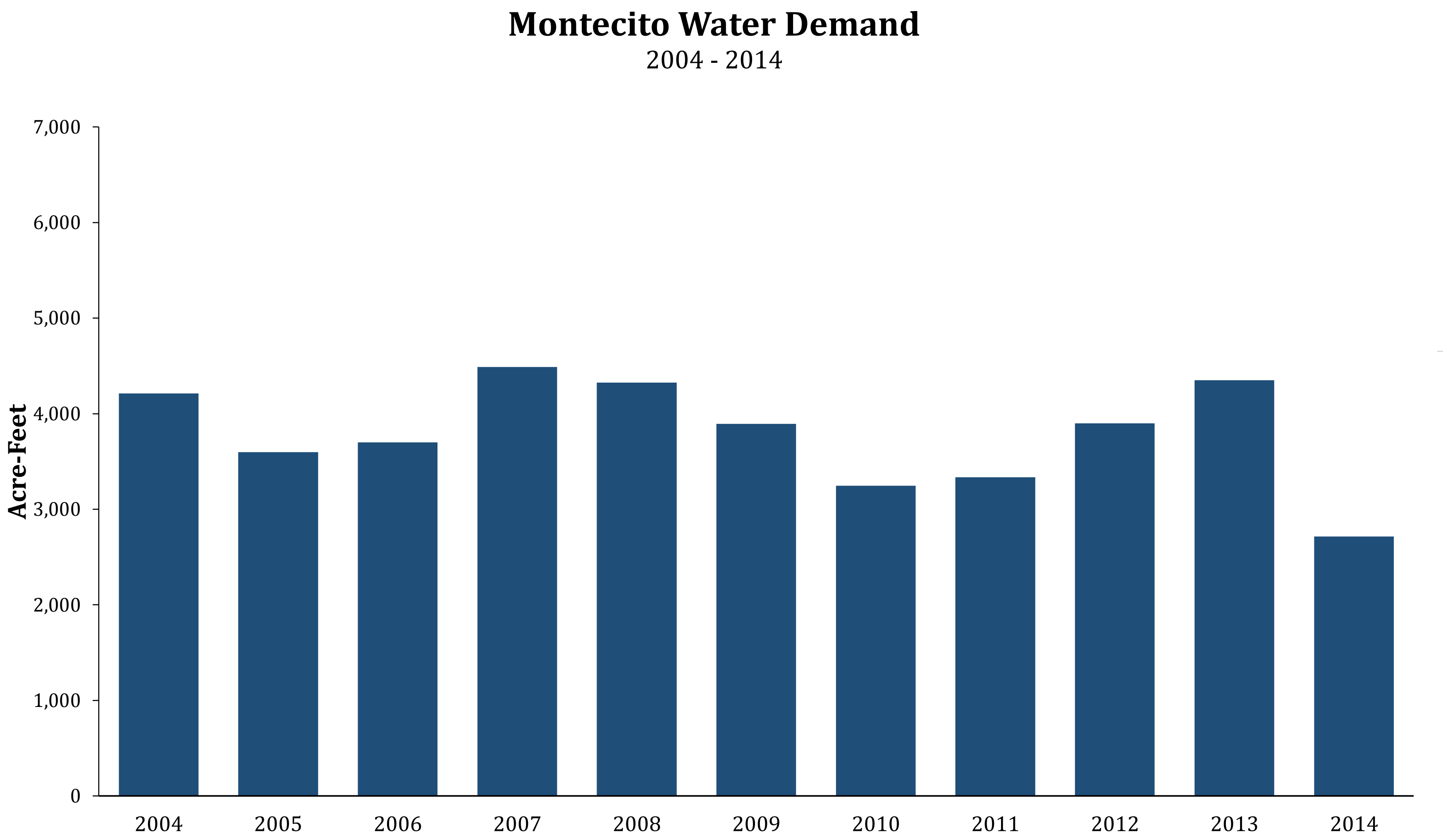
Goleta Customer Classes			
AGIRR	Agriculture Irrigation	AGWEST	Goleta West Conduit
COMM	Commercial	INSTL	Institutional
TEMP	Commercial Temporary	LSIRR	Landscape Irrigation
CONVY	Conveyance	MFR	Multi-Family Residence
FIRE	Fire Service	RECYC	Recycled Water Irrigation
		SFR	Single Family Residence



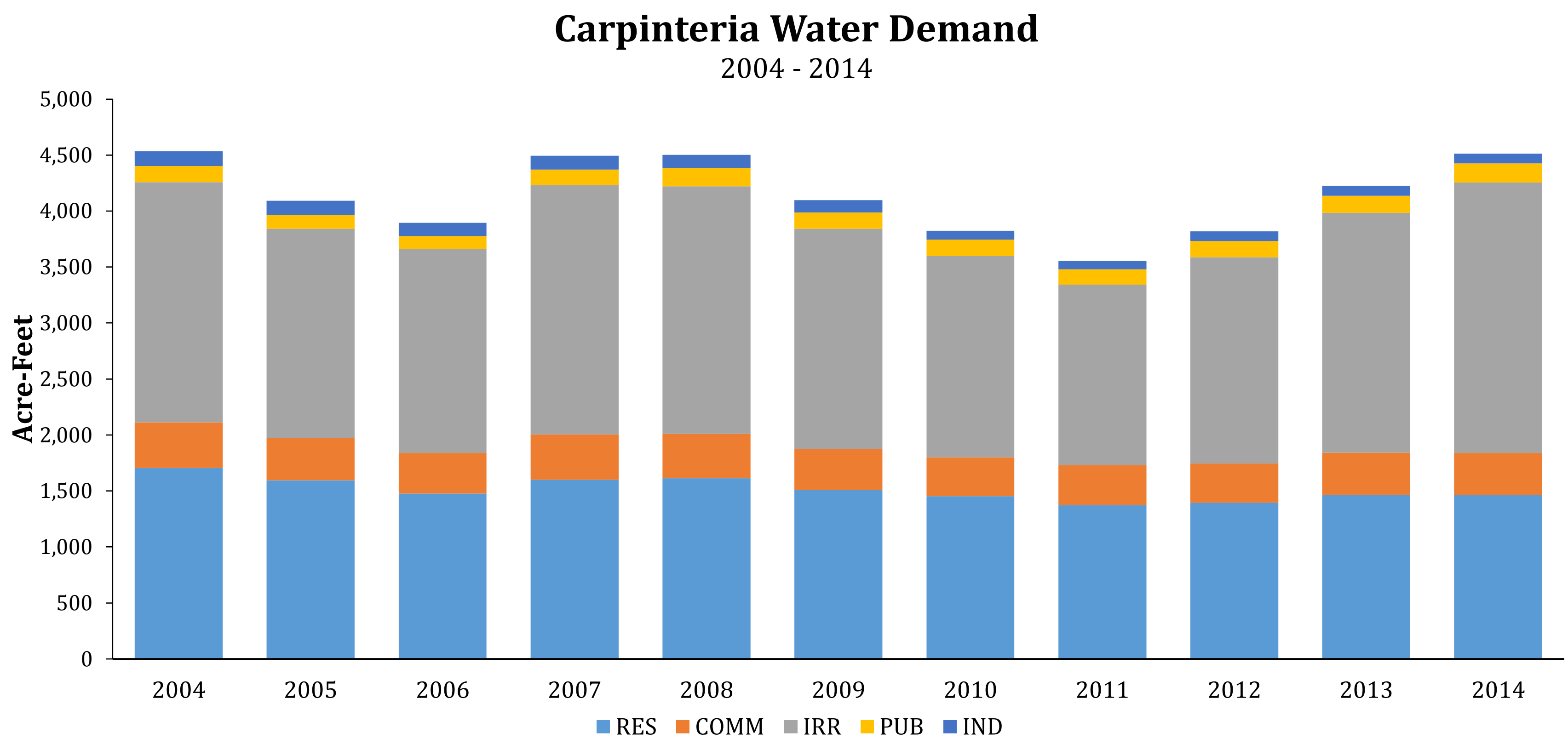
La Cumbre Customer Classes	
RES+COMM	Residential and Commercial
REC	Recreation (Schools, Golf Courses, and Hope Ranch Island)
AGIRR	Agricultural Irrigation



Santa Barbara Customer Classes	
MFR	Multi-Family Residence
RECYC	Recycled Water Irrigation
SFR	Single Family Residence
COMM	Commercial
IRR	Irrigation (includes Residential Irrigation, Outdoor Landscaping, and SB Bird Refuge)
INDUST	Industrial



Montecito Water Demand
2004 - 2014
Acre-Feet
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014



Carpinteria Customer Classes	
RES	Residential
COMM	Commercial
IRR	Irrigation
PUB	Public Authority
IND	Industrial

Appendix J: Cost Range Details

Table 39. Annual cost ranges associated with each supply source per water district. The entire range along the South Coast is used for financial cost comparisons in this report. Grey highlighted rows indicate variable costs. Variable costs are measured in $/AF; fixed costs are measured in $/year. "N/A" includes negligible costs; entire blocs of "N/A" denote districts that do not use that source. Capital costs are only included for projects with ongoing debt payments (i.e., were not paid for upfront). Available data from 2007-15 were retrieved from annual district budgets, water reports, County reports, and COMB budgets

Source	Districts					
	Goleta Water District	La Cumbre Mutual Water Company	City of Santa Barbara	Montecito Water District	Carpinteria Valley Water District	South Coast
Groundwater						
Associated Treatment Plant Costs (avg $/AF)	N/A	N/A	$410	$352	N/A	$352 - 410
Variable O&M ($/AF)	$107 - 489	$60 - 145	$365	$308 - 752	$114 - 176	$60 - 752
Upfront Capital Costs ($)	N/A	N/A	N/A	N/A	$90,956	$90,956
Fixed O&M Costs ($/year)	$14,913 - 1,234,777	N/A	N/A	N/A	$226,544 - 244,689	$14,913 - 1,234,777
Debt Service ($/year)	$441,800	N/A	N/A	N/A	$688,010	$441,800 - 688,010
Lifespan (years)	25	25	20 - 40	20	20	20 - 40
Desalination (3,125 AFY)	N/A	N/A		N/A	N/A	
Variable O&M ($/AF)			$581			$581
Fixed O&M Costs ($/year)			$1,068,484			$1,068,484
Debt Service ($/year)			$3,254,270			$3,254,270
Lifespan (years)			20			20
Desalination (7,500 AFY)	N/A	N/A		N/A	N/A	
Variable O&M ($/AF)			$541			$541
Fixed O&M Costs ($/year)			$1,492,363			$1,492,363
Debt Service ($/year)			$5,029,326			$5,029,326
Lifespan (years)			20			20
Recycled (Tertiary)		N/A		N/A	N/A	
Variable O&M ($/AF)	$181		$318			$181 - 318
Fixed O&M Costs ($/year)	$49,750 - 290,150		$477,507 - 616,495			$49,750 - 616,495
Upfront Capital Costs ($)	$0 - 290,000		$150,000 - 12,488,142			$0 - 12,488,142
Lifespan (years)	15 (pumps) 33.3 (infrastructure)		4 - 5 (membrane replacement)			4 - 5 for membranes; 15 for pumps; 33.3 for infrastructure

Source	Districts					
	Goleta Water District	La Cumbre Mutual Water Company	City of Santa Barbara	Montecito Water District	Carpinteria Valley Water District	South Coast
State Water Project (Table A)						
Variable Purchase Costs ($/AF)	$273 - 341	$273 - 341	$319 - 341	$273 - 341	$288 - 341	$273 - 341
Associated Treatment Plant Costs (avg $/AF)	$130	$137	$137	$137	$137	$130 - 137
Agency Fees ($/year)	$3,362,186 - 5,211,442	$762,618 - 1,108,349	$2,304,712 - 3,226,862	$2,164,240 - 3,269,736	$1,473,119 - 2,020,801	$762,618 - 5,211,442
Fixed O&M Costs ($/year)	$353,929 - 758,957	$145,656 - 202,389	$235,893 - 720,203	$235,893 - 648,434	$157,380 - 242,824	$145,656 - 758,957
Debt Service ($/year)	$2,810,830 - 2,826,403	$617,962 - 621,386	$1,728,188 - 1,737,478	$2,031,231 - 2,042,182	$1,161,283 - 1,167,507	$617,962 - 2,826,403
Cachuma Surface Water						
Associated Treatment Plant Costs (avg $/AF)	$130	N/A	$137	$137	$137	$130 - 137
Agency Fees ($/year)	$1,200,093 - 1,631,941		$2,400,000 - 3,100,000	$351,200 - 981,089	$0 - 350,804	$0 - 1,631,941
Fixed O&M Costs ($/year)	$1,222,340 - 2,072,784			$253,800 - 739,600	$105,989 - 519,888	$105,989 - 2,072,784
Debt Service ($/year)	$142,048 - 160,790			N/A	$38,684 - 47,893	$38,684 - 160,790
Gibraltar Surface Water	N/A	N/A		N/A	N/A	
Associated Treatment Plant Costs (avg $/AF)			$137			$137
Fixed O&M Costs ($/year)			$83,201 - 432,568			$293,944 - 372,337
Jameson Surface Water	N/A	N/A	N/A		N/A	
Associated Treatment Plant Costs (avg $/AF)				$352		$352
Fixed O&M Costs ($/year)				$94,300 - 120,500		$94,300 - 120,500
Rainwater Harvesting						
Upfront Capital Costs ($)	$38,000,000 - 50,000,000	$2,900,000 - 4,200,000	$42,300,000 - 53,000,000	$8,600,000 - 11,800,000	$6,200,000 - 8,200,000	$2,900,000 - 53,000,000
Lifespan (years)	20	20	20	20	20	20

Source	Districts					
	Goleta Water District	La Cumbre Mutual Water Company	City of Santa Barbara	Montecito Water District	Carpinteria Valley Water District	South Coast
Greywater						
Upfront Capital Costs ($)	$5,825,750 - 16,645,000	$504,700 - 1,442,000	$7,826,000 - 22,360,000	$1,399,650 - 3,999,000	$910,700 - 2,602,000	$504,700 - 22,360,000
Lifespan (years)	20	20	20	20	20	20
Demand Reduction (Program-level)				**N/A**		
Upfront Capital Costs ($)	$67,493 - 478,560	**N/A**	**N/A**		$11,148 - 92,900	$11,148 - 478,506
Annual Cost ($) (not itemized)	**N/A**	**N/A**	$707,588 - 2,228,112		**N/A**	$707,588 - 2,228,112
Fixed O&M Costs ($/year)	$234,448 - 242,771	**N/A**	**N/A**		$24,586 - 42,891	$24,586 - 242,771
Estimated Water Savings (AFY)	**N/A**	**N/A**	$23 - 711		**N/A**	$23 - 711
Marginal Cost of Saved Water ($/AF)	**N/A**	**N/A**	$56 - 1,970		**N/A**	$56 - 1,970
Lifespan (years)	depends on device/ program	depends on device/ program	depends on device/ program		depends on device/ program	depends on device/progra m

Appendix K: Cost Breakdown by Source and Year

Recorded costs of each source by districts, per year. For each district using a source in a year, the total production (AF), variable costs ($), fixed costs ($), and marginal full system costs ($/AF) are included. Each table summarizes South Coast ranges, means, and medians for each source.

Table 40. Groundwater cost details.

District	Year	AF Produced	Variable Costs ($)	Fixed Costs ($)	Full System Costs ($/AF)
Goleta	2014	2995	$321,623	$275,715	$314
Goleta	2013	1265	$189,614	$1,126,197	$1,099
Goleta	2012	108	$52,845	$3,520	$640
La Cumbre	2014	998	$118,065	$0	$118
La Cumbre	2013	1413	$118,065	$0	$84
La Cumbre	2012	1364	$118,065	$0	$87
*Santa Barbara**	2014	746	$272,290	N/A	$365
*Santa Barbara**	2013	1156	$421,940	N/A	$365
*Santa Barbara**	2012	577	$210,605	N/A	$365
Montecito	2013	320	$128,780	$0	$402
Montecito	2012	207	$155,737	$0	$752
Montecito	2011	168	$92,198	$0	$549
Montecito	2010	240	$93,941	$0	$391
Montecito	2009	299	$91,963	$0	$308
Carpinteria	2014	753	$132,467	$249,358	$497
Carpinteria	2013	864	$119,032	$234,746	$411
Carpinteria	2012	1155	$142,599	$243,125	$335
Carpinteria	2011	698	$108,894	$228,948	$486
Carpinteria	2010	1308	$186,905	$310,616	$381
Carpinteria	2009	1828	$207,527	$301,280	$279
RANGE		108 - 2995			$83 - 1,099
MEAN		923.1			$420
MEDIAN		808.5			$391

**Santa Barbara budgets are not itemized; full costs are not incorporated into this analysis.*

Table 41. Desalination cost details.

District	Year	AF Produced	Variable Costs ($)	Fixed Costs ($)	Full System Costs ($/AF)
Santa Barbara	2016	3125	$1,814,068	$4,322,754	$1,964
Santa Barbara	2016	7500	$4,054,105	$6,521,689	$1,410
RANGE					$1,410 - 1,964
MEAN					$1,687

Table 42. Recycled Water Cost Details.

District	Year	AF Produced	Variable Costs ($)	Fixed Costs ($)	Full System Costs ($/AF)
Goleta	2016	1325	$157,300	$290,150	$338
Goleta	2015	950	$190,800	$221,950	$434
Goleta	2014	1157	$190,800	$54,250	$212
Goleta	2013	976	$192,000	$145,250	$345
Goleta	2012	913	$191,614	$52,250	$267
Goleta	2011	916	$179,300	$49,750	$250
*Santa Barbara**	2016	750	$235,785	$150,000	$515
*Santa Barbara**	2015	0	$203,156	$150,000	*N/A*
*Santa Barbara**	2014	807	$256,922	$12,488,142	$15,785
*Santa Barbara**	2013	859	$275,970	$150,000	$496
*Santa Barbara**	2012	757	$241,873	$150,000	$518
RANGE		0 - 1,325			$212 - 434
MEAN		855.5			$308
MEDIAN		913			$303

**Due to different budget breakdowns, Santa Barbara is not included in report's financial analysis.*

Table 43. Lake Cachuma cost details.

District	Year	AF Produced	Variable Costs ($)	Fixed Costs ($)	Full System Costs ($/AF)
Goleta	2015	4527	$588,510	$3,545,807	$805
Goleta	2014	6634	$862,420	$3,054,945	$604
Goleta	2013	11991	$1,558,830	$3,143,745	$403
Goleta	2012	11991	$1,558,830	$3,270,714	$344
Santa Barbara	2015	3476	$476,212	$1,550,000	$583
Santa Barbara	2014	8720	$1,194,640	$1,550,000	$315
Santa Barbara	2013	9541	$1,307,117	$1,200,000	$263
Santa Barbara	2012	9613	$1,316,981	$1,200,000	$262
Santa Barbara	2011	9422	$1,290,814	$1,102,628	$254
Montecito	2015	473	$64,801	$747,500	$1,717
Montecito	2014	1171	$160,427	$967,286	$963
Montecito	2013	3610	$494,570	$981,089	$409
Montecito	2012	3610	$494,570	$753,329	$346
Montecito	2011	2752	$377,024	$632,869	$367
Carpinteria	2015	889	$121,793	$705,189	$930
Carpinteria	2014	2610	$357,570	$567,781	$355
Carpinteria	2013	3447	$472,239	$516,411	$287
Carpinteria	2012	3447	$472,239	$435,365	$263
Carpinteria	2011	2655	$363,735	$321,615	$262
RANGE		473 - 11,991			$262 - 1,717
MEAN		5293.6			$539
MEDIAN		3610			$361

Table 44. Other local surface cost details.

District	Year	AF Produced	Variable Costs ($)	Fixed Costs ($)	Full System Costs ($/AF)
Santa Barbara	2015	1765	$241,805	$139,451	$216
Santa Barbara	2014	964	$132,068	$83,201	$223
Santa Barbara	2013	3447	$472,239	$334,982	$234
Santa Barbara	2012	4208	$576,496	$432,568	$240
Montecito	2015	662	$764,700	$120,500	$1,337
Montecito	2014	1031	$704,500	$118,600	$798
Montecito	2013	1554	$695,300	$94,300	$508
Montecito	2012	2234	$702,733	$101,120	$360
RANGE		964 - 4,208			$216 - 1,337
MEAN		1983.1			$490
MEDIAN		1659.5			$300

Table 45. State Water Project cost details.

District	Year	AF Produced	Variable Costs ($)	Fixed Costs ($)	Full System Costs ($/AF)
Goleta	2015	3098	$402,740	$8,376,692	$2,704
Goleta	2014	4625	$601,250	$8,781,698	$1,899
Goleta	2013	810	$105,300	$6,542,518	$8,077
Goleta	2012	1054	$137,020	$7,131,387	$6,766
La Cumbre	2015	626	$81,380	$1,845,338	$2,948
La Cumbre	2014	715	$92,950	$1,883,443	$2,634
La Cumbre	2013	475	$61,750	$1,533,187	$3,228
La Cumbre	2012	352	$45,760	$1,871,967	$5,318
Santa Barbara	2015	4848	$664,176	$5,675,280	$1,171
Santa Barbara	2014	1591	$217,967	$5,141,985	$3,232
Santa Barbara	2013	399	$54,663	$4,278,083	$10,722
Santa Barbara	2012	703	$96,311	$4,568,848	$6,499
Montecito	2015	1089	$149,193	$5,917,988	$5,434
Montecito	2014	3451	$472,787	$5,788,859	$1,677
Montecito	2013	872	$119,464	$4,442,315	$5,094
Montecito	2012	703	$96,311	$5,352,201	$7,613
Carpinteria	2015	1089	$149,193	$3,394,183	$3,117
Carpinteria	2014	1230	$168,510	$3,424,926	$2,784
Carpinteria	2013	359	$49,183	$2,798,006	$7,794
Carpinteria	2012	470	$64,390	$3,058,031	$6,506
RANGE		352 - 4,848			$1,171 - 10,722
MEAN		1428			$4,761
MEDIAN		841			$4,163

Appendix L: Full System Costs Detail

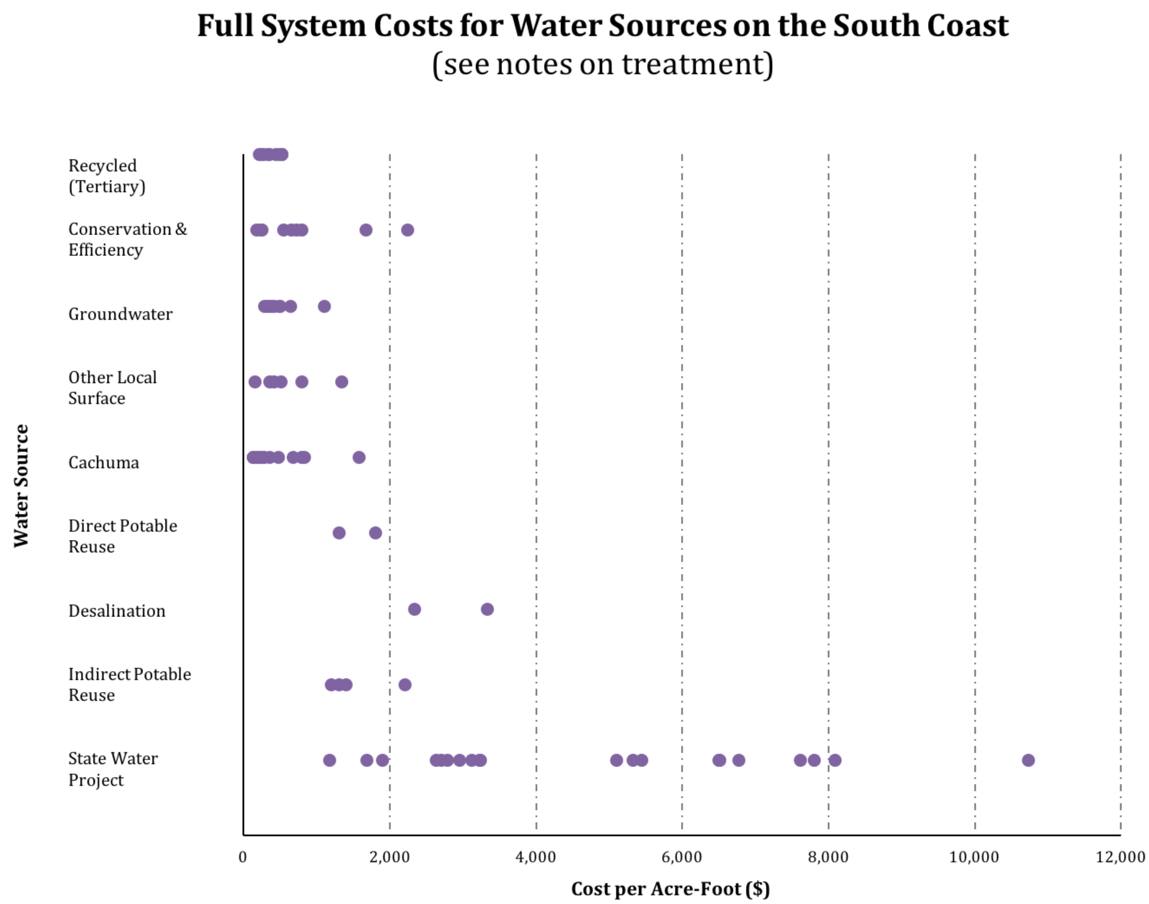


Figure 27. Full System Costs for Water Sources on the South Coast. Each point represents one observed cost per AF, for one year, in one district. Numbers of points differ by source due to differences in data availability. **It is important to note that treatment costs are excluded from this graph for some sources**, because treatment costs at Corona Del Mar and Cater encompass a separate range. Treatment costs are included in this graph for recycled (tertiary), desalination, direct potable reuse, and indirect potable reuse. Conservation and efficiency carry no treatment costs. Treatment costs are not included on this graph for groundwater, Cachuma, other local surface, or the State Water Project. These sources may be treated at Corona Del Mar, Cater, Bella Vista, or a combination of these WTPs. Costs of treatment at each of these plants are itemized in the main report. Direct potable reuse and indirect potable reuse costs are not observed, they are estimates from RMC's Long-Term Water Supply Alternatives study for Santa Barbara County. Desalination costs come from the plant bid proposal, and are also not observed costs.

Appendix M: South Coast Conduit Market Transfers

The districts on the South Coast are managing their water resources and deliveries with very distinct hydrogeological regimes, supply portfolios, customer demands, production costs, revenue streams, planning strategies, and governing bodies. Dissimilarities like these can create barriers for district managers to collaborate on centralized planning discussions. But they also present an opportunity for developing water markets, where an agency with limited supplies, high demand, and sufficient capital could purchase water from another district with more robust supplies and lower demand, provided there is a mechanism through which these transactions can be delivered.

The Public Policy Institute of California (PPIC) reported in 2013 that local water transfers have been increasing over the past few decades. Transfers within the same county have gone from under 20% of total water transfers from 1987-94 to nearly 50% during 2003-11.[1] They suggest that trades are less contentious within regions because the water stays within the local economy. Further, average annual purchases by cities have been steadily increasing. Though most of this water has been purchased from farmers, who have low water costs, the same kind of transactions can and do occur between two urban water purveyors, provided certain supply, demand, economic, infrastructure, and legal conditions are in place.

Unlike city utilities (such as Santa Barbara) and mutual water companies (such as La Cumbre) water districts are political subdivisions of the State of California. They are organized under Division 12 of the California Water Code[2] with the purpose of providing potable water within their districts.[3] Section 31022 of the California Water Code, Division 12, states that "a district may operate water rights, works, property, rights, and privileges useful or necessary to convey, supply, store, or make use of water for any purpose authorized by this division."[4] Section 31023 then adds, "A district may sell water or the use thereof for any useful purpose and whenever there is a surplus, dispose of the surplus to municipalities, public agencies, or consumers located without the district."[5] The districts are allowed to establish their own rules for the sale and distribution of water, but the CA Water Code has provided legal room to trade water between agencies. This alone, however, is not enough to kick-start a South Coast water market.

In order for water trading to occur, there needs to be supply and demand heterogeneity between two parties. Similar to physical hydrology, water markets will move water from areas of supply surplus to areas of supply deficit if given a route through which to travel. Additionally, the water seller needs to have well-defined rights to their water and the water they sell must be physically available, not just unused "paper" rights.[6]

When it comes to Santa Barbara County's South Coast in particular, there is a unique set of challenges to water transfers. One of the fundamental issues is that the districts generally have the same two main water sources - Lake Cachuma and the State Water

Project. Therefore, when these two sources are performing well, all districts may have plenty of water. During dry years or extended droughts, all the districts experience similar shortages. This may limit the potential for transactions. However, while the main water sources may be the same, customer bases in the districts vary widely. Some customers or districts have an extremely high willingness to pay for water. Because of this, even in situations where all districts face equal shortages, potential for transactions still exists.

Another barrier to water transfers on the South Coast is the region's relatively small water demand. Because of this, any water transfers are likely to be small-scale, which increases the relative transaction costs. This makes it impractical to invest in additional infrastructure that would facilitate trades.

South Coast water districts have the advantage of being connected by a mutual artery which delivers both Cachuma and State Water allocations. The South Coast Conduit could be used as a means of delivering traded water between the districts, although this could also be limited by the physical capacity of the conduit itself. However, assuming other South Coast districts do not substantially increase their South Coast Conduit conveyance and a purchasing district simply substituted its imported supplemental purchases with transfers, there would be no change in the amount of water carried through the pipeline. Therefore, the capacity of the conduit would not automatically be a limiting factor.

In addition to other management considerations, Lake Cachuma water may become more unreliable pending a biological opinion on steelhead in the Santa Ynez River. Decreased supply from Cachuma could create more differential demand for water among the districts (depending on who is equipped to deal with shortages), which would naturally beget a market solution. However, less Cachuma water would also mean that districts are more likely to use all the water they have available, which could make trading less likely.

A timely example of supplemental purchases comes from Montecito. In FY 2014, Montecito spent nearly $1.7 million on supplemental purchased water, 84% of their total annual drought expenses.[7] There is limited public data on the amount of water these expenses delivered though it is likely the costs vary depending on who the seller is. In September 2015, Montecito purchased 750 acre-feet of additional water from ID#1 for $761,250 in order meet its demand for the coming water year.[8] The unit cost for this was $1,015 per acre-foot of water from a relatively local seller. However, if South Coast districts could purchase water from each other, using a closer pool of water that that could be cheaper for the seller to produce and deliver than State Water, perhaps districts could save money and keep the economy more local.

The opportunity to take a regional approach to the desalination facility may provide a glimpse into what is politically feasible in terms of water trading. If districts are able to work together to optimize use of the desalination plant, then perhaps other transfers may be possible in the future.

With the multitude of barriers to water transfers (legal, economic, political, financial, and administrative), it is unsurprising that regional market solutions currently play only a small part in South Coast water supply. Water supplies have been relatively stable except in extended droughts, and these events seem to end in the nick of time for water managers. However, State Water may become increasingly unreliable, especially in a warming climate, and Cachuma deliveries could change based on the fate of local steelhead. These factors could compound the current water stress of the area and potentially increase the possibility of trading. Within-region transactions are on the rise overall,[9] and it is possible that given the proper set of circumstances, this trend could extend to the South Coast.

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[1] Ellen Hanak and Elizabeth Stryjewski. 2012. "California's Water Market, By the Numbers: Update 2012." Public Policy Institute of California. http://m.ppic.org/content/pubs/report/R_1112EHR.pdf

[2] California Water Code, Division 12, County Water Districts: http://law.justia.com/codes/california/2011/wat/division-12

[3] County of Santa Barbara. 2000. "Water Delivery & Oversight, Water Purveyors and Other Agencies." Santa Barbara County Water Agency. http://cosb.countyofsb.org/pwd/water/downloads/Part%205%20(Water%20Delivery%20-%20Oversight%20Water%20Use).pdf

[4] California Water Code, Division 12, Article 2, § 31022 (through 2012 Leg Sess). http://law.justia.com/codes/california/2011/wat/division-12/31020-31035.1/31022/

[5] CA Water Code, Division 12, Article 2, § 31023 (through 2012 Leg Sess). http://law.justia.com/codes/california/2011/wat/division-12/31020-31035.1/31023/

[6] Ellen Hanak and Elizabeth Stryjewski. 2012. "California's Water Market, By the Numbers: Update 2012." Public Policy Institute of California. http://m.ppic.org/content/pubs/report/R_1112EHR.pdf

[7] Montecito Water District. 2014. "Montecito Water District 2014/15 Budget." http://www.montecitowater.com/BUDGET%20DOC%20NEW%207032014%20FINAL.pdf

[8] Montecito Water District. 2014. "Montecito Water District 2014/15 Budget." http://www.montecitowater.com/BUDGET%20DOC%20NEW%207032014%20FINAL.pdf. It is unclear from the budget whether or not the total cost included transaction costs for the purchase.

[9] Ellen Hanak and Elizabeth Stryjewski. 2012. "California's Water Market, By the Numbers: Update 2012." Public Policy Institute of California. http://m.ppic.org/content/pubs/report/R_1112EHR.pdf