SUSTAINABLE WATER USE IN THE VENTURA RIVER WATERSHED

AUTHORED BY: RYAN GARDNER, NAHEED IQBAL, AUSTIN LOVE, BRENDA PONTON, JAKE SAHL, DAN YOCUM

ADVISOR: DR. ARTURO KELLER

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

Sustainable Water Use in the Ventura River Watershed

As authors of this Group Project report, we are proud to archive this report on the Bren School's website such that the results of our research are available for all to read. Our signatures on the document signify our joint responsibility to fulfill the archiving standards set by the Bren School of Environmental Science & Management.

Ryan Gardner

Naheed Iqbal

Austin Love

Brenda Ponton

Jake Sahl

Dan Yocum

The mission of the Bren School of Environmental Science & Management is to produce professionals with unrivaled training in environmental science and management who will devote their unique skills to the diagnosis, assessment, mitigation, prevention, and remedy of the environmental problems of today and the future. A guiding principal of the School is that the analysis of environmental problems requires quantitative training in more than one discipline and an awareness of the physical, biological, social, political, and economic consequences that arise from scientific or technological decisions.

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

Arturo A. Keller, Ph.D.

March 2013

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to the following individuals and organizations for providing valuable input and support that made this project possible:

Paul Jenkin, Surfrider Foundation
Dr. Arturo Keller, Professor, Bren School
Dr. Derek Booth, Professor, Bren School
Dr. Bob Wilkinson, Professor, Bren School
Lorraine Walter, Ventura River Watershed Council Coordinator, Ventura River Watershed Council
Lynn Rodriguez, Program Manager, Watersheds Coalition of Ventura County
Karen Waln, Management Analyst II, Ventura Water, City of Ventura
Jordan Kear, Principal Hydrogeologist, Kear Groundwater
Dale Zurawski, Water Quality Program Manager, Farm Bureau of Ventura County
All members of the Ventura River Watershed Council

ABSTRACT

The Ventura River Watershed is one of the few watersheds in Southern California that does not rely on imported water. This local water independence is threatened by decreasing water availability caused by population growth, climate change, and land use change. To ensure that local water supplies continue to meet both human and ecosystem needs, this study sought to identify water management strategies that effectively reduce water demand and increase water supply. A water budget model of the watershed was created using the WEAP System. This model, combined with economic analysis, was used to assess the impact of water management strategies, land use change, and climate change on local water resources. The strategies were evaluated using six criteria: ability to decrease demand, ability to increase supply, cost-effectiveness, benefits to ecosystem health, benefits to water quality, and suitability for Proposition 84 funding. Results from the analysis suggest that, while climate and land use change have the potential to decrease water availability within the watershed, implementing water resource management strategies can offset the impacts. Consumer-based strategies such as ocean friendly gardens and greywater systems are cost-effective options for reducing water demand and increasing local water supplies. By reducing water demand, these strategies can also provide benefits to aquatic ecosystems. While less cost-effective, infrastructure-based solutions such as decentralized infiltration basins were shown to provide substantial benefits to local water supplies. Finally, modifying residential water pricing structures was found to be an effective mechanism for decreasing demand by incentivizing conservation and water-use efficiency by watershed residents.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS AND ACRONYMS

ACP – Asian Citrus Psyllid
ASP – Activated Sludge Process
BMP –Best Management Practice
BO – Biological Opinion
CFS – Cubic Feet per Second
CMWD – Casitas Municipal Water District
DBS&A – Daniel B. Stephens and Associates
DO – Dissolved Oxygen
EMC – Event Mean Concentration
FAO – Food and Agriculture Organisation
FPWF – Foster Park Well Field
GPD – Gallons per Day
GSWC – Golden State Water Company
HCF – Hundred Cubic Feet
IRWM – Integrated Regional Water Management
IRWMP – Integrated Regional Water Management Plan
LARWQCB – Los Angeles Regional Water Quality Control Board
NMFS – National Marine Fisheries Service
NOAA – National Oceanic and Atmospheric Administration
NPV – Net Present Value
OBGMA – Ojai Basin Groundwater Management Agency
OVGCWC – Ojai Valley Green Coalition Watershed Council
OVLC – Ojai Valley Land Conservancy
OVSD – Ojai Valley Sanitary District
PED – Price Elasticity of Demand
SBCK – Santa Barbara Channelkeeper
TMDL – Total Maximum Daily Load
VCWPD – Ventura County Watershed Protection District
VHLC – Ventura Hillsides Land Conservancy
VRWC – Ventura River Watershed Council
WCVC – Watersheds Coalition of Ventura County

EXECUTIVE SUMMARY

The Ventura River Watershed is located along the south-central coast of California, stretching from the mountainous western Transverse Ranges to the Pacific Ocean in the County of Ventura. Land use within the watershed includes rugged, undeveloped scrubland in the Los Padres National Forest, extensive agricultural lands, and densely developed urban areas along the coast. Despite the substantial water demands, the Ventura River Watershed is one of the only watersheds in Southern California that does not import water. Currently, local water resources are used to meet all of the human and environmental demands in the basin.

The two major water sources within the Ventura River Watershed are the Lake Casitas Reservoir and groundwater. A number of public and private water companies, municipalities, and landowners extract water from Lake Casitas and the four local groundwater basins. Although human water needs are being met, local consumption has already begun to impact the water available for environmental functions. Increased demand caused by population growth and land use change, coupled with decreased supply resultant from climate change, may result in insufficient water to meet both human and environmental needs in the near future.

This study sought to address the long-term sustainability of local water resources in the Ventura River Watershed. A comprehensive water budget was created to quantify water supply and demand, and a number of water management strategies were investigated to study their impacts on water availability. The impacts of climate and land use change on water resources were also examined. Finally, the strategies were combined in a set of suites to investigate the ability of the water management strategies to offset potential water shortages resulting from future climate and land use change scenarios.

Previous studies have quantified a number of individual water demand and supply components within the watershed. This project combined data from these budgets into one comprehensive model using the Water Evaluation and Planning (WEAP) system. Now that it has been developed, this WEAP model can help facilitate planning and water resource management decisions at a watershed-wide scale. The water budget model also improves the understanding of current demands on local water resources, and provides the ability to evaluate the impacts of various water management strategies on short and long-term water availability. This project investigated eight water management strategies as well as the impacts of a wide range of climate and land use change scenarios on water resources within the Ventura River Watershed.

The water management strategies investigated in this study were separated into two categories, consumer- and infrastructure-based strategies. Consumer oriented strategies are implemented by residents within the watershed, while infrastructure strategies are implemented by local municipalities or water companies.

Consumer-based strategies considered in this study include ocean friendly gardens, laundry-to-lawn greywater systems, and water pricing structure changes. Ocean friendly gardens replace irrigation-dependent lawns with rain gardens and plants that require little or no irrigation. Rain gardens capture precipitation and runoff from roofs and impervious surfaces and allow it to infiltrate into the soil and groundwater basins instead of running off into the stormwater system. Removal of lawns can significantly reduce residential water demand and can save homeowners substantial amounts of money through water and lawn care savings. Laundry-to-lawn greywater systems allow wastewater from laundry systems to be used for lawn or garden irrigation. This can further reduce water demand and output to sewage systems.

Water prices are substantially lower for many of the residents in the Ventura River Watershed than elsewhere in California. The water rate changes investigated in this study include increasing the average cost of water for all residents of the watershed to the state average. Increasing residential water rates can lead to significant reductions in water demand. Although water companies and municipalities implement water rate changes, the financial impact of the change is borne by consumers. As a result, these strategies are considered consumer-based in our analysis.

Infrastructure-based water management strategies considered in this study include infiltration basins, a scalping plant in Ojai, replacing impervious street material with pervious streets, and the creation of San Antonio Spreading Grounds. Infiltration basins capture runoff from roads, parking lots, and other impervious surfaces. The basins decrease nutrient and pollution loading to local stormwater systems and waterways, while increasing infiltration to groundwater. A scalping plant enables extraction and reuse of wastewater in the City of Ojai, reducing local demand of potable water for non-potable uses such as irrigation and agriculture. Replacing impervious streets with pervious material increases groundwater infiltration while reducing stormwater runoff and pollution. Finally, the San Antonio Spreading Grounds is a project that will divert water from San Antonio Creek during high-flow periods to a nearby spreading ground where it can infiltrate to the Ojai Groundwater Basin.

Six criteria were used to evaluate the effectiveness of the water management strategies considered in this study: ability to decrease demand, ability to increase supply, cost-effectiveness, ability to improve ecosystem health, ability to improve water quality, and suitability for Proposition 84 funding.

The ability to decrease demand was accomplished by reducing water use by consumers in the watershed, and the ability to increase supply was calculated as any increase surface or groundwater. The cost-effectiveness of a strategy was calculated by determining the total costs of a strategy minus the total benefits, divided by the total water saved through decreased demand and increased supply. Our cost-effectiveness calculations relied on net present value, which includes the time value of money. Each strategy, therefore, can be evaluated by the average cost (in dollars) per acre-foot saved over a 20-year time frame. Benefits to ecosystem health were assessed by the impacts of a strategy on streamflow in the Live Reach of the Ventura River, a segment of the river that has been identified as important for endangered steelhead trout. Water quality improvements were evaluated by estimating the nutrient loading reductions from each strategy. Water projects that are submitted for Proposition 84 funding are evaluated on fourteen criteria, and the project must meet at least one criterion to qualify for funding. To evaluate our water management strategies' suitability for Proposition 84 funding, each water management strategy was scored on how many Proposition 84 criteria it met.

Results for each water resource management strategy under each evaluation criteria were normalized on a scale of 0-3, with a score of 0 given for strategies that have no significant beneficial impact on an evaluation criteria and a score of 3 assigned to strategies that have a significant beneficial impact for a criteria. Ocean friendly gardens, greywater systems, and infiltration basins all scored high on multiple criteria. While raising water rates to the state average did not score high on multiple criteria, it is the most effective means of reducing demand. The remaining strategies are effective at some criteria, but were not as effective overall.

Future water demand and supply may be impacted by climate and land use change. Climate change is predicted to have impacts on temperature, precipitation, and vegetation cover within the Ventura River Watershed. In addition to climate variability, the group analyzed how various land use change scenarios could impact the Ventura River Watershed. WEAP enabled the team to simulate how multiple land use changes and climate change projections could influence future water resources in this area.

In order to determine the ability of the water management strategies to mitigate the negative impacts of climate and land use change, the water management strategies were combined with climate and land use changes into suites of scenarios using the WEAP model. The three main suites include a baseline suite, a temperature increase suite, and a worst-case suite. In the baseline suite, historical temperature and precipitation data was extrapolated out to year 2099. In the temperature increase suite a four-degree temperature increase resulted in higher environmental water use, which led to a decrease in surface and groundwater supplies. These decreases, however, could be offset by adopting ocean friendly gardens and greywater systems in half of the households within the watershed, and by increasing the lowest water rates to the state average. In the worst-case scenario, a four-degree temperature increase was combined with a twenty percent decrease in precipitation and a widespread crop conversion from oranges to raspberries, a crop with greater irrigation demands. In this scenario, implementing consumer-based solutions and infrastructure-based solutions is not sufficient to offset the substantial decrease in water supply. Consequently, more aggressive targets for installation of consumer and infrastructure-based solutions will be needed.

Ocean friendly gardens, laundry-to-lawn greywater systems, decentralized infiltration basins, and modifying water-pricing structures within the watershed are cost-effective strategies for maintaining local water sustainability. These strategies effectively reduce demand, increase supply, improve ecosystem health, and reduce nutrient pollution. Investing in low cost water management solutions now can address future water demand increases and supply decreases caused by climate change and population growth. Ocean friendly gardens, greywater, and decentralized infiltration basins are all strong candidates for Proposition 84 funding, and the funding would further increase cost-effectiveness of the strategies. This study recommends the use of these water management strategies in the Ventura River Watershed to ensure that local water resources are able to meet human and environmental water needs now and in the future.

1. INTRODUCTION

1.1 Purpose Statement

The Ventura River Watershed is unique to Southern California as it does not import any water from sources outside of the watershed. However, in the face of climate change, land use change, and population growth, there is growing concern that local water supplies may soon fail to meet local demands. These local demands include water for residential and commercial uses, water for environmental uses, and water for agricultural uses. Because the Ventura River Watershed does not import any water, these major demands are all in competition for a finite amount of this increasingly stressed resource.

This project sought to identify water resource management strategies to ensure the sustainable use of the limited water resources in the Ventura River Watershed. Strategies identified by this study include both consumer-based and infrastructure-based approaches that were shown to be effective options for reducing water demand, increasing water supply, improving water quality, and improving riparian & riverine ecosystem health in the Ventura River Watershed.

1.2 Project Objectives

The goal of this project was to facilitate the sustainable management of water resources within the Ventura River Watershed. To accomplish this goal, the following objectives were established:

1. Integrate existing water budgets for the Ventura River Watershed into one comprehensive model.

2. Determine levels of water use that meet human needs while allowing for healthy, functioning ecosystems within the Ventura River stream network.

3. Evaluate the effects of climate change and land use change scenarios on the water budget within the Ventura River Watershed.

4. Use the comprehensive model to identify actionable water management strategies in accordance with the priorities of the Ventura River Watershed Council. These priorities include augmenting water supplies to maintain independence from imported water, enhancing water quality, and restoring ecosystem functions.

5. Propose a set of recommendations to the Ventura River Watershed Council relevant to securing Proposition 84 funding, increasing water availability, and improving ecosystem function within the watershed.

1.3 Description of Watershed

1.3.1 Physical

The watershed is located in the northwest corner of Ventura County in Southern California; a small portion of the watershed is located in the southeastern edge of Santa Barbara County (Figure 1. 1). This fan shaped watershed covers 228 square miles (approximately 146,000 acres) that ranges from rugged 6,000 foot mountainous terrain in the northern reaches of the basin to sea level in the south at the Ventura River estuary (Figure 1. 1). The U.S. Bureau of Reclamation classified the topography of the watershed as fifteen percent valley, forty percent foothill, and forty-five percent mountain (CRWQCB, 2012).

Figure 1. 1: Topography of the Ventura River Watershed.

The major tributaries of the Ventura River are Matilija Creek, San Antonio Creek, Cañada Larga, and Coyote Creek (Figure 1. 2). The headwaters of the Matilija Creek are located in the Santa Ynez Mountains in the northwestern corner of the watershed and flows southeastward for about 15 miles until it meets Matilija Reservoir. After the reservoir it continues for about a half mile until it joins with the North Fork of Matilija Creek. The North Fork of Matilija Creek is about 12 miles long and flows southward out of the mountainous Los Padres National Forest.

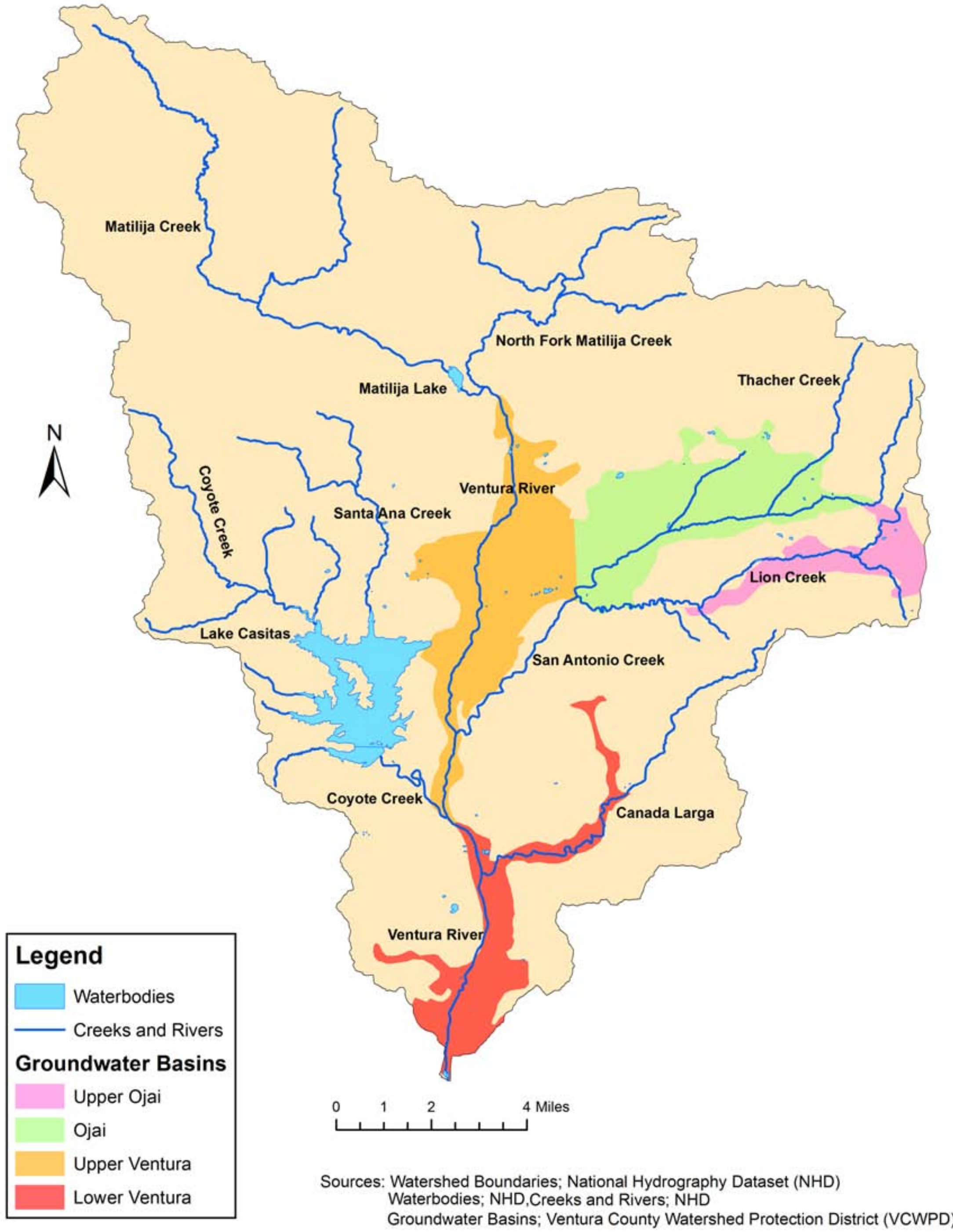

Figure 1. 2: Hydrology of the Ventura River Watershed.

The Ventura River begins at the confluence of Matilija Creek and the North Fork of Matilija Creek. Below the confluence, the Ventura River flows southward for about 16 miles until it reaches the Pacific Ocean. Eight miles downstream from this confluence, San Antonio Creek flows into the

Ventura River from the east and two miles further downstream Coyote Creek joins the river from the west. The last major tributary of the Ventura River before it drains into the ocean is Cañada Larga, which joins the Ventura River from the east.

The Matilija Reservoir and Lake Casitas are the two significant reservoirs in the Ventura River Watershed. Matilija Reservoir was built in 1947 and was originally designed to hold 7,000 AF for municipal and agricultural uses. However, the reservoir quickly filled with sediment after it was completed and is essentially non-functional as of today; the removal of Matilija Dam was authorized in 1998 and the removal plan is still being debated. Lake Casitas, located on Coyote Creek, provides the only significant source of surface water for municipal and agricultural use in the watershed. The Casitas Dam was completed by the U.S. Bureau of Reclamation in 1959 and the reservoir has a capacity of 254,000 AF.

There are four groundwater basins in the watershed: Upper Ojai, Ojai Valley, Upper Ventura, and Lower Ventura Groundwater Basins (Figure 1. 2). The Ojai Valley Groundwater Basin and the Upper Ventura Groundwater Basin are both heavily utilized by agricultural and municipal users. There are a number of water companies that pump water out of the Ojai Valley Groundwater Basin in order to supply residents of the City of Ojai with drinking water. Additionally, there are a number of private agricultural wells that draw water from both the Ojai Valley Groundwater Basin and the Upper Ventura Groundwater Basin. The City of Ventura also has a well field that draws water from the southerly border of the Upper Ventura Groundwater Basin to provide potable water for municipal uses. Within the Upper Ojai and Lower Ventura Groundwater Basins there are agricultural users who draw water from these aquifers in order to irrigate their orchards and crops.

1.3.2 Climate

The Ventura River watershed has a Mediterranean climate with wet, mild winters and dry, warm summers. Most of the precipitation comes during the months of November through March with very little precipitation occurring during the rest of the year. On average, February is the wettest (5.39 in.) month and July is the driest (0.03 in.) month (Monthly Weather for Ojai, 2012). Precipitation patterns vary spatially within the watershed with more rain falling in the higher elevations and less rain falling in the low-lying regions (Tetra Tech, 2008). Depending on the year, some snow will fall in the highest portions of the watershed; however, this snow rarely remains more than a few days before melting. Annual precipitation in the watershed ranges from 8 to 61 inches with an average of 26 inches (Figure 1. 3). An average about 346,000 AF fall on the entire 228 square miles of the watershed; in very dry years this drops to 101,000 AF and in wet years it can climb as high as 740,000 AF.

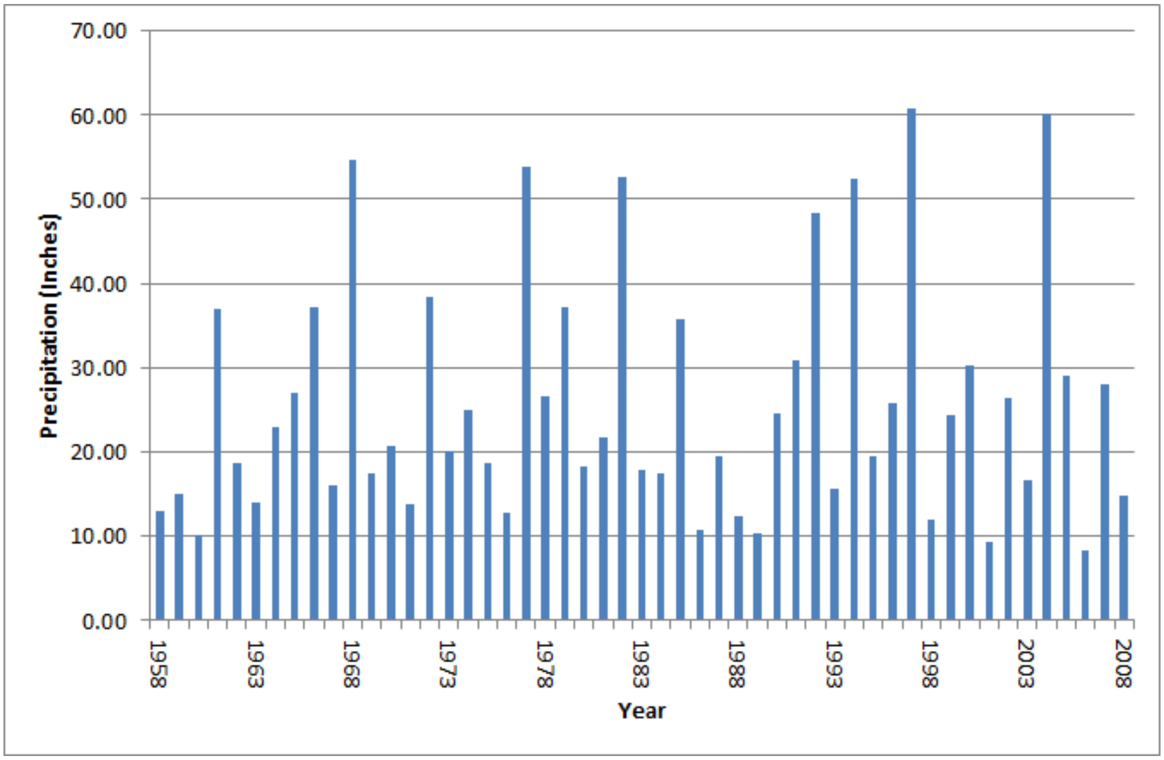

Figure 1. 3: Precipitation of the Ventura River Watershed (Wickstrum & Merckling, 2011).

Average temperatures in the watershed range from 50 °F in the winter months to 70 °F in the summer months (Figure 1. 4). July is the warmest month on average and December is the coolest month. The highest temperature recorded in Ojai, a city centrally located in the watershed, was 112 °F in 1960, and the lowest recorded temperature was 16 °F in 1990 (Monthly Weather for Ojai, 2012).

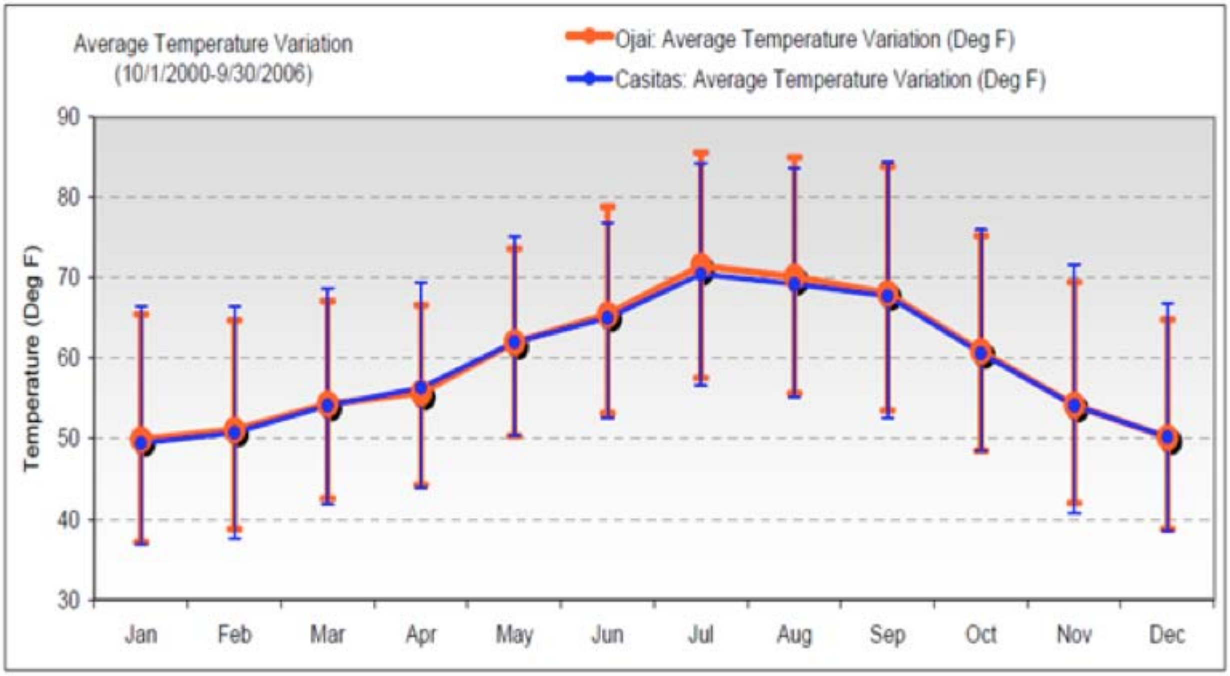

Figure 1. 4: Average temperature by month in the Ventura River Watershed (Tetra Tech, 2008).

1.3.3 Land Use

The Ventura River Watershed supports a variety of land use types including agricultural, residential, commercial, and industrial (Figure 1. 5). While the watershed does support an array of uses, about 85% of the land is classified as open space, of which about 50% lies within the Los Padres National Forest in the northern part of the watershed (CRWQCB, 2012). The plant communities in these open areas include chaparral, coastal sage scrub, oak woodland, non-native annual grasslands, and a variety of riparian woodland (Cardno Entrix, 2012).

After open space, residential and agricultural lands make up the largest land uses in the area. Overall, residential lands account for 4.8% of the land use and agricultural lands account for 4.5% (CRWQCB, 2012). The residential areas are mostly localized around the rural city of Ojai in the central part of the watershed and the more urbanized City of Ventura on the southern border. The agricultural use consists primarily of citrus and avocado orchards, though there is also some cattle grazing and irrigated row crops in the area (Tetra Tech, 2008).

The largest industrial use in the area is oil and gas extraction in the southern portion of the watershed (Figure 1. 5). There is also a rock quarry located along the North Fork of Matilija Creek. Commercial use accounts for a very small percentage of land use within the watershed and is primarily located in the City of Ventura (Table 1. 1).

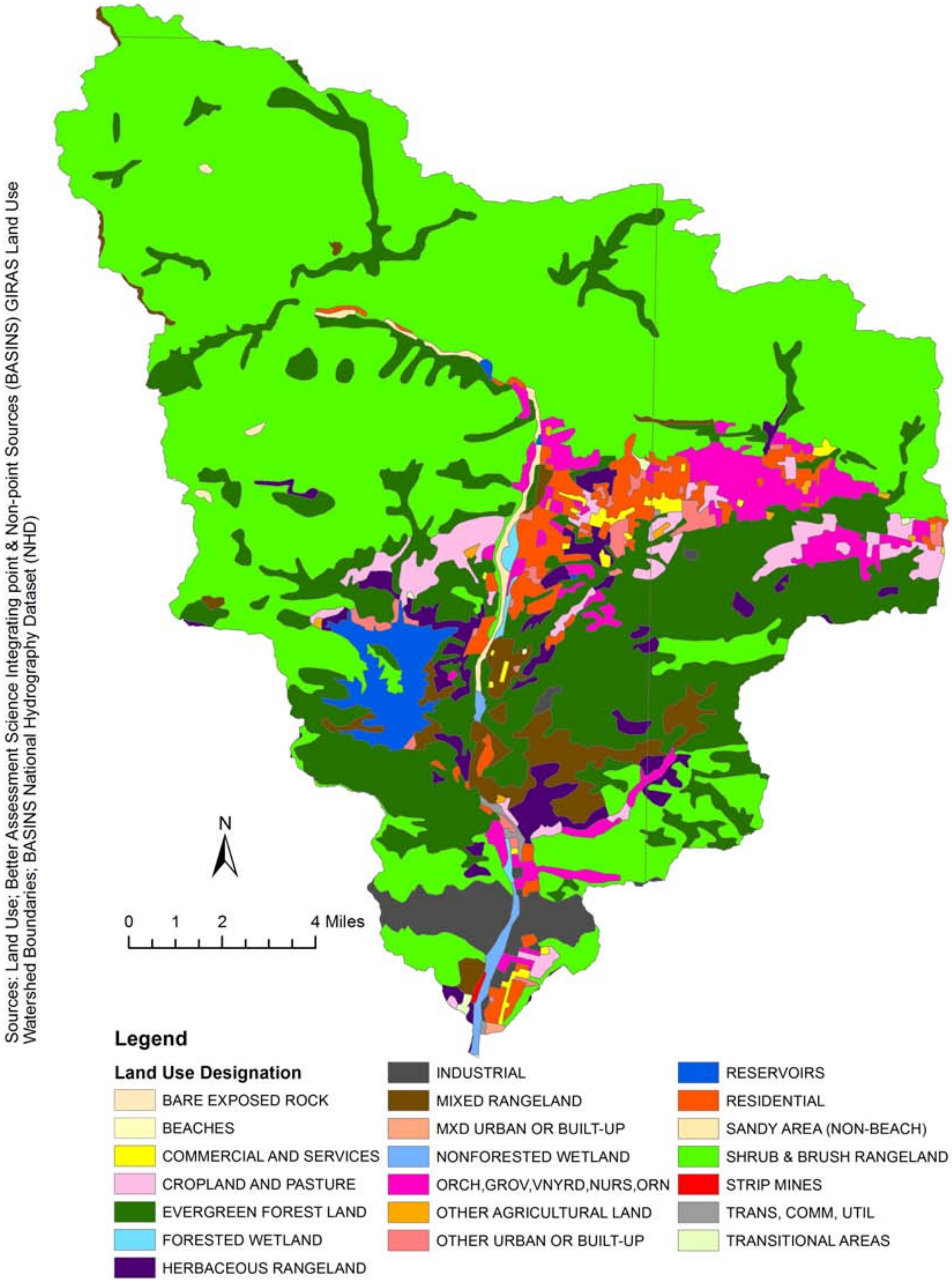

Figure 1. 5: Land use in the Ventura River Watershed.

Land Use	Area (square miles)	Area (% of total watershed)
Open Space	186	84.6
Residential	10.41	4.8
Agricultural	9.98	4.5
Industrial	4.65	2.1
Commercial	0.7	0.3
Water Bodies	4.17	1.9
Other	3.89	1.8
Total	219.8	100

Table 1. 1: Land use in the Ventura River Watershed (CRWQCB, 2012).

1.3.4 Demographics

The Ventura River Basin's population is concentrated in two urban areas: Ojai and Ventura. Future water demand will depend largely on population and the economic growth patterns within the basin. The estimated population of the Ventura River Basin in 2010 was 68,557 people (Wickstrum & Merckling, 2011). Of that population, about 33,000 live in the City of Ojai and its surrounding rural areas and the remaining 35,500 live in the City of Ventura. Compared to Ojai, the City of Ventura is much more densely populated (Figure 1. 6).

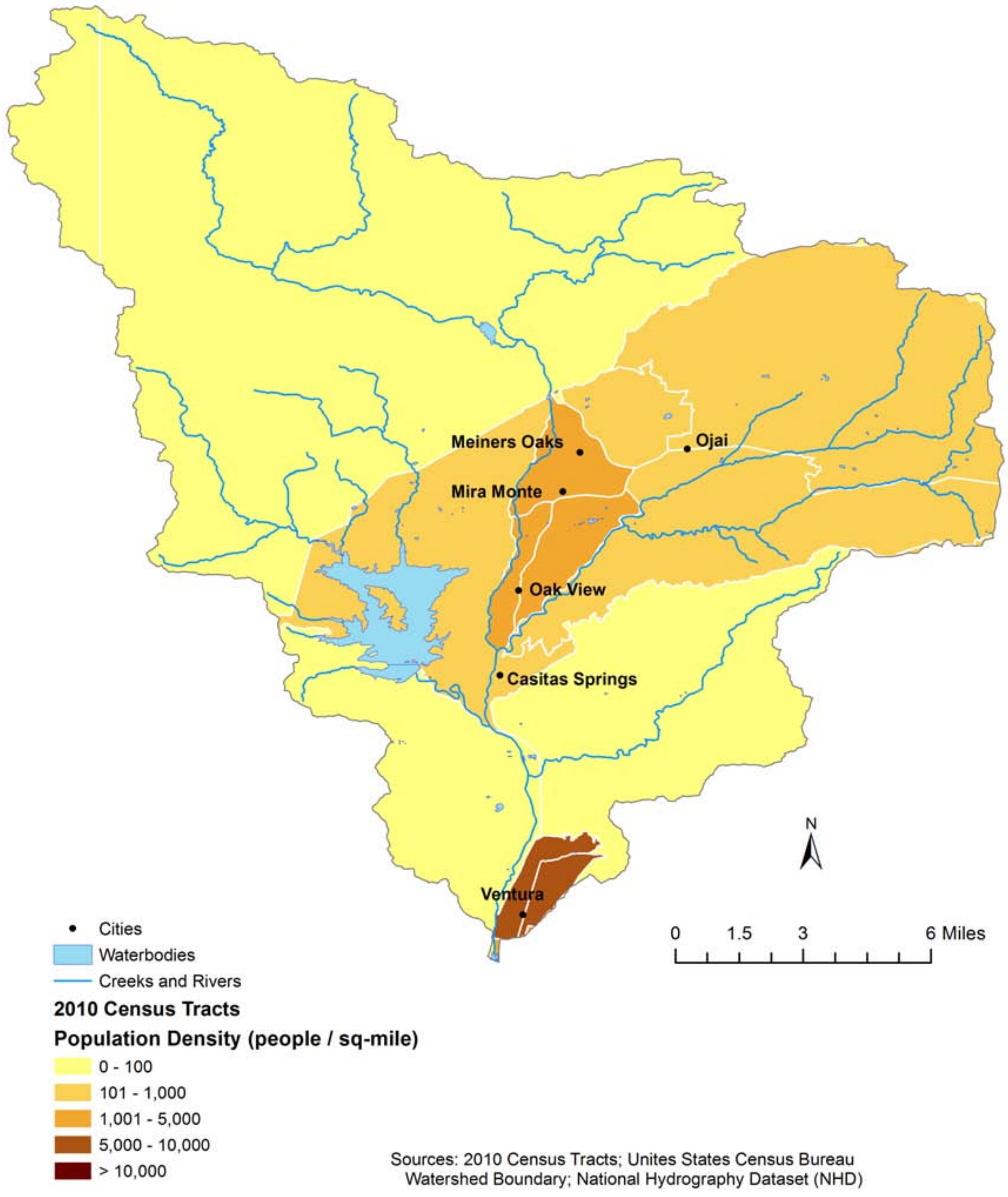

Figure 1. 6: Population density in the Ventura River Watershed.

Projected population growth within the Ventura River Watershed through 2035 is much lower than the average for Southern California. According to Casitas Municipal Water District (CMWD) the growth rate within the Ventura River Watershed is expected to be about 0.7% annually through the year 2035 (Wickstrum & Merckling, 2011).

Within the Ventura River Basin agriculture plays a main economic role, and orchards and ranches are prevalent, primarily in the northeastern reaches of the basin. Ojai fosters light industry, primarily for agricultural support. Ventura County, however, predicts that the growth of industry will drive the County's economic growth in the next ~25 years (CA Department of Transportation, 2012).

1.3.5 Waterbody Impairments

Currently, there are nine impaired water bodies in the Ventura River Watershed according to the U.S. EPA (Table 1. 2). In the watershed there are three water bodies whose impairment is labeled as "Fish Barrier". The cause of this impairment is the existence of the Matilija Dam and the fact that no steelhead trout can actually climb the existing fish ladder to swim to the upper reaches of the watershed to spawn.

Water Body Name	Water Body Type	303(d) Impairment
Cañada Larga	Creek	Dissolved Oxygen & Fecal Coliform
Matilija Creek Reach 1	Creek	Fish Barriers
Matilija Creek Reach 2	Creek	Fish Barriers
Matilija Reservoir	Reservoir	Fish Barriers
San Antonio Creek	Creek	Nitrogen
Ventura River Estuary	River	Algae, Eutrophication, Total Coliform, Trash
Ventura River Reach 1 & 2	River	Algae
Ventura River Reach 3	River	Pumping, Water Diversion
Venture River Reach 4	River	Pumping, Water Diversion

Table 1. 2: Impaired waterbodies in the Ventura River Watershed (US EPA, 2012).

Eutrophication is an impairment that results from excess nitrogen and phosphorus concentrations in a water body causing algal blooms and low dissolved oxygen (DO) concentrations. Stretches of the Ventura River are subject to high levels of these nutrients and have become impaired by an overabundance of algae and low DO levels. The likely sources of the pollutants leading to eutrophication in this watershed are agricultural runoff, urban runoff, horse & cattle manure, runoff from golf courses, wastewater treatment plant effluent, as well as septic tank leakage. The combination of these impairments can cause negative effects on the native organisms in the Ventura River such as steelhead trout, amphibians, and plants. A Total Maximum Daily Load (TMDL) is currently being developed to address the water bodies being affected by eutrophication in the watershed (CRWQCB, 2012).

Reaches 3 & 4 of the Ventura River are both impaired for the over-extraction of groundwater. This pumping is mostly carried out through wells operated by the City of Ventura where the water is used for urban activities. At times, groundwater pumping in these reaches has resulted in the reduction of surface water flows that are critical to the survival of some species in the river, particularly steelhead trout. A TMDL has not been completed for the 303(d) impairments in Reaches 3 & 4 of the Ventura River.

In addition to eutrophication, groundwater overdraft, and fish barriers, high concentrations of potentially harmful microorganisms have led to impairments in the watershed. These impairments have been identified in both Cañada Larga and in the Ventura River Estuary. Likely sources for the high levels of fecal coliform in these waterbodies are horse & cattle manure as well as malfunctioning septic systems. A TMDL has not been created to address these fecal coliform impairments.

1.3.6 Water Purveyors

There are three major water purveyors in the Ventura River Watershed, Casitas Municipal Water District (CMWD), Golden State Water Company (Golden State), and the City of Ventura. CMWD is the largest of these three as they deliver roughly 18,000 acre-feet (AF) on average to agricultural and urban users in the basin (Wickstrum and Merckling). CMWD also operates Lake Casitas. This reservoir is the major source of CMWD's water supply and the only major surface water source in the watershed. CMWD does operate one well, the Mira Monte Well, which is only used to extract a small amount of water, about 300 AF / yr. (Wickstrum and Merckling). CMWD delivers water both directly to consumers and to other water resale agencies throughout the watershed.

The second largest water purveyor is the City of Ventura. They buy surface water from CMWD for resale and also pump groundwater at their Foster Park Well Field. In 2010 the City estimated that it would purchase 6,000 AF from CMWD and would pump 4,200 AF from the Foster Park Well Field, annually (Kennedy/Jenks Consultants).

Golden State Water Company is the third largest purveyor and they serve the City of Ojai. In 2010 Golden State purchased 265 AF from CMWD and pumped 1,741 AF from their five wells located in the Ojai Groundwater Basin (Golden State Water Company).

Besides these three major water suppliers there are seven smaller water companies in the watershed: Ventura River County Water District (VRCWD), Meiners Oaks Water District (MOWD), Senior Canyon Municipal Water Company (Senior Canyon), Tico Municipal Water Company (TMWC), Sisar Municipal Water Company (SMWC), Hermitage Municipal Water Company (HMWC), and Siete Robles Municipal Water Company (SRMWC). These small agencies deliver water to smaller communities in the basin such as Meiners Oaks and to outlying rural areas such as the Upper Ojai

Valley. VRCWD and MOWD are the largest of these purveyors. In 2008 VRCWD purchased 222 AF from CMWD and pumped 1,133 AF from their groundwater wells (Wickstrum and Merckling). In the same year MOWD purchased 2 AF from CMWD and pumped 1,112 AF from their wells. The other five water companies deliver about 600 AF or less of water annually. For example SCMWC delivered 595 AF of water while SMWC only delivered 12 AF to its customers in 2008 (Wickstrum and Merckling).

1.5 Previous Studies

1.5.1 HSPF Model

In 2008, under contract from the Ventura River Watershed Protection District (VRWPD), Tetra Tech completed a hydrologic model for the Ventura River Watershed using the EPA's Hydrological Simulation Program-Fortran (HSPF). Data integrated into this model includes precipitation, evapotranspiration, land use and land cover, soils, slopes and elevations, watershed segmentation, planning and zoning, fire regime, hydrography, channel characteristics, flood elevation modeling (HEC-RAS), reservoir management for Casitas and Matilija, diversion structures, debris and detention basins, groundwater recharge, discharge, and surface water interactions, irrigation, point sources, and stream gaging. While the HSPF model accounts for groundwater, groundwater-surface water interactions are a potential source of uncertainty. The HSPF model was validated against data from water years 1997-2007. Following the validation, the model was used to perform a natural conditions simulation to determine what the state of water resources in the Ventura River Watershed would be without human influence. The input data and the results of the model runs are listed in the associated 2008 and 2009 reports (Tetra Tech, 2008); (Tetra Tech, 2009); (Tetra Tech, 2009).

The HSPF model provided a range of useful data for this study, including climate data, watershed characteristics, and dam and diversion structure location. The HSPF report also referenced many of the other reports used in this study.

1.5.2 Groundwater Studies

Following the creation of the HSPF model, two detailed groundwater studies were performed within the Ventura River Watershed leading to the creation of groundwater budgets for three of the four major groundwater basins in the area: the Upper and Lower Ventura River Groundwater Basins, and the Ojai Valley Groundwater Basin. These basins are managed by several different agencies and there is no single model that illustrates the complex inter-basin groundwater interactions in the watershed.

The Ventura River Groundwater Basin extends along the Ventura River Valley from the Pacific Ocean to just south of Matilija Canyon, and is divided into two subbasins: the Upper Subbasin and the Lower Subbasin (Figure 1. 2). In 2010, Daniel B. Stephens and Associates created a groundwater budget for the Ventura River Groundwater Basin in order to inform their creation of a groundwater management plan for the basin (Daniel B. Stephens & Associates, Inc., 2010). This budget was created using data from water years 1997-2007.

The Ojai Valley Groundwater Basin is located in the northeast portion of the watershed (Figure 1. 2). In 2005, Jordan Kear wrote his master's thesis at California State University, Northridge on the hydrogeology of the Ojai Valley Groundwater Basin (Kear J. L., 2005). This report provides an in-depth look into the geology and connectivity of the basin. Building on this report, Daniel B. Stephens and Associates created a groundwater model for the Ojai Valley Groundwater Basin in 2011 (Daniel B. Stephens & Associates, Inc., 2010). This model was created using MODFLOW-SURFACT, an upgraded version of the USGS MODFLOW. The model was calibrated using water level observations from wells monitored by the Ventura County Watershed Protection District from 1970 through 2009. After calibration, the model outputs generally matched the observed well data.

The Upper Ojai Groundwater Basin is located southeast of the Ojai Valley Groundwater Basin and is drained by Lion Creek (Figure 1. 2). While surface water within this basin flows into the Ventura River stream network, groundwater within the basin flows into the Santa Clara River Watershed (Kear J. , 2012). Given the hydrologic complexity of the basin and the potentially politically contentious nature of inter-watershed water resource allocation, no detailed studies concerning groundwater-surface water interactions have been completed for this basin.

The groundwater reports provided the majority of the groundwater data used within this study, including aquifer capacity, inputs, outputs, and known surface water interactions. Groundwater data within this study was calibrated using data from these reports.

1.5.3 NOAA Steelhead Restoration Plan

In January 2012, the NOAA National Marine Fisheries Service (NMFS) released its Southern California Steelhead Recovery Plan (NMFS, 2012). This plan provides a roadmap for restoring Southern California steelhead populations, highlighting necessary actions in every watershed in southern California. Because of the large spatial scope of the report, suggestions are generally non-specific within watersheds. For example, the report does not identify key reaches within the Ventura River watershed, but it does state that the most important management action within the watershed is to remove impassable fish barriers either by altering operating schedules or by physically removing structures.

1.5.4 NMFS 2003 Biological Opinion for the Robles Diversion

NMFS, in conjunction with the U.S. Bureau of Reclamation, has published a biological opinion (BO) that defines minimum water flow availability necessary to support steelhead in the Ventura River (NMFS, 2003). This BO is directed at flows below the Robles Diversion canal, which diverts water from the Ventura River into the Casitas Reservoir. Although flow regime is important throughout the lifecycle of the steelhead, the primary focus of restoring flow levels is on maintaining flow during the migration period of January to June. Because winter storms are a vital component of migration, identifying storm events and maintaining sufficient water flows following these events is key.

1.5.5 NMFS 2007 Biological Opinion for the Foster Park Well Field

In 2007, NMFS published a draft BO regarding repairs to the Foster Park Well Field (FPWF) in a reach of the Ventura River that serves as critical habitat for steelhead (NMFS, 2007). This critical area affected by the well repairs is approximately 6 miles long, begins 100 feet upstream of the City's "Nye well no. 7, and continues down to but does not include the Ventura River Estuary". Flows in this "area are naturally perennial, due to the geology of the bedrock formations beneath the river facilitating groundwater from the aquifer to rise, and partially, because of the subsurface dam". This 975 ft. subsurface dam extends almost completely across the river channel. It was constructed between 1906 and 1908 in order to bring subsurface flow to the surface so it could be used for agricultural and residential use.

The FPWF has a very high degree of hydraulic connectivity between the surface water and the groundwater. It is assumed in the BO that there is a "1-to-1 relationship between well field withdrawals and surface flows" in the FPWF area. This high degree of hydraulic connectivity means that the City of Ventura's pumping at their FPWF can have significant impacts on water levels and therefore aquatic species in this reach of the river.

Within this six-mile reach of the Ventura River, approximately 5 miles are classified as habitat suitable for steelhead juvenile rearing and over-summering habitat. "Over summering habitat is important in the Ventura River Watershed and for [steelhead] as a whole because it is the most geographically restricted type of habitat in the Southern California [steelhead]". There is a USGS stream gauge (no. 111185000) in this area and based on data from this gauge, spring and winter flows in this area normally range from several hundred cubic feet per second (cfs) to 12 cfs, depending on precipitation (NMFS, 2007).

During the summer and fall, flows in the action area can range from less than 1 cfs during extreme dry conditions to about 12 to 15 cfs during years with wet winters. Low flow conditions during summer and fall still sustain productive over-summering habitat for steelhead, and survival for over-summering wild steelhead is high (about 80%) in the Lower Ventura River just upstream of the FPWF when flows are around 15 cfs, based on studies by Moore (1980). Summertime survival of wild steelhead is substantially lower (19%) during drought conditions when flows are between 2 to 4 cfs (Moore, 1980)" (NMFS, 2007). This reach of the Ventura River near the FPWF is critical for steelhead survival. The NMFS recommended that pumping at the FPWF should not allow the flows at USGS gauge station 111185000 to fall below 11 to 12 cubic feet per second.

This biological opinion was integral to calculating the effects of water management strategies within this study on ecosystem health. The primary mechanism used for measuring the impact of a strategy on ecosystem health is the ability to increase flow within the Live Reach of the Ventura River to greater than 12 cfs.

1.5.6 Matilija Dam Removal Feasibility Study

Discussions about the removal of Matilija Dam have been ongoing for over 15 years. While a number of groups have agreed that the dam should be removed, they have not been able to reach consensus on how to complete the removal as a result of the complex nature of the operation. In 2001, work began on a feasibility study for removal of the dam. This study concluded that complete removal with short-term sediment stabilization would be the optimal path forward (ACOE, District, & VCWPD, 2004) however, more than 10 years after the completion of the study, little progress has been made towards removal of the dam.

1.5.7 Urban Water Management Plans

Division 6 Part 2.6 of the California Water Code §10610 – 10656 requires all urban water suppliers who serve more than 3,000 AF or 3,000 connections annually to prepare an Urban Water Management Plan (UWMP) every five years (California Water Code Division 6, 2013). These plans require retailers to assess the availability of water resources versus projected growth in their area for 20 years into the future, while considering normal, dry, and multiple dry years. The UWMPs are submitted to the California Department of Water Resources (DWR) every five years. With the passing of SB X7-7 in November of 2009, all water retailers are required to reduce per capita use by 20% by 2020. This requirement must be reflected in their UWMPs.

Within the Ventura River Watershed, there are three urban water retailers large enough to be required to file a UWMP: Casitas Municipal Water District, Ventura River County Water District, and Golden State Water Company (GSWC). The most recent UWMPs for each of these companies were completed in 2010.

The UWMPs provided a range of valuable information for this study, including the water usage within each sector, number of accounts for each sector, and total surface and groundwater usage for the water purveyor. The majority of the urban and agricultural demand data used in this study was extracted from the UWMPs.

1.5.8 Ventura River Watershed Protection Plan Report

Working for the Ventura County Watershed Protection District, Cardno ENTRIX completed the Ventura River Watershed Protection Plan report in February 2012. This report is a summary of all existing information and reports pertaining to watershed management within the Ventura River Watershed. It is intended to be used as a tool to facilitate development of a comprehensive Watershed Management Plan. The report emphasizes water-supply issues more than water quality issues within the basin, and provides a solid basis for future water management planning efforts.

The Ventura River Watershed Protection Plan Report provided substantial amounts of data for this study, including watershed and subwatershed delineations and numerous climate and hydrological data sources. The report also identified the other important studies within the region as well as data gaps within the available data.

1.5.9 Draft TMDL (CRWQCB, 2012) for Algae

In July 2012, the Los Angeles Regional Water Quality Control Board (LARWQCB) completed a draft TMDL regulation for algae, eutrophic conditions, and nutrients on several reaches of the Ventura River. This came in response to the 303(d) listing of several reaches of the Ventura River which are impaired for a variety of pollutants that restrict the designated beneficial uses of the stream reaches. The draft TMDL will be finalized in 2013, following a public comment period (CRWQCB, 2012).

The TMDL identifies a set of target waste load allocations for the primary polluters within the watershed. These targets set reduction goals in pounds of Total Nitrogen and Total Phosphorous for pollutant sources such as the City of Ventura's Stormwater system. The targeted reductions provide a useful benchmark for evaluating the effectiveness of the water management strategies within this study for reducing nutrient pollution.

1.6 Integrated Regional Water Management Plan Framework

Integrated Regional Water Management (IRWM) planning was formally initiated in 2002 with the passing of Senate Bill 1672, the Integrated Regional Water Management Act. This Act encouraged local agencies to manage water resources more cooperatively (BAIRWMP, 2012). In 2002, California voters also passed Proposition 50, the Water Security, Clean Drinking Water, Coastal and Beach Protection Act, which provided funding for the planning and implementation of IRWM projects. In

2006, the Watersheds Coalition of Ventura County (WCVC) formed and initiated the creation of the Ventura County IRWM Plan using Proposition 50 funding (WCVC, 2006).

In 2006, California voters passed Proposition 84, the Safe Drinking Water, Water Quality, and Supply, Flood Control, River and Coastal Protection Bond Act. Under this act, $215 million was made available to the Los Angeles/Ventura County Region for projects consistent with a State approved Integrated Regional Water Management Plan (IRWMP) that helps local agencies meet the long term water needs of their area (WCVC, 2012). The Ventura River Watershed Council (VRWC) was formed in 2006 and is working on developing a Watershed Management Plan for the Ventura River Watershed that will outline current conditions in the watershed, identify concerns, and prioritize potential projects to address those concerns (VRWC, 2012).

The IRWM framework has led to many of the studies that are integrated within this report. The process has funded a number of local surface and groundwater studies. In addition, future funding of projects may be possible through Proposition 84. One of the criteria for evaluating water management strategies within this report is the suitability for Proposition 84 funding.

1.7 Current Efforts

A number of watershed management projects addressing water supply, flood control, water quality, ecosystem restoration, and education and public outreach are underway within the Ventura River Watershed. Given the interconnectedness of these goals, most projects within the watershed relate to more than one goal. These efforts are led by a variety of groups within the government, private, and nonprofit sectors including, but not limited to: the Ventura River Watershed Council, the Surfrider Foundation, Santa Barbara Channelkeeper, Ojai Valley Land Conservancy, Ojai Valley Green Coalition, Ventura Hillsides Conservancy, Friends of the Ventura River, and the Matilija Coalition.

1.7.1 Creation of a Watershed Management Plan

The Ventura River Watershed Council (VRWC) is a group of stakeholders who share the goal of improving and facilitating watershed planning efforts within the Ventura River Watershed. The VRWC is currently in the process of creating a Watershed Management Plan, informed by the input of council members and other stakeholders within the watershed. Completion of the plan is expected in 2013 (VRWC, 2012).

1.7.2 Matilija Dam Ecosystem Restoration Project

The Surfrider Foundation and the Matilija Coalition are leading this project to try to hasten the removal of the Matilija Dam. The Matilija Dam is no longer functioning and blocks access to critical habitat for Southern Steelhead. An agreement has been reached by multiple agencies to remove the dam however, a decade since the agreement, the dam remains in place. The Matilija Dam Ecosystem Restoration Project (MDERP) is currently focused on an extensive education and outreach campaign to build support for the removal of the dam (Surfrider Foundation, 2012); (Matilija Coalition, 2012). The ultimate goal of the project is to fully restore the area affected by the dam, though efforts cannot begin until the dam is actually removed.

1.7.3 Ocean Friendly Gardens (OFG) Campaign

The Surfrider Foundation is leading the Ocean Friendly Gardens (OFG) campaign. The OFG campaign seeks to improve water quality and increase groundwater levels by reducing urban runoff and decreasing urban water use for landscape irrigation (Surfrider Foundation, 2012). These goals will be accomplished by encouraging homeowners within the Ventura River Watershed to convert their lawns to 'ocean friendly gardens' which are made up of native vegetation which requires no watering and whose landscapes contain sumps and swales to retain rainwater and allow it to infiltrate rather than run off into the stream network. The OFG campaign is ongoing and will likely continue for several years.

1.7.4 Rise Above Plastics (RAP) Campaign

The Surfrider Foundation is leading the Rise Above Plastics campaign (RAP). The RAP seeks to reduce impacts associated with plastic waste on marine environments within the Ventura River Watershed (Surfrider Foundation, 2012). The RAP campaign is ongoing and is largely focused on public outreach and education.

1.7.5 Stream Team Water Quality Monitoring

Coordinated by the Santa Barbara Channelkeeper (SBCK), Stream Team recruits and trains volunteers to monitor water quality at several key locations along the Ventura River stream network. Monitoring takes place on a monthly basis and includes testing for dissolved oxygen levels, pH, conductivity, turbidity, temperature, flow, nitrate, phosphate, and bacteria including coliform (Stream Team, 2012). As the only current water quality monitoring effort within the Ventura River Watershed, the data collected by the Stream Team represents the most comprehensive and up-to-date information regarding the parameters being tested. Monitoring efforts by the Stream Team are ongoing, but are subject to funding availability.

1.7.6 Land Conservation and Protection

The Ojai Valley Land Conservancy (OVLC) has preserved thousands of acres of land within the Ventura River Watershed either by the purchase of the land or the purchase of conservation easements. The land it protects contributes to the healthy function of the watershed and associated ecosystems and improves water quality, water supply, and public education. The lands protected by the OVLC are: the Ojai Meadows Preserve, the Ventura River Preserve, the Ventura River Confluence Preserve, the San Antonio Creek Preserve, the Ventura River Steelhead Preserve, the Ilvento Preserve, the Cluff Vista Park, the Fuelbreak Road Trail Easement, and various conservation easements (Ojai Valley Land Conservancy, 2012). The efforts of the OVLC are ongoing.

The Ventura Hillsides Land Conservancy (VHLC) is a land trust that seeks to protect open space in the Ventura Region. The VHLC currently owns two properties, totaling around 17 acres: the Tiera Dominguez Preserve, and the Foster Park Area Preserve (Ventura Hillsides Conservancy, 2012). The efforts of the VHLC are ongoing.

1.7.7 Ojai Valley Green Coalition Watershed Council

The Ojai Valley Green Coalition Watershed Council (OVGCWC) is a subgroup of the Ojai Valley Green Coalition. The OVGCWC's purpose is to preserve the Ventura River watershed through outreach and advocacy (Ojai Valley Green Coalition, 2012). The Council is involved with a variety of projects, including: resource asset mapping, public education, and habitat restoration. No projects are currently underway though future projects are planned, pending funding.

1.7.8 Watershed U – Ventura River

The Watershed University, or 'Watershed U' for the Ventura River is sponsored by UC Cooperative Extension and the Ventura River Watershed Council with support from the Ventura Watershed Protection District and the UC Hansen Trust (Friends of Ventura River, 2012). Watershed-U is focused on public outreach and education regarding issues of concern within the Ventura River Watershed. The last Watershed U in the watershed was held in 2010. There are no scheduled future sessions in the area.

1.7.9 San Antonio Creek Spreading Grounds Rehabilitation Project

The Ojai Basin Groundwater Management Agency (OBGMA), the Ojai Water Conservation District (OVCD), the Golden State Water Company (GSWC), the Casitas Municipal Water District (CMWD), and the Ventura County Watershed Protection District (VCWPD) have teamed up to fund and complete this project. The project seeks to rehabilitate the historically functional San

Antonio Creek spreading grounds, which recharge water to the Ojai Groundwater Basin by diverting flows from San Antonio Creek. The project should increase groundwater recharge in the basin allowing for increased reliability of groundwater supplies for pumpers in the area. This would reduce dependency on surface water supplies from Lake Casitas. The project was approved by Ventura County in 2011, but is being challenged by several stakeholders who are concerned about the project's effect on steelhead (VenturaRiver.org, 2011).

1.8 The Water Budget Model

The central component of this project is a water budget model that was used to integrate data from existing hydrologic studies to simulate surface and groundwater interactions in the Ventura River Watershed. The Water Evaluation and Planning (WEAP) System software package was utilized to construct this model. The WEAP System is a software tool that assists resource planners with integrated water management. The software has been used for water assessments at a variety of scales, by organizations such as the US Environmental Protection Agency (EPA) and the US Army Corps of Engineers (SEI, Why WEAP?). Across the globe, WEAP has been used for water resource planning in a number of countries, from managing water resources in the Jordan River Basin, to estimating water demand scenarios in South Africa, to examining climate change in the Sierra Nevada of California (Hoff, Bonzi, Joyce, & Tielborger, 2011); (McCartney & Arranz, 2009); (Null, Viers, & Mount, 2010).

1.8.1 Overview of the WEAP System

A distinguishing feature of WEAP is its ability to perform spatial modeling, enabling the model to link natural factors and engineered structures to effectively simulate interactions between groundwater and surface water bodies. Water systems can therefore be assessed in terms of current and future water supply and demand scenarios. This ability of WEAP, together with its financial analysis features, allows for the creation of a dynamic water balance that can then be evaluated in terms of water resources and the economic impacts of differing water management policies. Additionally, the software is highly user friendly and can be linked to spreadsheets and other water supply and water quality models. Another major advantage of using WEAP is the ease with which the model can be scaled and customized depending on the available information (SEI, Why WEAP?); (SEI, WEAP User Guide).

1.8.2 Why WEAP?

The water budget components are influenced by human activities and climatic variations. A model for the Ventura River Watershed that takes into account surface water and groundwater interactions is needed so that the impacts on water budget components can be investigated. This will assist in identification of feasible projects and policy measures to meet the objectives outlined earlier.

Given its capabilities, WEAP is a powerful tool for watershed managers. The model's flexibility and approach make WEAP ideal for building a comprehensive water budget for the Ventura River Watershed. Because the model can be easily updated to reflect new data, alterations to the water budget can be replicated in the model allowing planners to utilize this tool beyond the timeframe of this study. Storing the data in the water balance database also allows it to be efficiently updated, managed, and analyzed (SEI, WEAP User Guide).

One of the most important strengths of WEAP is that it is an integrated supply and demand model and simulates the interaction between supply and demand sites. Various modeling studies have been completed for Ventura River Watershed in the past however, unlike the previous models, the WEAP Ventura River Watershed model connects the supply and demand sites in the watershed, and therefore is immensely useful for analyzing various management options.

Climatic data as well as water demand and supply data were required for building a water budget of the Ventura River Watershed. Relevant data from existing studies was used for this purpose. The conceptual model for WEAP is provided in Figure 1. 7.

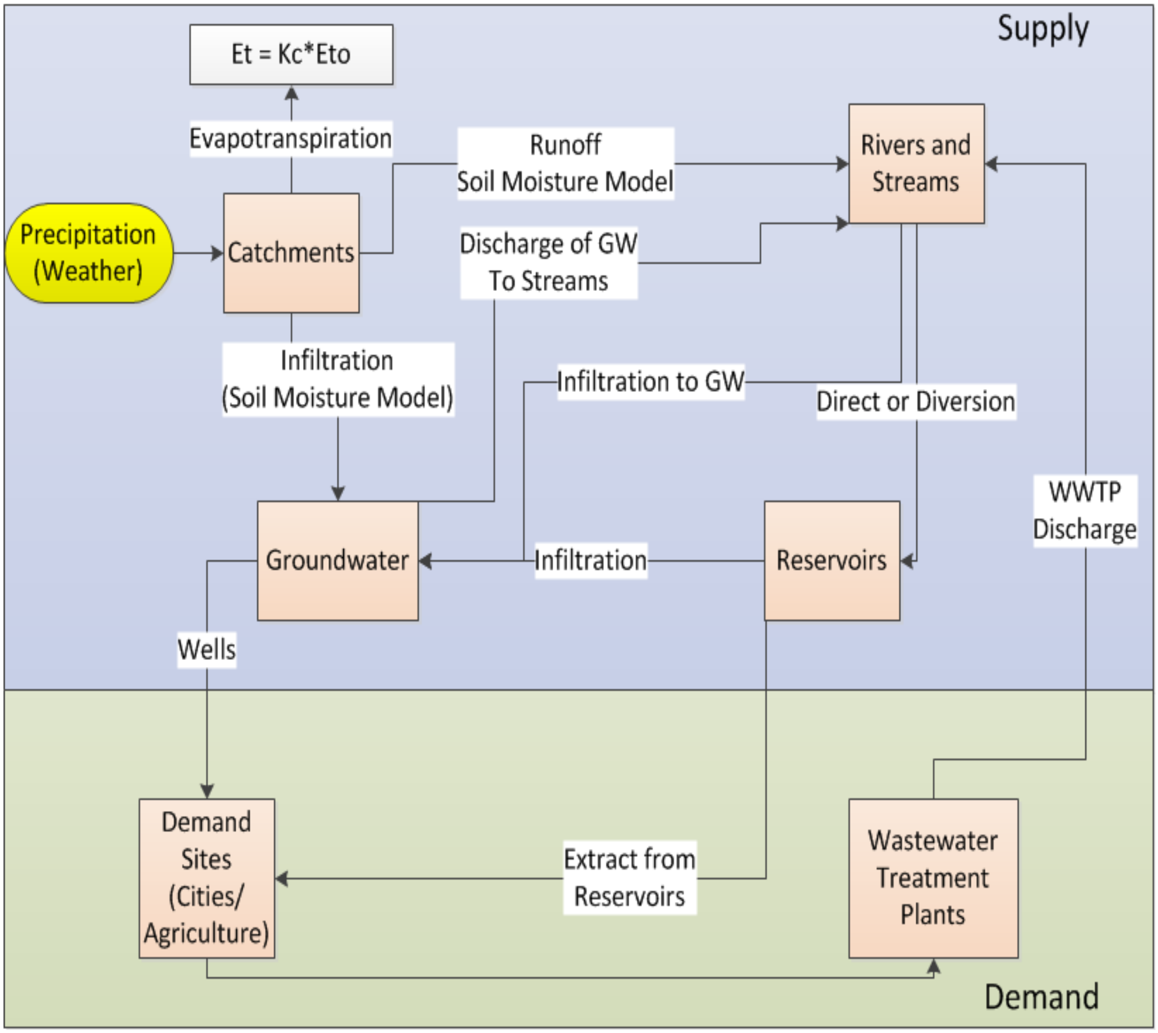

Figure 1. 7: Conceptual diagram of the WEAP model.

Figure 1. 7 shows the main components of the model. The supply is represented by the water input to the system (precipitation). This supplied water either evapotranspires and is lost from the system, infiltrates into groundwater, or runs-off the catchments into the stream network. The actual evapotranspiration (E_t) is a product of the crop evapotranspiration factor or crop coefficient (K_c) and the background or reference evaporation (E_{to}). There are three methods to simulate catchment processes in WEAP and these are (1) the Rainfall Runoff and (2) Irrigation Demands Only versions of the Food and Agriculture Organization (FAO) Crop Requirements Approach, and (3) the Soil Moisture Method (SEI, WEAP User Guide). The Soil Moisture Method is the most complex of the three and was used for developing the Ventura River Watershed model to achieve better simulation of the infiltration processes. The surface water can be diverted to reservoirs or can infiltrate to groundwater. Infiltration to groundwater can also occur from reservoirs. Likewise, the model also simulates groundwater discharge into streams.

The demand sites (including cities and agriculture) extract water via wells from groundwater or from reservoirs. The wastewater treatment facilities receive water from the demand sites and release that water as "WWTP Discharge" back into the stream network.

2. METHODS

2.1 WEAP Model Construction

The WEAP model of the Ventura River Watershed was built using available data for the components of the model. These components represent the supply, demand, and transmission of water within the watershed. The supply-side components include catchments, streams and rivers, diversions, reservoirs, and groundwater. The demand side is comprised of demand sites and wastewater treatment plants. Cities and agricultural sites make up the demand sites. Finally, transmission links carry water from supply sources to the demand sites and return links carry water from demand sites back to the supply. Figure 2. 1 illustrates these specific linkages. This section of the document will detail each of the components, the data sources, and calculations that were done to fill in any missing data.

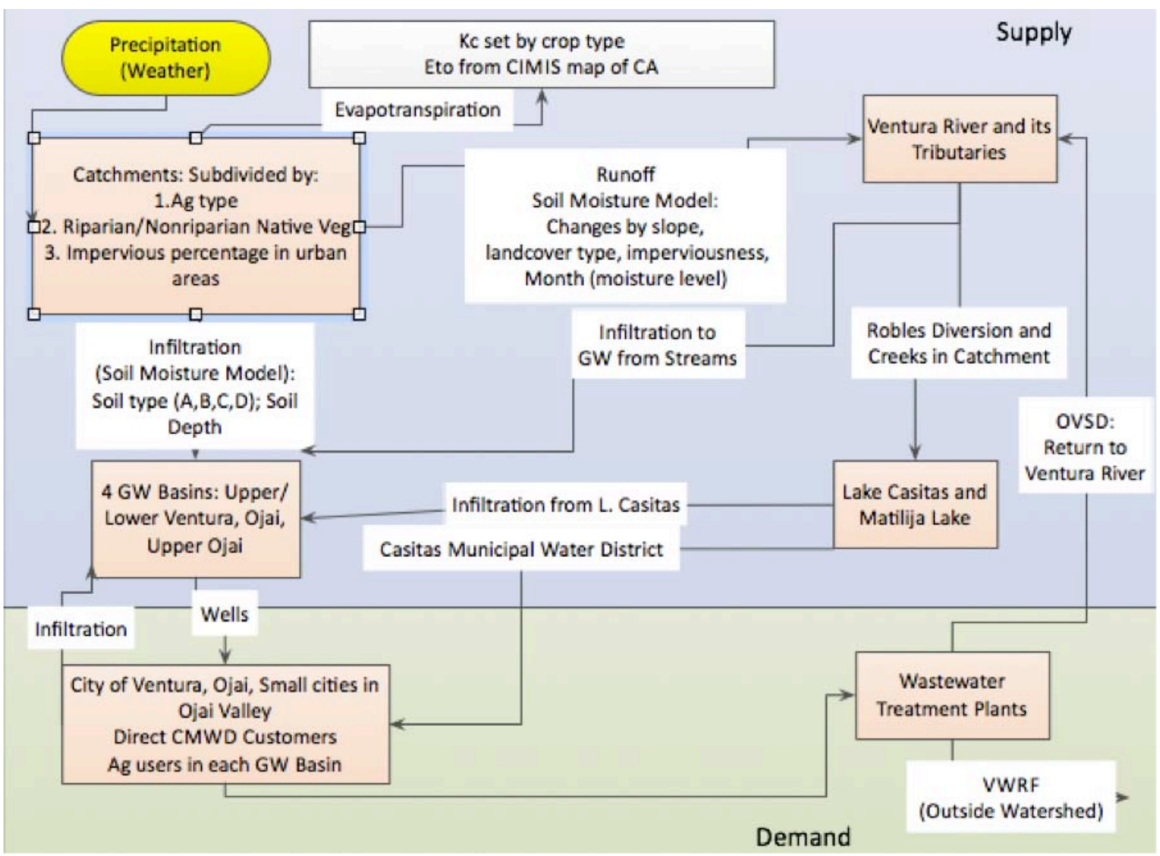

Figure 2. 1: Components of the WEAP model of the Ventura River Watershed.

2.1.1 Catchments

The Ventura County Watershed Protection District (VCWPD) supplied the catchment boundaries within the Ventura River Watershed. There were 31 subwatersheds defined in this segmentation (Figure 2. 2). Surface water supply within the WEAP model is primarily determined by runoff from the catchments. Runoff to surface waters can be described with the following equation (Equation 1):

$$R = P - (E_t + I_{gw})$$

Equation 1

where:

R is the runoff

P is precipitation

E_t is evapotranspiration from plants

I_{gw} is the infiltration to groundwater

In order to accurately model runoff, it is necessary to first identify precipitation within each catchment. Precipitation gage data within the watershed was provided by VCWPD, and each catchment was assigned precipitation data from the nearest gage (VCWPD, 2006). Rainfall data from 1990-2009 was used for eleven gages. Temperature, wind speed, cloudiness, and humidity data was also assigned to each catchment based on the closest available weather station data.

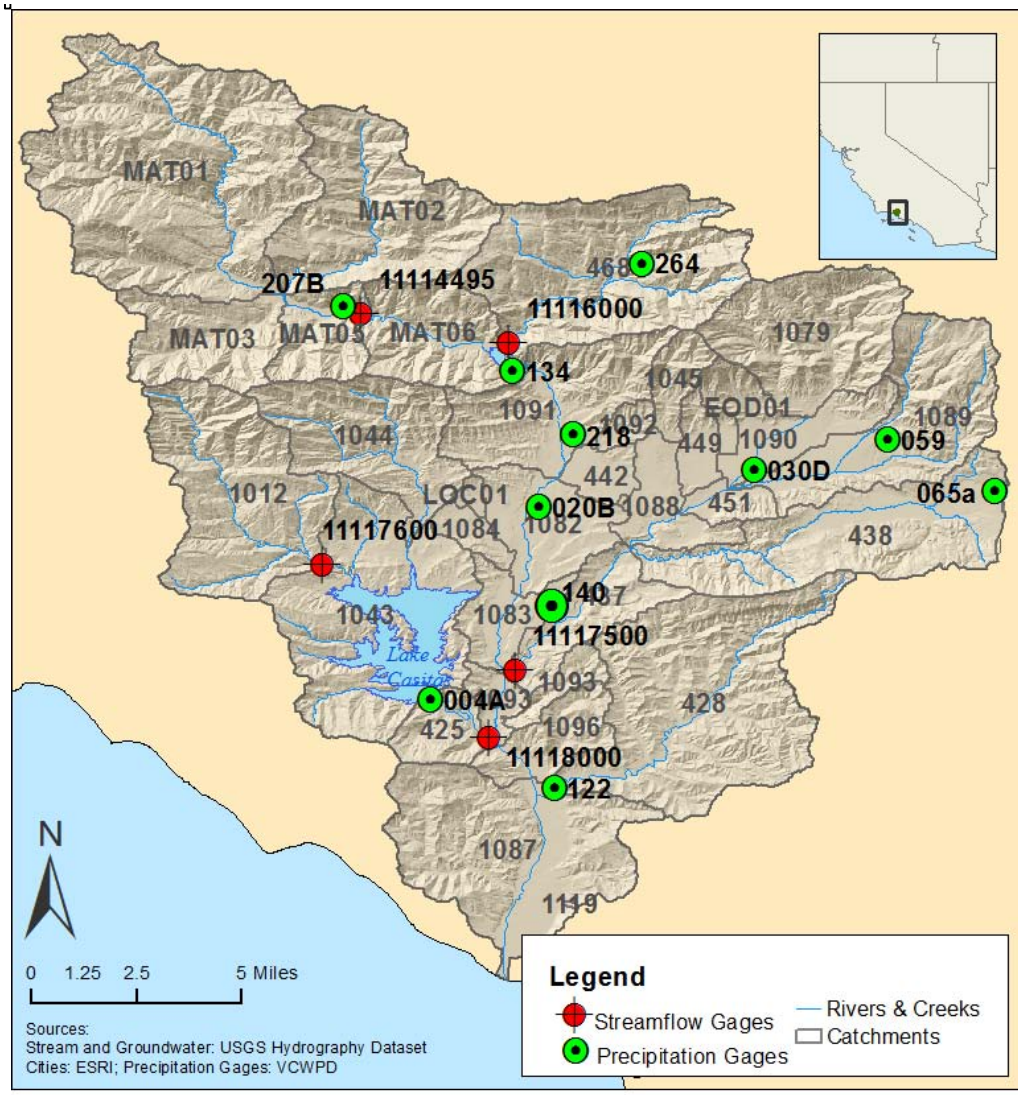

Figure 2. 2: Catchments within the Ventura River Watershed (VCWPD, 2006). Stream gages used in the calibration are shown in red; precipitation gages are shown in green (USGS, 2012).

To calculate the water available for runoff and infiltration, the model must subtract evapotranspiration. Within WEAP, evapotranspiration is calculated by multiplying a crop coefficient times a reference evapotranspiration value. Maps with reference evapotranspiration values are provided by the State of California's CIMIS service (DWR Office of Water Use Efficiency, 2012). Each catchment was assigned an evapotranspiration value by overlaying the state's reference evapotranspiration map. To calculate crop coefficients, each catchment was split into sub-catchments based on land cover.

2.1.2 Land Cover

Agricultural land cover, as specified by the California State Department of Water Resources (DWR), was used to separate the catchment into native vegetation and agriculture land uses (DWR, 2000). Native vegetation was further subdivided into riparian and non-riparian classes using National Land Cover Dataset (NLCD) land cover data (USGS, 2006). Finally, urban land use areas were split into subtypes with zero, low, medium, and high impervious values based on the NLCD Impervious Surface Layer for 2006 (USGS, 2006). Impervious areas within the data are classified into four categories on a scale of 0-100, with 0 being permeable and 100 being completely impervious.

Runoff to surface water and infiltration to the groundwater was calculated within WEAP using the Food and Agricultural Organization of the United States (FAO) soil moisture model (WEAP Web Help, 2012). Infiltration is a function of soil depth and other infiltration characteristics such as hydraulic conductivity. Runoff is a function of slope, vegetation type, and soil saturation. Each land cover type was assigned values for these characteristics, and these values determined the fraction of water that infiltrates into the soil and the fraction that runs off to surface waters. For a full description of the Soil Moisture Method Calculation, see Appendix 1.

2.1.3 Rivers and Streams

Streams were delineated using the USGS hydrography dataset (VCWPD, 2006). All named streams were added to the model, with inflow originating primarily from catchment runoff. Groundwater discharge from the Upper and Lower Ventura River Groundwater Basins also contributes to the Ventura River and San Antonio Creek flow (Daniel B. Stephens & Associates, Inc., 2010). The terminal catchment of the Ventura River discharges water to the Pacific Ocean.

2.1.4 Diversions

Robles Diversion redirects water from the Ventura River to Lake Casitas. Monthly diversion values for the years 2004-2009 were provided by Casitas Municipal Water District's annual hydrology reports (CMWD, 2012). The reports also provided monthly diversions for 1959-2010. This diversion data was plotted against precipitation at Lake Casitas to generate monthly linear regression equations. The monthly regression equations are used to estimate diversions for future scenarios where precipitation is estimated but diversions are unknown. Appendix 1 lists the monthly regression equations used for future scenarios.

2.1.5 Reservoirs

Lake Casitas receives water from surrounding catchments, the creeks that drain them, and from the Robles Diversion. Runoff is calculated within the WEAP model based on precipitation, as described in the catchment section earlier. Monthly diversion data is described in the previous section. Maximum storage volume and initial storage volume for the calibration period of 2004-2009 was provided by the Casitas Municipal Water District (Wickstrum & Merckling, 2011). In cases where the reservoir exceeds the maximum storage capacity, water is released downstream into Coyote Creek. However, there were no releases during the calibration period.

2.1.6 Groundwater Basins

Recharge to the groundwater basins occurs through infiltration from the overlying catchments. The quantity of water that reaches the basins is determined by the characteristics of the soil, land cover, and slope of the catchments as described in the catchments section. Infiltration also occurs from the agricultural and urban demand sites. The estimates for the quantity of infiltration are based on values within the Ojai Basin and Upper and Lower Ventura River Groundwater Basin Reports (Ojai Basin Groundwater Management Agency, 2010) (Daniel B. Stephens & Associates, Inc., 2010). These reports also detail maximum storage and storage volumes for the aquifers. Although a detailed groundwater report has not been completed for the Upper Ojai Valley Groundwater Basin, estimates for recharge, maximum storage, and current storage volume are available in California Groundwater Bulletin 118 (DWR, 2004).

Discharge from the groundwater basins include natural discharge to the overlying streams, where indicated in the groundwater basin reports (Ojai Basin Groundwater Management Agency, 2010) (Daniel B. Stephens & Associates, Inc., 2010). In addition, these reports describe domestic, municipal, and agricultural wells that extract groundwater from each basin. Agricultural extraction is estimated for the Upper Ojai Valley Groundwater Basin from data within the California Groundwater Bulletin 118 (DWR, 2004).

2.1.7 Demand Sites

Demand sites within the WEAP model include cities, towns, and aggregated agricultural demand. When possible, demand sites were further subdivided based on sector usage, including Single and Multi-Family Residential, Commercial, Industrial, Institutional/Government, Landscaping, and Other Uses. The urban water management plans (UWMPs) published for the City of Ventura, Golden State Water Company in Ojai, and the Casitas Municipal Water District provide detailed information for water deliveries to their customers, including deliveries across various sectors (Wickstrum & Merckling, 2011) (Golden State Water Company, 2011) (Kennedy/Jenks Consultants, 2011). For towns without UWMPs, smaller, private water companies provide water through a combination of groundwater pumping and purchases from CMWD. Although the volume of water delivered to the private resellers is reported by CMWD, the sector breakdown is not provided. For the purposes of modeling, these demand sites were assumed to have the same percentage of single-family residences as the nearby City of Ojai.

A number of residences within the Ojai area use septic systems. These systems deliver water to the underlying groundwater basins instead of the Ojai Valley Sanitary Treatment Plant. The quantity of water that infiltrates to the groundwater from septic tanks is estimated from values provided in the Upper and Lower Ventura River Groundwater Basin Report (Daniel B. Stephens & Associates, Inc., 2010). The quantity of wastewater delivered to the OVSD is approximately 33% lower than the quantity of water delivered to urban areas within the segment of the watershed that is served by the OVSD. These system losses are calculated with the following equation:

$$Losses = W_s + W_{gw} - (OVSD + I_{st})$$

Equation 2

where:

W_s is the surface water deliveries from CMWD

W_{gw} is the groundwater extractions

OVSD is the quantity delivered to the Ojai Valley Sanitary District

I_{st} is the estimated infiltration to the groundwater from septic tanks

Groundwater extraction demands were estimated from groundwater management plans and the Casitas 2010 UWMP (Daniel B. Stephens & Associates, Inc., 2010) (Ojai Basin Groundwater Management Agency, 2010) (Wickstrum & Merckling, 2011). These reports also reported infiltration from irrigation to the groundwater basins, and these values were used. For the Upper Ojai Valley Groundwater Basin, estimates of agricultural demand were taken from California Groundwater Bulletin 118 (DWR, 2004).

2.1.8 Wastewater Treatment Plants

There are two wastewater treatment plants within the Ventura River Watershed. The Ojai Valley Sanitary District (OVSD) receives the wastewater for non-septic tank residences in the City of Ojai, unincorporated Ojai Valley, and the north Ventura Avenue area in the City of Ventura (Figure 2. 3). OVSD discharges processed wastewater to the Ventura River downstream of the Foster Park area. Wastewater for most Ventura residences is processed at the Ventura Water Reclamation Facility. The Ventura Water Reclamation Facility releases wastewater into the Santa Clara River Estuary, which is outside the watershed.

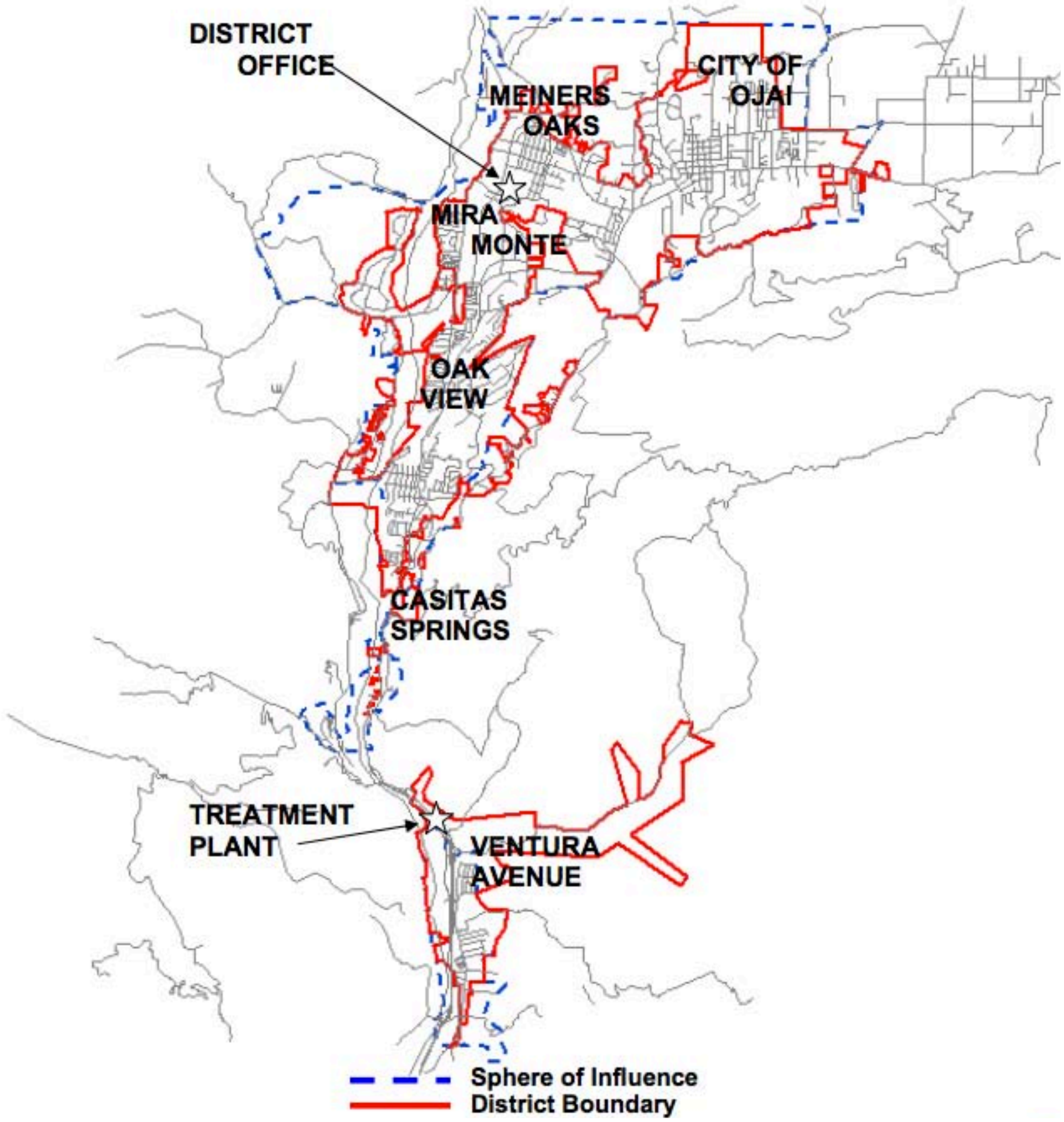

Figure 2. 3: Ojai Valley Sanitary District boundaries (Ojai Valley Sanitary District, 2012).

2.2 Model Calibration

2.2.1 Streamflow Calibration

The WEAP model was calibrated using the 2004-2009 timeframe. During the calibration timeframe, modeled streamflow was compared to streamflow observed at four stream gage stations throughout the watershed (Figure 2. 2). The following figures show the observed and modeled monthly average streamflow for the calibration period at the Matilija Creek gage (Figure 2. 4), the North Fork Matilija Creek gage (Figure 2. 5), the San Antonio Creek gage (Figure 2. 6), and the Ventura River gage near Foster Park (Figure 2. 7).

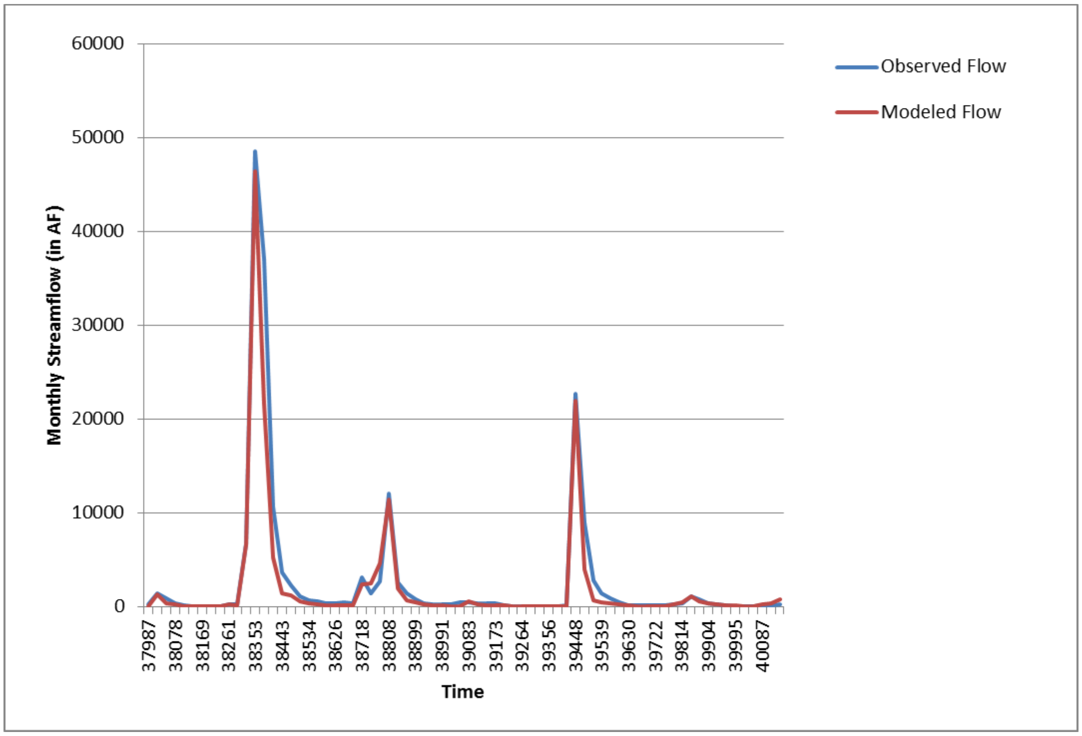

Figure 2. 4: Observed (USGS Gauge 11114495) and modeled streamflow at Matilija Creek from 2004-2009.

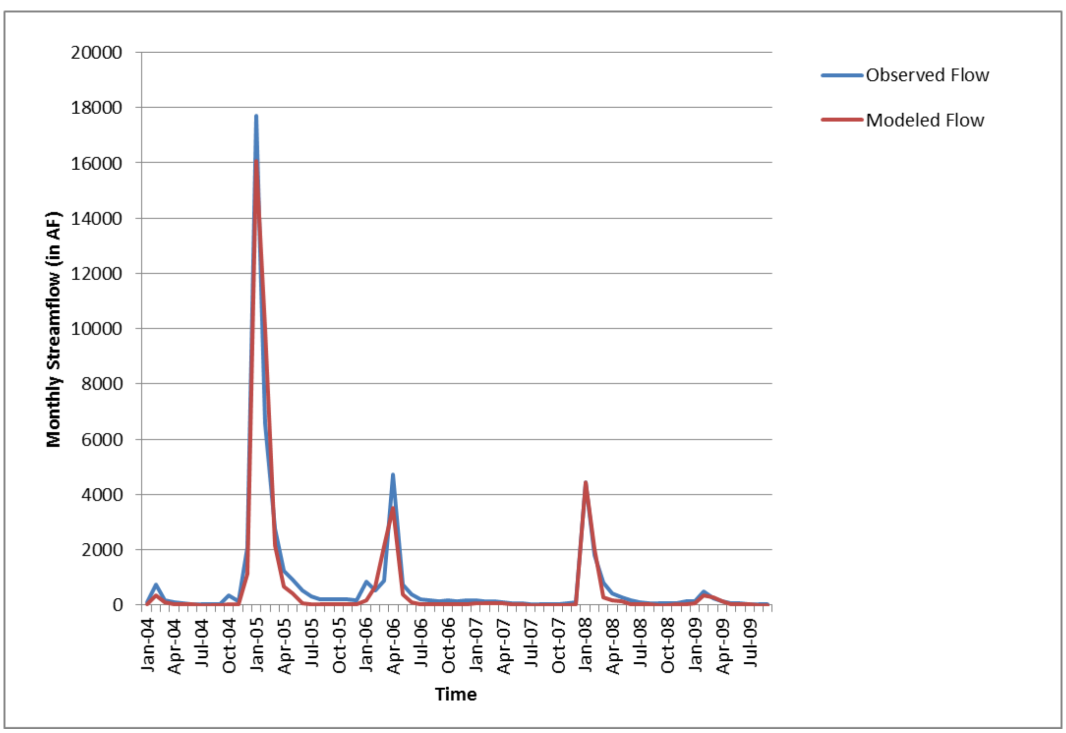

Figure 2. 5: Observed (USGS Gauge 11116000) and modeled streamflow at North Fork Matilija Creek from 2004-2009.

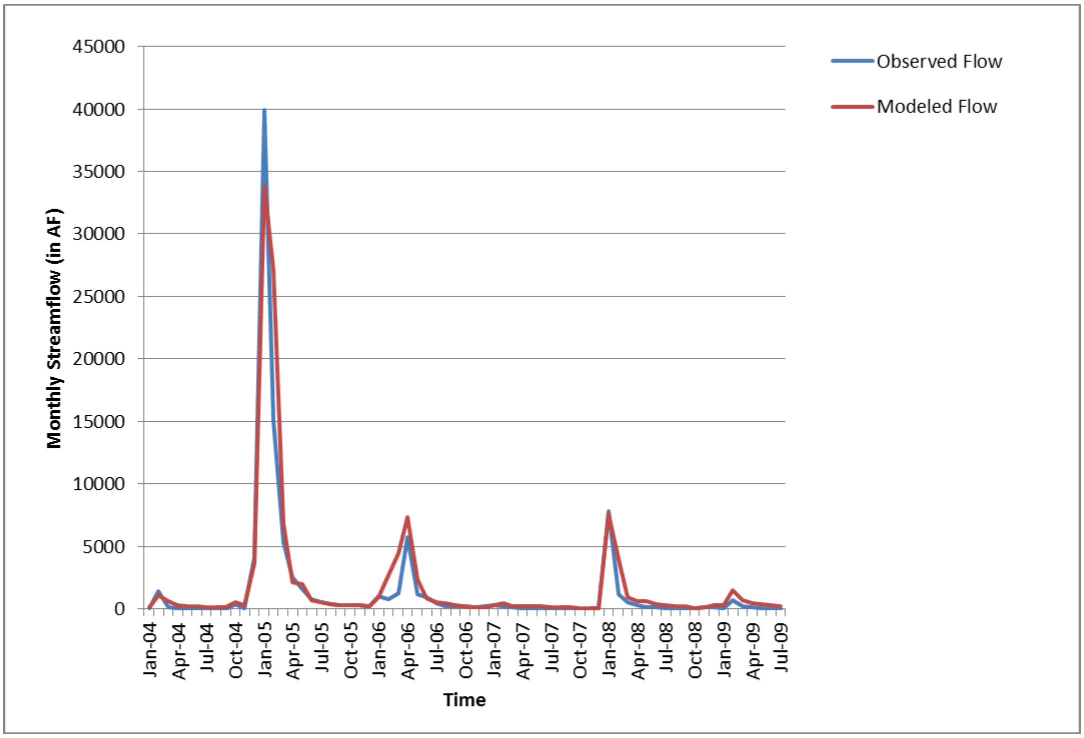

Figure 2. 6: Observed (USGS Gauge 11117500) and modeled streamflow at San Antonio Creek from 2004-2009.

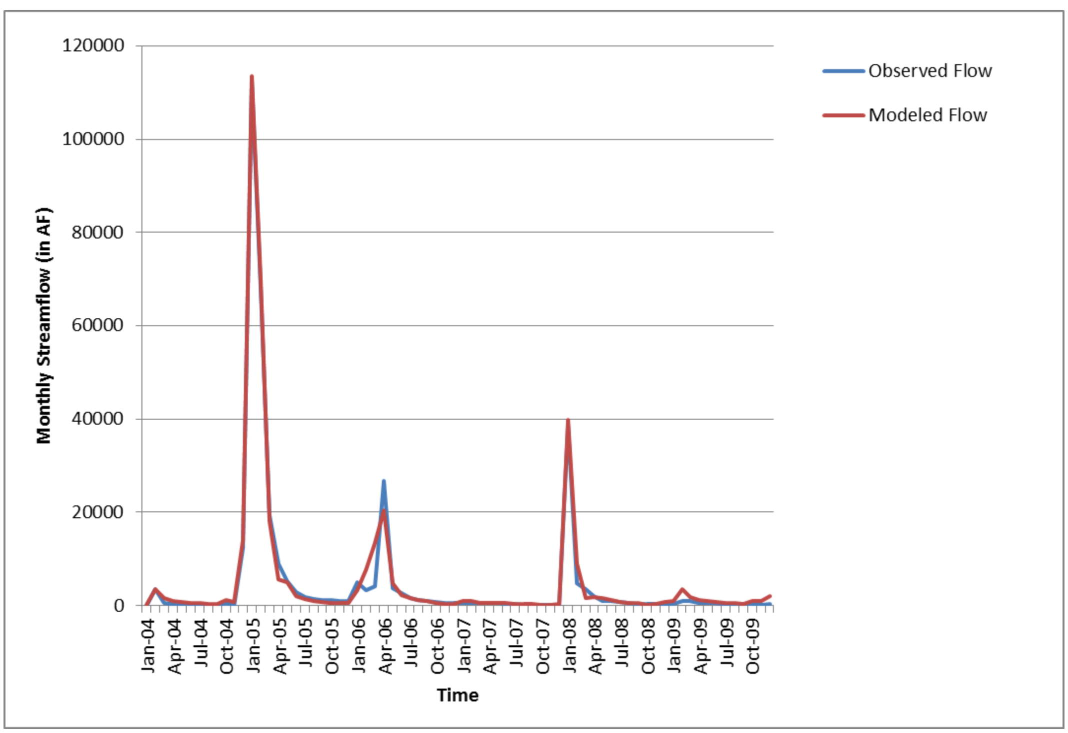

Figure 2. 7: Observed (USGS Gauge 11118000) and modeled streamflow at Ventura River near Foster Park from 2004-2009.

The Nash-Sutcliffe model efficiency coefficient is a widely used statistic for assessing the goodness of fit of hydrologic models, including the calibration of WEAP models (Joyce, Kirschen, & Mitchel, 2008). The coefficient is calculated by comparing the modeled values against observed values using the following equation (Nash & Sutcliffe, 1970):

$$E = 1 - \left(\sum_{t=1}^{T}(Q_o^t - Q_m^t)^2\right) / \sum_{t=1}^{T}(Q_o^t - \overline{Q_o})^2$$

Equation 3

where: E is the model efficiency coefficient, between negative infinity and 1

Q_o^t is the timestep observed value at time t

Q_m^t is the modeled value at time t

Q_o is the mean observed values

Using the Nash-Sutcliffe equation, values were calculated for the monthly streamflow at the stream gage locations shown in Figure 2. 2. The Nash-Sutcliffe values are 0.92 at Matilija Creek, 0.98 at the North Fork of Matilija Creek, 0.88 at San Antonio Creek, and 0.98 at the most downstream gage on the Ventura River. Table 2. 1 summarizes the results of the calculations. Nash-Sutcliffe coefficient values range from zero to one, with one indicating a model that exactly matches the observed data. The Nash-Sutcliffe values for the stream gages in the WEAP model range between 0.88 and 1.0, indicating a good level of fit between the model and the observed values. In a study of the water supply system in Sharon, MA, for example, researchers found a model efficiency coefficient of 0.647 for streamflow (Joyce, Kirschen, & Mitchel, 2008). An additional study using the WEAP model found a model coefficient of between 0.59 and 0.93 for streamflow in the Olifants catchment in South Africa (LeRoy, 2005).

Stream	Nash-Sutcliffe Coefficient Value
Matilija Creek	0.92
North Fork Matilija Creek	0.98
San Antonio Creek	0.88
Ventura River	0.98

Table 2. 1: Nash-Sutcliffe Coefficients for four stream gages in the Ventura River Watershed.

2.2.2 Lake Casitas Storage Calibration

Lake Casitas storage was also calibrated using the Nash-Sutcliffe model efficiency coefficient, with observed lake storage being compared with modeled volumes. Figure 2. 8 shows modeled versus observed data from the calibration time period. The Nash-Sutcliffe coefficient value for Lake Casitas storage is 0.89.

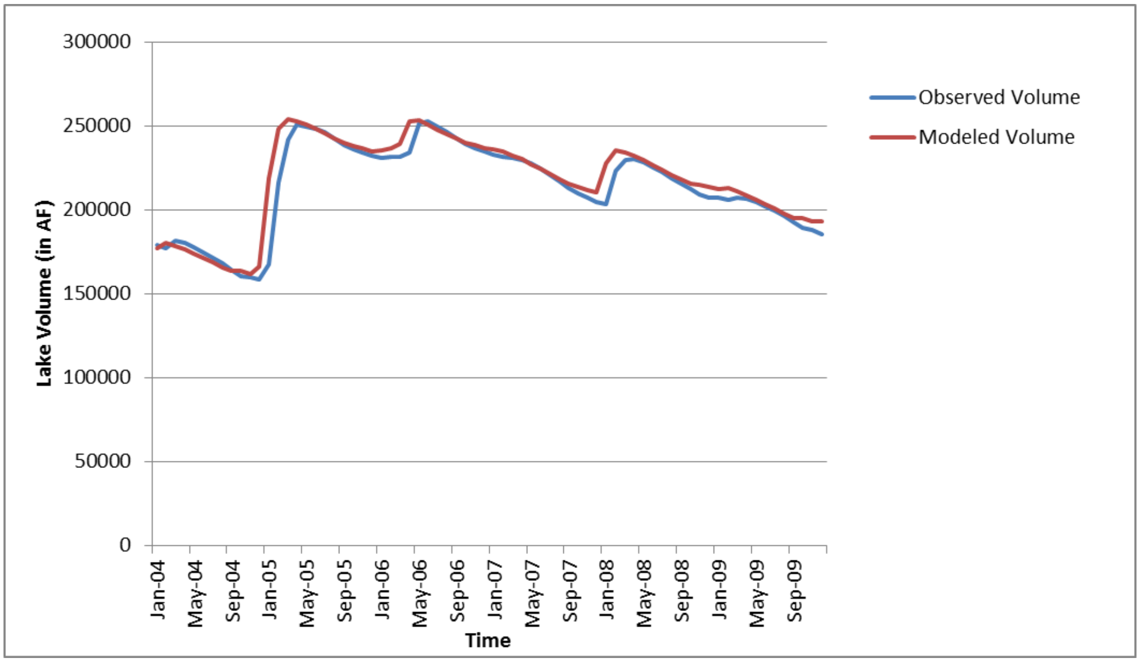

Figure 2. 8: Observed and modeled Lake Casitas volume from 2004-2009.

2.2.3 Groundwater Storage Calibration

Although sufficiently detailed information was not available to allow Nash-Sutcliffe coefficient values to be calibrated for the change in groundwater basins volume within WEAP model of the Ventura River Watershed, comparisons could be made to modeled values between WEAP and other groundwater models for the Upper and Lower Ventura River Watershed and the Ojai Groundwater Basin. The model produced by Daniel B. Stephens and Associates for the Ventura River Groundwater Basins estimates an annual groundwater increase in the Upper Ventura River Groundwater Basin of approximately 1466 acre-feet per year for the modeled years of 1997-2007 (Daniel B. Stephens & Associates, Inc., 2010). Estimates from the WEAP model indicate that the Upper Ventura River Groundwater Basin is increasing by approximately 1,166 AF per year during the calibration period of 2004-2009. Daniel B. Stephens and Associates also estimates that the Lower Ventura River Groundwater Basin was decreasing approximately 2,423 AF per year for the 1997-2007 time period, primarily from down-gradient loss to the Pacific Ocean. The WEAP model estimates yearly losses of 2,150 AF/yr to the Pacific Ocean for the 2004 to 2009 calibration period.

Daniel B. Stephens and Associates released a numerical model of the Ojai Groundwater Basin in 2011 for the water years from 1970-2009 (Daniel B. Stephens & Associates, Inc., 2010). The model estimates a small annual decrease in the groundwater level of 30 AF per year with current pumping rates. The WEAP model calculates a similar loss of 43 AF/yr between 2004 and 2009. Detailed models of the Upper Ojai Valley Groundwater Basin have not been completed. Estimates of the extraction and infiltration rates within the WEAP model were matched to values published by the California Department of Water Resources (DWR, 2004). Additional information, such as more accurate groundwater storage and annual input and outputs, are necessary to refine modeling of this groundwater basin in WEAP.

2.3 Building the Water Budget

Once the WEAP model was calibrated, it was then used to create a water budget for the watershed. The water budget showed for the first time, how much water is going to each sector of human and environmental uses within the Ventura River Watershed. In order to calculate the water budget, catchment data was aggregated for the entire basin to determine the total annual water input to the system and the fate of water within the system. Given that the Ventura River Watershed does not import water, the only input to the system comes from precipitation. The potential fates of water that enters the basin as precipitation are: evapotranspiration, runoff to the stream network, or infiltration to groundwater. Because water that is evapotranspirated is lost from the system, only water that reaches the stream network or infiltrates into the groundwater is available for human and environmental uses. Based on average annual demand, we determined the amount of water that goes towards human and environmental uses each year. For human uses, this was further broken down into annual groundwater and surface water extractions. Finally, using a sector-by-sector breakdown of average annual demand, we determined what percentage of human extractions goes towards different uses, such as: agricultural, urban, industrial, etc.

2.4 Water Management Strategies

This project investigated a number of water management strategies that affect water supply and demand within the Ventura River Watershed. The goal of the analysis was to explore the costs and water savings associated with each strategy. The following section describes each water management strategy, identifies the strategy's objective, and details how the analysis was conducted.

2.4.1 Evaluation Criteria

The Ventura River Watershed Council has defined a number of criteria that are central to the long-term sustainability of the watershed. Using these goals as a framework, we have selected six criteria to use to evaluate each water management strategy. These include the ability to decrease water demand, the ability to increase physical water supply, the overall cost-effectiveness, the ability to improve ecosystem health, the ability to improve water quality, and suitability for Proposition 84 funding. The relative importance of each of these criteria is reflected in the weighting schemes discussed later in this section.

Ability to Decrease Water Demand

Projects were evaluated on their potential to decrease water demand within the watershed and to help water purveyors achieve the requirements set forth in Senate Bill 7x7 (DWR, 2013). This bill mandates that the State of California must reduce per capita water use by 20% by the year 2020. The 20% per capita reduction applies to urban water purveyors within the watershed. Agricultural water suppliers do not have reduction targets mandated within the bill, but the water delivered must be measured and the pricing structure must be based at least in part on the quantity of water delivered (DWR, 2013).

Ability to Increase Water Supply

Each water management strategy was evaluated based on its ability to increase the physical water supply within the watershed, mainly through decreasing runoff and increasing levels of infiltration to the groundwater system. In such cases, the benefits of increasing water supply were weighed against the costs associated with lower flow levels in the river system.

Cost-Effectiveness

The cost-effectiveness of each water management strategy was calculated using the following formula:

$$CostEffectiveness = (NPV\ of\ Costs - NPV\ of\ Benefits)/(DemandDecrease + Supply\ Increase)$$

Equation 4

Net present value of cost and benefits were calculated over a 20-year time period with a 3% discount rate using the following equation:

$$NPV(0,20) = \sum_{t=0}^{20} R_t/(1+0.03)^t$$

Equation 5

where:

R_t is the net cash flow – cash outflow at time t
The time period is 20 years
The discount rate is 0.03

Total water saved for each water management strategy is the water saved through decrease in demand added to any supply increases, such as increased flow to groundwater, totaled over a 20-year time period. For this analysis, cost-effectiveness is calculated as the average cost per AF over 20 years. Due to the discounting process, an AF in one year would have a different present value than other years. Thus, the numbers that are provided for cost-effectiveness are not the cost to purchase any one AF, but the average cost per AF of the water over the 20-year time period.

When determining the discount rate for municipal projects, it is usually acceptable to use the 10-year US municipal bond rate, which is currently 1.86% (Bloomberg, 2013). However, the current rate is at a historical low due to the poor economy and we felt that using this low rate would distort the decision making process. In order to present a more conservative estimate of costs and benefits, we decided to use a more historically typical rate of 3%.

A discount rate of 3% was also used to discount the value of the consumer-based solutions such as ocean friendly gardens and greywater systems. A discount rate of 3% would be considered low if these projects were solely based on creating wealth. However, these projects are about increasing the water availability for ecosystem and human use. The values of these projects are not realized in monetary value alone. Furthermore, the value of water is expected to continue to rise over time decreasing the risk of this investment even lower.

For comparison, the San Antonio Spreading Grounds project is expected to cost at least $1.4 million and is expected to provide roughly 225 AF of recharge per year, for an average cost-effectiveness of $311/AF. Connecting Ventura River Watershed infrastructure to the State Water Project was estimated to cost $109 million dollars in 1987, a cost of $216 million in present value (CMWD, 2010). Assuming the City of Ventura used their entire allocation of 10,000 AF/yr for a 20-year period and the cost of water imported from the State Water Project was $1,000/AF, the cost-effectiveness of state water would be on average $1,445/AF. Given current restrictions on state water project distributions, it is unlikely that the City of Ventura would receive their full allotment, which would drive the cost per AF of water even higher. These projects will serve as baselines against which the cost-effectiveness of alternative water management strategies can be assessed.

Ability to Improve Ecosystem Health

In order to measure the potential ecological benefits of each water management strategy, it was evaluated for its effect on streamflow in a section of the Ventura River termed the Live Reach. This reach of the Ventura River was identified in a NMFS 2007 Biological Opinion (BO) as a segment of the river that provides critical habitat for Southern California steelhead (NMFS, 2007). The BO published by NMFS identifies a target flow of 12 cfs within the Live Reach during the months with low flow to maintain adequate over-summering habitat (Moore, 1980).

The only known direct human-driven mechanism for altering the flow in this reach is pumping by the City of Ventura at the Foster Park Well Field. Although other mechanisms, such as groundwater pumping higher in the watershed, may indirectly alter flow levels within the Live Reach, they are difficult to quantify. To evaluate the effectiveness for each water management strategy, therefore, we examined the effects of reduced pumping at Foster Park. For each strategy, the reduced annual demand in the City of Ventura was divided over the 4-month dry period of July, August, September, and October. Pumping at Foster Park was reduced within these months, and it was assumed that one-gallon of extraction from the well field translated to one gallon less flow within the Live Reach (Hopkins, 2006). For each of these months, one "positive event" was recorded if, with average historical pumping, the modeled average monthly flow in the Live Reach would have been below 12 cfs but with reduced pumping – as a result of lowered demand – the modeled average monthly flow within the Live Reach would be above 12 cfs. Figure 2. 9 shows a simplified example of positive event. In this example, a positive event occurs when the flow with reduced pumping is above 12 cfs, but the flow is below 12 cfs with historical pumping rates.

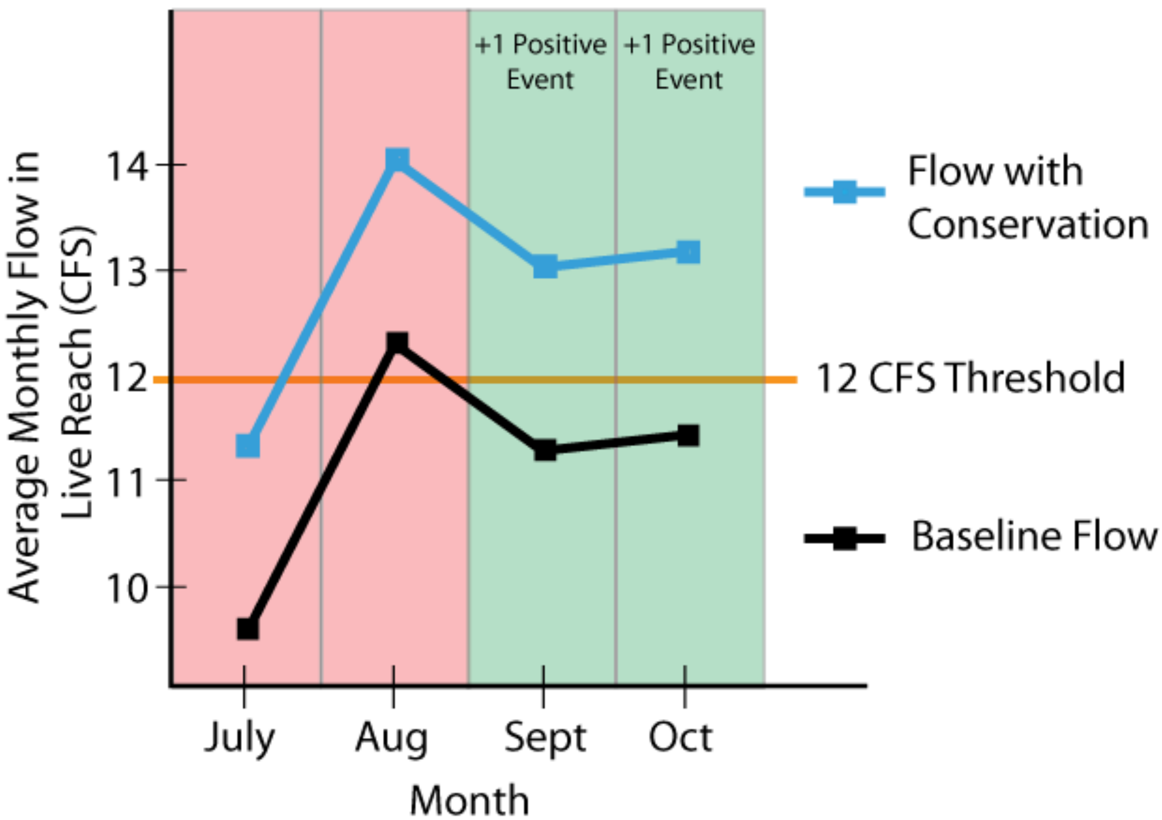

Figure 2. 9: Simplified example of positive event calculation for ecosystem health.

Water management strategies are deemed to improve ecosystem health by resulting in positive events, and the greater the number of those events, the greater the ecosystem health benefit. The maximum ecosystem health improvement from reduced pumping can be estimated by stopping all pumping during the dry summer months. For the study period of 1992-2009, stopping all pumping in the summer months yields 28 positive events. All water management strategies, therefore, could only produce a maximum of 28 positive events.

Ability to Improve Water Quality

There are a number of water quality impairments within the Ventura River watershed, including high nitrogen concentrations, low dissolved oxygen levels, pumping & diversion, high algae levels, trash, and high fecal coliform concentrations. For this study, we only examined the ability of a water management strategy to reduce the nutrient loading (nitrogen and phosphorus) within the Ventura River. For each strategy with the potential to reduce nutrient loading, an estimate of nutrient loading reduction was calculated.

Suitability for Proposition 84 Funding

In order for a project to be eligible for Prop 84 funding it must meet one or more of the following 14 elements.

- Water supply reliability, water conservation and use efficiency
- Stormwater capture, storage, treatment, and management
- Removal of invasive species
- Creation/enhancement of wetlands
- The acquisition, protection, and restoration of open space and watershed lands
- Non-point sources pollution reduction, management and monitoring
- Groundwater recharge and management projects
- Contaminant removal through reclamation, desalting, or other treatment technologies
- Conveyance of reclaimed water for distribution to users
- Water banking, exchange, reclamation and improvement of water quality
- Planning and implementation of multi-purpose flood management programs
- Watershed protection and management
- Drinking water treatment and distribution
- Ecosystem and fisheries restoration and protection

Eligible projects should produce multiple benefits. Preference is given to regional projects that address drought preparedness, water use efficiency, climate change response actions, integrated flood management, surface water and groundwater quality protection, tribal water and natural resource improvement, and the equitable distribution of benefits to disadvantaged communities. We evaluated our proposed projects based on their relevance to these requirements (DWR, 2012). Each water management strategy received a point for each of the listed criteria that it satisfied. Water management strategies with the most points received the highest criteria ranking.

2.4.2 Ocean Friendly Gardens

Ocean friendly gardens promote water conservation, infiltration, and water retention through the use of native landscaping, water diversion structures, and rain gardens (Surfrider Foundation, 2012). Rain gardens are landscaped depressions that collect runoff from surrounding impervious surfaces and allow the water to infiltrate the soil, increasing groundwater recharge and decreasing polluted runoff. Native plants can be used in rain gardens and surrounding areas as xeriscaping to help filter water, create porous soils, and reduce irrigation needs. Rain gardens need to be watered for the first 1-2 years to allow the plants to establish, but after that point, little to no watering is necessary and only minimal weeding and pruning maintenance is required to keep the garden functioning (The Groundwater Foundation, 2012). Rain gardens in Southern California can reduce landscaping water use by more than 70% over the converted area, depending on which plants are used and how much precipitation occurs (Long Beach Water Department, 2012).

WEAP Model Setup

To evaluate how a widespread conversion from lawns to ocean friendly gardens would affect the water budget, we assessed a range of situations. We calculated the percent household water reduction for single-family homes when 25%, 50%, 75%, and 100% of single-family accounts convert 25%, 50%, 75%, and 100%, of their lawns to ocean friendly gardens, respectively. The equation for calculating the reduced water demand for each household within a demand site is as follows:

$$R_{hh} = (PC_y * PC_{hh} * PR_{ofg} * D_T)/N_{hh}$$

Equation 6

where:

R_{hh} is the reduced demand for each household in the demand site
PC_y is the percentage of yard that is converted to OFG (25%, 50%, 75%, 100%)
PC_{hh} is the percentage of households that install OFGs (25%, 50%, 75%, 100%)
PR_{ofg} is the percentage reduction in demand converting from lawn to OFG (76%)
D_T is the total single-family water demand for a demand site
N_{hh} is the number of households within a demand site

This conversion included installation of one 150 sq-ft rain garden appropriately sized to capture the first inch of rainfall off of an average 1000 sq-ft roof, and the remaining portion of the percent converted was assumed to change to native landscape. According to the calculated percent water reduction estimates, we reduced the total water use by the affected sector and increased the groundwater infiltration over the different groundwater basins. For these water management strategies, we used water use rates for the different water resellers throughout the watershed. Finally, we combined all areas to investigate the effect of a watershed-wide implementation of ocean friendly gardens to conserve water and increase infiltration.

Calculating Decreased Demand

For each water management strategies, we calculated the percent reduction in demand. To do this we used the percent of households that convert, the percent of household water used outdoors, the percent of lawn per household that is converted, and the percent of water reduction for the converted area. Estimates for outdoor water use range from 42% to 70%, so we assumed a conservative 50% of all household water use in single-family homes is used for landscaping (Hanak & Davis, 2006). We also assumed a 76% reduction in water use for the converted area relative to traditional irrigated lawns as estimated in a xeriscaping conversion study by Southern Nevada Water Authority (Sovocol, 2005).

Calculating Increased Supply

We estimated increased infiltration to groundwater using precipitation data from the water year 2002/2003, identified as the average year over a 30-year period from 1980-2010 (Wickstrum & Merckling, 2011). Infiltration was calculated by assuming 90% of all rainfall that occurs in rainstorms up to one inch on a 1,000 sq-ft roof is captured in a rain garden. The other ten percent is lost through evapotranspiration. Only households that had converted to ocean friendly gardens in each scenario increased the groundwater infiltration.

Calculating Cost-Effectiveness

To estimate cost-effectiveness we calculated the upfront conversion cost, subtracted the water and maintenance cost savings for a 20-year period with a 3% discount rate and divided the total 20-year cost by the 20-year total water benefit (in AF). Total water benefit was assumed to be the decreased demand plus the increase in infiltration. To calculate the net cost of ocean friendly gardens, discounted maintenance and water savings were subtracted from the one-time installation costs. For the City of Ventura, where sewage rates are billed as a function of water use, the savings of reduced sewage bills was also included. Both installation costs and maintenance savings vary if the homeowner or a professional gardener completes the garden installation or yard maintenance. Water savings also vary depending on water purveyor. For a detailed breakdown of cost-effectiveness methods, see the Appendix 2.

	Homeowner Installation and Maintenance	Gardener Installation and Maintenance
Cost per square foot for installation	$1.37/sq-ft	$1.93/sq-ft
Yearly maintenance savings, excluding water	$0.12/sq-ft	$0.23/sq-ft

Table 2. 2: Installation costs and maintenance savings associated with ocean friendly gardens (Sovocol, 2005) (Hanak & Davis, 2006).

Quantifying Ecosystem Health

To estimate improvements in ecosystem health for each OFG scenario, reductions in demand were calculated using equation 6 for the City of Ventura. The water savings for each scenario were then translated into reduced pumping during the dry months at the Foster Park Well Field and positive events were recorded.

Quantifying Water Quality Benefits

Improvements to water quality were calculated during wet and dry days, where dry days were days with no recorded precipitation. During dry weather, nutrient runoff is a function of the concentration of dry weather runoff and the total volume of runoff. Dry weather nutrient concentration measurements were obtained through the Ventura County Stormwater program for 2010-2011, and average Total N concentrations were 3.55 mg/L and average Total P concentrations were 0.043 mg/L (VCWSQMP, 2012). To estimate the volume of runoff reduced through OFGs, 5% of the irrigation water was assumed to runoff during lawn irrigation, 15% infiltrated to groundwater, and 80% was consumed through evapotranspiration (Tetra Tech, 2008). For example, installing OFGs in the City of Ventura is estimated to reduce the runoff from irrigation by 17 AF/yr (5% of reduced demand). Using the N and P concentrations listed above, dry weather reductions were calculated as 210 pounds of Total N and 2 pounds of Total P.

During wet weather, total nutrient load reductions were calculated by estimating the volume of water that could be captured through rain gardens using average event mean concentration (EMCs) reported in the LARWQCB TMDL report (CRWQCB, 2012). The EMC concentrations used for our calculations were 4.57 mg/L for Total N and 0.54 mg/L of Total P. A variety of studies reported Total N and P reductions for bioswales and other bio-treatment options. (Roy-Poirier, Champagne, & Filion, 2010); (Davis, Hunt, Traver, & Clar, 2009). For this analysis, we used the mid-range estimates of 45% reduction for Total N and 70% reduction for Total P for OFGs. Converting 50% of the lawns to OFGs in 50% of the households in the City of Ventura, for example, is estimated to capture 147 AF/yr of rainwater. Using the nutrient concentrations listed above, loading was reduced in the runoff by 45 and 70% for N and P.

2.4.3 Greywater

The greywater water management strategy assesses laundry to landscape greywater systems. Laundry-to-landscape systems are the most simple greywater systems and only utilize greywater produced by washing machines. The system consists of either a pumped or gravity fed line that takes greywater out of the house and into underground irrigation lines outside the house. These systems can cost between $100 and $1000 dollars depending on whether they are self-installed and if a pump is needed. Three scenarios were run in order to show the effect of 25%, 50%, and 75% of single-family households utilizing a laundry to landscape system.

WEAP Model Setup

This water management strategy was entered into WEAP as a decrease in demand. Decreases in demand were determined for each demand site and under each conversion scenario (25%, 50% and 75%). The water savings at each demand site were converted into a new average annual water use per person and entered into WEAP.

Calculating Decreased Demand

Decrease in demand was calculated by determining the water savings of an average greywater system. For this water management strategy, we assumed an average household has three people, does six loads of wash a week and has a washing machine that uses 35 gallons a load, for a rounded average of 11,000 gallons a year (National Research Center, 2002). Greywater production was assumed to represent a decrease in outdoor water demand of equal magnitude. The calculated per person water demand reduction was then multiplied by the total number of households using the systems to get total decrease in demand. Total decrease in demand was then used to find a new average per person water demand, which was in turn entered into WEAP. Appendix 3 shows the full set of parameters input into the WEAP model for this scenario.

Calculating Increased Supply

Although there may be some infiltration due to the use of a greywater system, it will be very low due to evapotranspiration. For our purposes we will assume that greywater does not contribute to supply.

Calculating Cost-Effectiveness

Cost-effectiveness was calculated by finding the net present value of the costs and benefits associated with the system operating for 20 years. Costs are up front and thus are not discounted. However, benefits occur over 20 years and must be discounted. A 3% discount rate was chosen because of the low risk involved with the investment as well as the high probability that water costs will increase in the future. We assumed a $2.5 dollar per HCF cost of water when calculating the water cost benefits.

Quantifying Ecosystem Health

Total water savings were calculated for 25%, 50% and 75% of City of Ventura households that installed a greywater system. The savings for each scenario were then translated into reduced pumping during the dry months at the Foster Park Well Field and positive events were recorded.

Quantifying Water Quality Benefits

Although installing a greywater system will decrease the amount of water running to the wastewater treatment plant, the increase in water quality will be minimal. For this analysis we assume that the increase in water quality due to greywater use will be zero.

2.4.4 Scalping Plant in Ojai

Currently there is no use of OVSD treated water for recycling purposes. Although the OVSD system is treating the water to tertiary standards, this water is discharged to the river without being considered for further reuse. The OVSD plant receives wastewater from Ojai, unincorporated areas of Ojai Valley, and the north Ventura Avenue area via a system consisting of 120 miles of trunk and main sewer line (Ojai Valley Sanitary District, 2012).

A scalping plant is a small-scale wastewater treatment system that is used for production of reclaimed water. They are located upstream of wastewater treatment facilities and provide water for reuse in nearby areas. Scalping plants remove a volume of water from a main wastewater line. This water is then treated to a level necessary for the particular type of reuse. The scalping plant examined in this water management strategy will treat water to tertiary level for irrigation use. Unlike a conventional treatment plant, scalping plants do not treat the solid portion of sewage or biosolids (Byrne, 2012). The sludge from the settling units is returned to wastewater lines and continues on to the central wastewater treatment facility for treatment (AECOM, 2012). One major benefit of the scalping plant is that the reclaimed water is produced and used locally which decreases the associated pumping and infrastructure costs. These plants need to be sited in places where they receive a considerable amount of sewage. This treated water can then be used for various purposes, including irrigation of golf courses and parks. The treatment can be achieved using membrane bioreactors or conventional treatment. In Southern California, both these methods are being used for scalping plants (Byrne, 2012).

WEAP Model Setup

A decentralized scalping plant using Activated Sludge Process (ASP) technology and having a treatment capacity of 200,000 gpd was evaluated for this water management strategy. Some advantages of using the ASP process in a scalping plant include simple design and operation, production of good quality effluent that may be used for Type I reuses (including landscape irrigation), and lower costs compared to other wastewater reuse technologies (AECOM, 2012). This plant will provide 220 AF/yr in water savings.

There are two golf courses in Ojai each using an estimated 250 AF/yr for irrigation. We examined the feasibility of installing the decentralized scalping plant in Ojai to provide 220 AF/yr of reclaimed water. The combined water use rate for the two golf courses was reduced from 500 AF/yr to 280 AF/yr, based on the assumption that all the reclaimed water produced by the plant would be used only for irrigating these golf courses. Decreasing the yearly discharge from OVSD by 220 AF/yr simulated the effect on downstream flows.

To model this decrease, a transmission link from the OVSD WWTP to the Ojai Groundwater Basin was added in the Schematic view of WEAP. In the Data view, another branch 'Ojai Groundwater Basin' under 'Return Flow from OVSD WWTP' category was created. The calculated percentage loss value (approximately 10%) was entered in this new branch and the value for return flow was adjusted to 90% from 100%.

In order to determine the loss of water through evapotranspiration the crop coefficient was also calculated. The crop coefficient, K_c, is a dimensionless number that is multiplied by the reference evapotranspiration (the reference crop used in this report is grass) to estimate crop evapotranspiration for a specific crop. The loss due to evaporation ('Loss from System' in WEAP) was set to 99% for the branch 'Ojai Groundwater Basin', assuming the golf courses have turf grass with a crop coefficient of K_c=1 and the irrigation efficiency is nearly 100% (Appendix 4).

Calculating Decreased Demand

For this water management strategy, the decrease in water demand was calculated as the difference in the water use rate for the golf courses as a result of changing the rates from 500 AF/yr to 280 AF/yr.

Calculating Increased Supply

Changes in water supply were estimated using the values produced from the model.

Calculating Cost-Effectiveness

A scalping plant using ASP technology and having a treatment capacity of 200,000 gpd will provide water savings benefits of 730,000,00 gallons/yr or 224 AF/yr. For the cost-effectiveness element of this analysis, the price of reclaimed water was set at $2.5/unit (HCF). One HCF is equivalent to 100 cubic feet of water (or 748 gallons) and the price of $2.5 is close to the State average price for potable water. If 748 gallons comprise one unit, the water savings translate to 97,594 units per year. At a reclaimed water price of $2.5/unit (HCF), the expected benefit from sale of reclaimed water is $243,984/yr.

The cost estimates for construction, and operation and maintenance of this plant are $2,022,246 and $ 210,000/yr respectively (AECOM, 2012). A discount rate of 3% was applied to the operation costs and benefits from sale of reclaimed water over a period of 20 years. The NPV was calculated by adding up the one-time infrastructure costs and the discounted operation costs for 20 years and subtracting the discounted benefits for 20 years from this sum.

To evaluate cost-effectiveness, the NPV for 20 years was divided by the total amount of water savings in 20 years to calculate the average cost/AF of water saved (Appendix 4).

Quantifying Ecosystem Health

The water management strategy was analyzed for any potential effects it may have on water demand in City of Ventura and consequently pumping activities at Foster Park to determine whether ecosystem health (as defined in this study) would be affected by this water management strategy.

Quantifying Water Quality Benefits

The water management strategy was analyzed for any potential effects it may have on water quality in Ventura River Watershed. Relevant literature was consulted in this regard. Preliminary analysis suggested this strategy would not have any significant impacts on water quality.

2.4.5 Infiltration Basins

Infiltration basins are an example of structural Best Management Practices (BMPs) that can be used to capture stormwater runoff, reduce pollutant discharge, and increase groundwater recharge. For infiltration basins to be feasible, several design criteria must be considered. They should be constructed in areas of high soil permeability to achieve sufficient infiltration rates and treatment of stormwater runoff. Additionally, although the infiltration basins have been successfully implemented as regional facilities in certain areas, they are more effective for drainage areas less than 10 acres (US EPA, 2012). Finally, they are more suitable for urban areas, where a large amount of polluted runoff can be captured and treated (Detention Ponds and Basins), but are not recommended for ultra-urban areas due to space constraints (US EPA, 2012). An ultra-urban area is that where high degrees of development and imperviousness are present. In these areas, room for large detention ponds and basins is not available.

WEAP Model Setup

To explore the feasibility of infiltration basins for stormwater runoff management in the Ventura River Watershed, infiltration basins were simulated by adding another branch, "infiltration basins" in the urban category of four catchments, namely 449, 1082, 1083 and 442 (Figure 2. 2). An infiltration basin size of 20,000 m^2 or 4.94 acres was assigned in the four catchments and the equivalent amount of area deducted from low, medium, and high impervious branches so that the total urban area in each catchment remained the same. In addition to this scenario, another scenario was run in which 10% of the impervious area of urban category in catchment 449, (the catchment containing Ojai), was converted to infiltration basins.

While the water quality and cost estimates were calculated for both the infiltration basin scenarios mentioned above (Appendix 5), only the calculations for the 10% impervious area conversion scenario were considered for the criteria analysis (including cost-effectiveness) because the recharge to groundwater from the other scenarios was too small to be captured by the model. For the 10% impervious area conversion scenario, the drainage area is about 59 acres or 236520 m^2.

Calculating Decreased Demand

Preliminary analysis suggested this water management strategy would not have any significant impacts on demand.

Calculating Increased Supply

Changes in water supply were estimated using results from the model.

Calculating Cost-Effectiveness

Cost estimates for infiltration basins can vary widely depending on site characteristics such as soil and location as well as the design of the basin. In this report, only costs of construction, design contingency and other capital costs, and maintenance costs of basins have been considered. Although land acquisition costs were not included in our analysis, it is worth noting that the amount of land needed for an infiltration basin is around 2-3% of the impervious area that would be draining to the basin (US EPA, 1999). The land cost is the variable that most significantly affects the overall costs of the project; land costs differ widely from state to state as well as regionally and depend on zoning and surrounding land uses. In places required to have open space allocations within a developed area, the land cost for a BMP may be reduced to zero (US EPA, 1999).

The following equation proposed by Schueler in 1987 (US EPA, 1999) was used to determine the construction costs of infiltration basins:

$$Construction\ Cost = 13.2 * V^{0.69}$$

Equation 7

where:

V is the total basin volume (in cubic feet)

It was assumed that the infiltration basins are designed to capture the first inch of runoff from the drainage area. Typical Design Contingency and Other Capital Costs were estimated as 30% of construction costs, and annual maintenance costs were estimated as 8% of construction costs (US EPA, 1999). The total cost was adjusted for rainfall zone 6 since the study area falls in that zone (US EPA, 1999) and finally, the costs were adjusted for inflation from 1987 dollars using the inflation calculator provided on United States Department of Labor Website (US Department of Labor, 2012).

For cost-effectiveness, a discount rate of 3% was applied to the operation costs for the Infiltration Basins (10% of impervious area conversion) water management strategy over a period of 20 years. The NPV was calculated by adding up the one time infrastructure costs and the discounted operation costs for 20 years. To evaluate cost-effectiveness, the NPV was divided by the total amount of recharge over a 20-year period (Appendix 5).

Quantifying Ecosystem Health

The water management strategy was analyzed for any potential effects it may have on water demand in City of Ventura and consequently pumping activities at Foster Park to determine whether ecosystem health would be affected by this strategy.

Quantifying Water Quality Benefits

Although little data is available concerning the pollutant removal efficiency of infiltration basins, all the water percolates underground and therefore these basins are expected to have high pollutant removal efficiency. A well maintained infiltration basin designed to treat runoff from a 1-inch storm is estimated to have 60-70% removal efficiency for phosphorus and 55-60% removal efficiency for nitrogen (US EPA, 2012). To obtain the lbs/year reduction estimates for Total Nitrogen (TN) and Total Phosphorus (TP), these percentages were used in conjunction with the wet weather loadings for the drainage area given in draft algae and nutrient TMDL report for the Ventura River (CRWQCB, 2012).

2.4.6 Water Rate Increase to State Average

This water management strategy explored the impacts of increasing all water rates within the watershed to at least the state average of $2.50 per HCF at the 15-HCF tier (Veatch, 2006). Each water purveyor has differently structured tiers, or no tiers at all. In order to compare the various structures, the price was taken for each purveyor for the 15th HCF purchased. Two water purveyors, Casitas Municipal Water District and Meiners Oaks, were identified as having water rates below the state average. Casitas rates at the 15 HCF level are currently 284% lower than the state average. Meiners Oaks rates at the 15 HCF level are currently 182% lower than the state average. These low rates are not sending the pricing signals that water is a valuable and scarce resource. Because these current rates are so low, using the US average price elasticity of demand of -0.30 (Olmstead & Stavins, 2007) resulted in a decrease in demand of over 100%. In order to predict the response to a significant price increase a more applicable price elasticity of demand was needed.

A study conducted at UC Santa Cruz (Nataraj, 2007), analyzed the effect of a 200% increase in water rates in Santa Cruz, CA in 1994. The resulting economic analysis gave a price-elasticity of demand of between -0.15 in the short-term and -0.25 for the long-term. The study defined long-term as after four billing cycles.

WEAP Model Setup

Decreases in demand were calculated outside the model and input into WEAP as reductions in annual average single-family household water use.

Calculating Decreased Demand

Decreases in demand for this water management strategy were calculated for three possible price elasticity's of demand: -0.15, -0.2, and -0.25. The price elasticity was used to determine the decrease in demand for the associated increase in price. The decrease in demand was then used to calculate a new per capita water use, which was then entered into WEAP. The new per capita water usages, calculations for reduction of water use, and parameters for average single-family household water use are outlined in Appendix 6.

Calculating Increased Supply

Preliminary analysis suggested this water management strategy would not have any significant impacts on supply.

Calculating Cost-Effectiveness

In order to calculate cost-effectiveness for this water management strategy, the per capita increase in cost per year was multiplied by the total number of consumers affected by the price increase. The yearly total was then discounted over 20 years to determine the 20-year cost of implementing this project. This number was then divided by the 20-year total number of AF that was saved in order to determine the average cost per AF number for this water management strategy.

Quantifying Ecosystem Health

Preliminary analysis suggested this water management strategy would not have any significant impacts on ecosystem health.

Quantifying Water Quality Benefits

Preliminary analysis suggested this water management strategy would not have any significant impacts on water quality.

2.4.7 Water Rate Increase to Full Cost Pricing

Currently, the CMWD operates at a reported $2,582,357 loss (CMWD, 2010). This operating loss is covered by government subsidies, property taxes, and surcharges. This method of financing effectively subsidizes high water use by lowering water prices for high users, which is partly paid for by leveling a tax on all users. The structure and magnitude of water rates play an important role in the amount of water people use. In general, as prices go up, people use less water. This water management strategy examines the impact of increasing the cost of water on water demand for CMWD customers. In this strategy, we only considered residential water prices, not commercial or agricultural prices. This was done due to the political implications of increasing costs on commercial and agricultural entities. In order to completely remove all non-operating revenues, it would be necessary to levy a price increase across all sales.

WEAP Model Setup

In order to determine the effect of a decrease in demand on the watershed we calculated decrease of demand in Excel and then entered the new per person water use into the WEAP model. The water use per year per customer for Casitas was changed to reflect the new demand after rate increases. The calculations for decreases in demand were done in excel and only the new demand figure was entered into WEAP.

Calculating Decreased Demand

For this water management strategy, we used a price elasticity for water of -0.3 (Olmstead & Stavins, 2007). Because increasing the water rates by 10% will decrease demand by 3% we need to raise water rates by 33% in order to raise revenue by 20%. A step-by-step analysis of this calculation is shown in Appendix 7. This will result in a decrease in demand of 10%. This decrease in demand will decrease the per person annual water use of Casitas customers from 0.763 AF/yr to 0.687 AF/yr. This new per person annual water use was entered into WEAP in order to model the effects of a rate increase.

Calculating Increased Supply

Preliminary analysis suggested this water management strategy would not have any significant impacts on supply.

Calculating Cost-Effectiveness

The cost-effectiveness calculations for this water management strategy are the same as those for the rate increase to state average strategy above.

Quantifying Ecosystem Heath
Preliminary analysis suggested this water management strategy would not have any significant impacts on ecosystem health.

Quantifying Water Quality Benefits
Preliminary analysis suggested this water management strategy would not have any significant impacts on water quality.

2.4.8 Conversion to Pervious Streets

Impervious surfaces, such as roofs, parking lots, and roads increase the volume of urban stormwater runoff into the stream network. In this water management strategy, we investigated the effects of converting impervious roads within the watershed to pervious asphalt. This conversion has the potential to increase the quantity of water that infiltrates to the groundwater while also decreasing the nutrient and pollutant loads delivered to streams during storm events.

WEAP Model Setup
In order to model this within WEAP, we created a new sub-branch entitled 'Pervious' under the 'Urban' branch within catchment 449, the catchment that contains the City of Ojai (Figure 2. 2). We then reduced the total area of the 'low impervious', 'medium impervious', and 'high impervious' sub-branches by 25% and added this area (12,700,000 square-feet) to the 'pervious' sub-branch. Within the 'pervious' sub-branch, we assigned a K_c value of 0.1, indicating that a small amount of evapotranspiration would occur (see Appendix 8). We also assigned a runoff resistance factor of 8, indicating that very little runoff would occur before water had a chance to infiltrate. The runoff resistance factor was assigned based on a case study (City of Portland Oregon, 2012) that estimates that pervious roads are 80% efficient when it comes to capturing stormwater runoff. This simulates converting impervious roads to pervious asphalt that would allow water to infiltrate into the ground.

Calculating Decreased Demand
Preliminary analysis suggested this water management strategy would not have any significant impacts on demand.

Calculating Increased Supply
The WEAP model was run for 20 years to calculate increased water supply associated with this water management strategy. Annual Ojai Groundwater Basin levels were averaged over that time period and compared to baseline model results.

Calculating Cost-Effectiveness
Based on a case study from the Portland Green Streets Program, the cost of conversion of a street with a 60,000 square-foot drainage area is around $400,000 (City of Portland Oregon, 2012). Capturing runoff from 25% of Ojai (12,700,000 sq-ft) would entail converting 212 streets to pervious asphalt, assuming that each project captured runoff from a 60,000 square-foot drainage

area. At a cost of $400,000 per project, the total cost of 212 conversions would be $85 million. Because streets are repaved on a regular basis in Ojai, we only considered the difference in cost between a conventional street repave and a pervious asphalt repave when calculating cost-effectiveness for this study. Converting a street to pervious asphalt costs around 15% more than a conventional street repave, meaning that actual cost of converting 212 streets would be around $13 million (LID Center, 2007) (University of Rhode Island, 2005) (US EPA, 1999). Because the life expectancy of pervious asphalt is around 20 years, we summed the total increases in groundwater levels over twenty years when calculating the cost-effectiveness of this water management strategy (LID Center, 2007) (University of Rhode Island, 2005) (US EPA, 1999).

Quantifying Ecosystem Health

Preliminary analysis suggested this water management strategy would not have any significant impacts on ecosystem health.

Quantifying Water Quality Benefits

To quantify reductions in nitrogen and phosphorus loading to the stream network associated with this water management strategy, it was assumed that the increase in recharge to groundwater corresponded directly to decreases in residential runoff to the stream network. Event mean concentrations of nitrogen and phosphorus in residential stormwater runoff for the watershed have been estimated to be 4.57 mg/l and 0.54 mg/l, respectively.

2.4.9 San Antonio Creek Spreading Grounds

During times of high flow, surface water from San Antonio Creek is diverted into the San Antonio Spreading Grounds. The spreading grounds are used to increase groundwater recharge within the underlying aquifers. Although this project is not yet completed, VCWPD hopes to complete the project within the next several years. The goal of this water management strategy is to simulate the effects of the San Antonio Spreading Grounds Rehabilitation Project on both surface and groundwater supplies.

WEAP Model Setup

In order to model the water management strategy, we created a diversion canal named 'SASG_ Diversion' (SASG refers to San Antonio Spreading Grounds) and a river reach named 'San Antonio Spreading Grounds'. The diversion canal diverts water from San Antonio Creek to the 'San Antonio Spreading Grounds' river reach, which flows into the Ojai Valley Groundwater Basin. Historic monthly diversion values were found from data provided in the San Antonio Creek Spreading Grounds Rehabilitation Project Draft Mitigated Negative Declaration (Padre Associates, Inc, 2011). Using these historic diversion values, we created a regression equation for the amount of flow diverted based on precipitation from the precipitation gauge 030D in catchment 449 (Figure 2. 2). Using precipitation levels from future climate data, the regression equation was used to predict the magnitude of diversions into the San Antonio Creek Spreading Grounds in the future. Evaporative losses were set to 20% in the model based on estimates of evapotranspiration within the San

Antonio Spreading Grounds Draft Impact Statement (Padre Associates, Inc, 2011). Because the maximum annual diversion for the SASG is 914 AF (Padre Associates, Inc, 2011) an Excel formula was created to cap the diversion to 914 AF for each year. The formula adjusts the monthly diversion values calculated from the regression equations so that the yearly diversion never exceeds than 914 AF/yr.

Calculating Decreased Demand

Preliminary analysis suggested this water management strategy would not have any impacts on demand.

Calculating Increased Supply

In order to calculate yearly average increases in supply resulting from the San Antonio Spreading Grounds, the model was run to simulate years 2010 through 2099. Ojai Groundwater Basin levels over that time period were averaged and compared with Ojai Groundwater Basin levels over that time period without the San Antonio Spreading Grounds. This difference was used as the supply increase.

Calculating Cost-Effectiveness

The San Antonio Spreading Grounds project has an estimated cost of $1,315,000 (Padre Associates, Inc, 2011). Assuming that the project remains functional for 20 years with no operation and maintenance costs, we divided the cost of the project by the total number of AF sent to the groundwater over 20 years to calculate the cost-effectiveness.

Quantifying Ecosystem Health

Preliminary analysis suggested this water management strategy would not have any impacts on ecosystem health.

Quantifying Water Quality Benefits

Preliminary analysis suggested this water management strategy would not have any impacts on water quality.

2.5 Normalization of Results

In order to facilitate comparison of water management strategies that impact the Ventura River watershed in different ways, a normalization scheme was developed. Each water management strategy that was considered in our study was given a value from 0 to 3 within each 'Evaluation Criteria' category, discussed above. Low values indicate that the strategy is not effective in achieving a particular goal, while high values indicate that the strategy is effective in achieving a particular goal. The criteria by which the effectiveness of each water management strategy was assessed are: (1) Ability to Decrease Demand; (2) Ability to Increase Supply; (3) Cost-Effectiveness; (4) Ability to Improve Ecosystem Health; (5) Ability to Improve Water Quality; and (6) Suitability for Proposition 84 Funding.

2.6 Weighting Scheme

In order to account for the fact that the relative importance of the different evaluation criteria employed in this study may change over time and across organizations, we have incorporated a weighting scheme into our analysis. This involves assigning a numerical score from 0.0 to 1.0 to each evaluation criteria by which the associated benefits of each water management project will be multiplied. These numerical scores must sum to 1.0 in any given weighting scheme. In order to account for the variability in stakeholder priorities within the Ventura River Watershed, a variety of weighting schemes were used and a framework for the creation of future weighting schemes was established. Examples of the weighting schemes are shown in Table 2. 3.

	Cost Focus	Ecosystem Health Focus	Water Quality Focus	Water Supply Focus	Neutral
Cost-Effectiveness	0.3	0.2	0.2	0.3	0.167
Decreased Demand	0.1	0.05	0.1	0.1	0.167
Increased Supply	0.1	0.05	0.1	0.4	0.167
Water Quality	0.1	0.2	0.4	0.1	0.167
Ecosystem Health	0.1	0.4	0.1	0	0.167
Proposition 84	0.3	0.1	0.1	0.1	0.167

Table 2. 3: Weighting schemes for evaluating water management strategy.

The aim was not to advocate one weighting scheme over another, rather, the purpose of using different weighting schemes is to assist the concerned stakeholders in selection of suitable projects and ensure that their different priorities are taken into account. Additionally, this analysis will identify the projects whose ranking is not affected by different weighting schemes, highlighting the most desirable water management options. In developing our weighting schemes, significant consideration was given to the stated goals of the Ventura River Watershed Council. As of December 2012, these goals are to provide sufficient local water supplies, clean water, integrated flood management, healthy ecosystems, access to nature, sustainable land and resource management, and coordinated watershed planning (VRWC, 2012).

2.7 Land Use Change (Crop Conversions)

In the Ventura River Watershed, Asian Citrus Psyllid (ACP) is a disease that is threatening citrus produce (VRWC, 2012). As a result, some farmers within the area are considering replacing their citrus crops with raspberries. This scenario examines the effects of a change in water demand associated with the conversion of orange cropland to raspberry cropland.

WEAP Model Setup

To simulate the effect of this crop change on water demand in the watershed, a new "Raspberries" branch was created under the agriculture category for all catchments with orange crops. Three scenarios were run to show the effect of a 25%, 50%, and 75% crop conversion from oranges to raspberries. For each scenario, 25%, 50%, and 75% of the area dedicated to orange crops was added to the 'Raspberries' branch. The runoff resistance factor for Truck Crops (i.e. row crops) was assigned to the 'Raspberries' branch for all scenarios. In doing this, we assumed that runoff magnitudes from a raspberry field would be similar to those from other row crop fields (i.e. tomatoes, corn, etc.) in the watershed.

The crop coefficient (K) of strawberries was calculated from the Basic Irrigation Scheduling Application Program (English units), 'BISe.xls' (Snyder R. L., Orang, Bali, & Eching, 2007). This value was used as an approximation for K_c of raspberries. The K_c of strawberries was chosen because the BISe does not include raspberries in the list of crops and literature review indicates that these two crops have similar K_c values (Ministry of Food and Fisheries, 2012). The K_c value for raspberries varies from 0.2 to 0.7 and monthly K_c values were assigned by considering the typical peak harvest season for raspberries in Ventura County (Farm Bureau of Ventura County, 2012). Given that the peak harvest season extends from January to April, K_c value of 0.25 were given for Jan, 0.3 for Feb, 0.35 for March, 0.4 for April, 0 for May, June, July and August, 0.7 for September and October (assuming the growing season starts in September), 0.2 for November and 0.25 for December.

Estimates of annual irrigation allowance for citrus and raspberries are available for the Oxnard region of Ventura County, located roughly 20 miles southeast of the watershed (ITRC, 2010). These estimates (31 inches and 54 inches for citrus and raspberries respectively in a typical year) were used for each of the 25%, 50%, and 75% crop change scenario to calculate the annual water use rates (in AF) for both oranges and raspberries for each catchment. The difference in water use rates of the two crops is the demand increase that would occur under each scenario. Consequently, the water use rate of the entire watershed was increased by 1412 AF, 2824 AF, and 4235 AF for 25%, 50%, and 75% crop change scenarios respectively. Agricultural extractions from groundwater and purchases from CMWD are allocated according to groundwater basin in the model by the groundwater basin that the demand site overlies. The associated increase in demand was applied to each agricultural demand site based on the proportion of agricultural water demand prior to the crop conversion.

2.8 Climate Change

Climate change represents a major challenge for water resource managers in Southern California. Increases in temperature and changes in precipitation have the potential to severely impact future water supplies, both locally (less groundwater recharge) and regionally (decreased Sierra snowpack). The climate change section of this study was developed as a way to model several potential futures for the Ventura River Watershed. Although the uncertainty associated with climate change is high, these scenarios are meant to provide a range of possible outcomes on which to base future water management decisions.

WEAP Model Setup

In order to model climate change in the watershed we retrieved historical temperature and precipitation data from local meteorological stations. We used meteorological data from the twenty-year period of 1990-2009 in order to capture a timespan that included a number of dry, normal, and wet years. To construct a baseline scenario, we considered the historical meteorological record from 1990-2009 and assumed that this same pattern would repeat cyclically until 2099. Starting with the historical data sets we then applied specific factors in order to simulate the potential impacts of climate change using the WEAP model. These factors are described below.

We retrieved only one source of temperature data for the watershed; this station was located in the City of Ojai. Average temperature data from that station was applied to all catchments in the WEAP model of the Ventura River Watershed. Daily temperature data was converted into monthly averages used in the WEAP model

We retrieved precipitation data from 11 gauge stations that are distributed throughout the watershed (VCWPD, 2006). These stations were located in both the low-lying regions of the watershed and in the upper elevations; they were chosen in order to capture the heterogeneity of precipitation that occurs within the basin. Rainfall data from these 11 stations was assigned to WEAP catchments that were the closest to each gauge station and by matching each gauge station to catchments with elevation profiles that were similar to the station's elevation. Daily precipitation data was converted into monthly totals that were used in the WEAP model.

In order to simulate climate warming in the future we increased average annual temperature by 4 °C from their historic values. This increase in warming was chosen because it was consistent with current projections for climate warming and because this projected increase has been used in previous studies using WEAP (World Bank, 2012) (Null, Viers, & Mount, 2010). Beginning in the year 2010, the annual average temperature was increased linearly until the year 2099 (Figure 2. 10). By that time, the average annual temperature is 4 °C higher than baseline temperature values (see Appendix 11 for procedure).

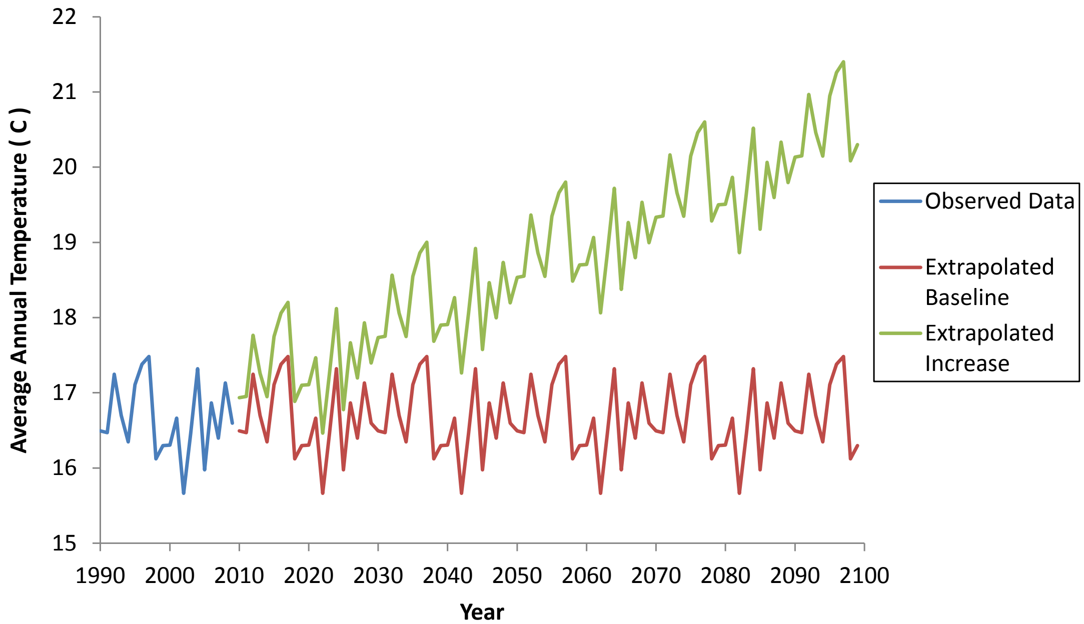

Figure 2. 10: Result of extrapolating observed temperature data.

To evaluate the potential increase or decrease in precipitation, we increased the baseline precipitation by linearly increasing it by 10% and 20% and by decreasing it by the same two percentages. This range of precipitation variability was chosen because it is consistent with the current range projected for Southern California by various global circulation models (California Energy Commission, 2012). Additionally, we chose this wide range because predictions of future rainfall are much less certain than temperature (Dettinger, 2005). Like the temperature data, annual average precipitation data was ramped linearly up or down (to a maximum 10% or 20%) starting in the year 2010 out to 2099 (see Appendix 11 for procedure).

In total the future projections were used to create 6 distinct climate scenarios: "baseline", "T4", "T4 +20", "T4 -20", "T4 +10", and "T4 -10". The baseline scenario from 2010-2099 used recycled, unaltered historic data; the remaining 5 scenarios were all built from the baseline. In the T4 scenario only temperature was increased by 4 °C and precipitation was unchanged. In the T4 +10 and the T4 -10 scenarios temperature was increased by 4 °C and precipitation was increased or decreased by 10% respectively. For the T4 +20 and the T4 -20 scenarios temperature was increased by 4 °C and precipitation was increased or decreased by 20% respectively. Other meteorological values such as wind speed, relative humidity, and cloudiness fraction remained unchanged for every climate change scenario.

A predicted Robles Diversion file was also created for each climate change scenario. The Robles Diversion structure diverts water from the Ventura River to Lake Casitas. The monthly diversions from the river to the reservoir were calculated using 12 regression equations (one for each month) that were created by plotting historic monthly diversion data and historic precipitation at the Casitas

Dam (see Appendix 1). Based on the precipitation at the Casitas Dam rain gauge and these regression equations we calculated monthly diversions to Lake Casitas for every climate change scenario. The file created from this work was used to model diversions from the river to the reservoir throughout the entire 1990-2099 time-period modeled in each climate change scenario.

Each of the six climate scenarios were analyzed with the WEAP model (**baseline**; no change in precipitation or temperature, **T4-20;** temperature increased by 4 degrees and precipitation decreased by 20%, **T4-10;** temperature increased by 4 degrees and precipitation decreased by 10%, **T4;** increase in temperature by 4 degrees, **T4+10;** temperature increased by 4 degrees and precipitation increased by 10%, **T4+20;** temperature increased by 4 degrees and precipitation increased by 20%). The WEAP model outputs used to analyze these scenarios were potential ET, actual ET, average monthly streamflow, water storage in the Ojai and Lower Ventura Groundwater basins, Lake Casitas storage, and human water demand from the years 2010-2099 (see section 3.2.10). We chose these five model outputs because they are good indicators of how human and environmental water needs will be affected in the watershed.

2.9 Scenario Suites

We created several 'scenario suites' to determine how the individual water resource management options analyzed in this study could be used in concert to offset the effects of population growth, climate and land use change in the watershed. The WEAP Model was used to determine the effects of these suites on water resources within the Ventura River Watershed for the time period 2000-2099. A summary of the water management strategies and land use and climate change scenarios we chose to include in each suite is shown in Table 2. 4.

		Baseline	Temperature Increase	Temperature Increase Infrastructure	Temperature Increase Consumer	Worst Case	Worst Case Infrastructure	Worst Case Consumer	All Scenarios Implemented
Climate Change	Baseline Climate Conditions	x							x
	T4, No Change in Precip.		x	x	x				
	T4, 20% Decrease in Precip.					x	x	x	
Land Use Change	Conversion of 50% Oranges to Raspberries					x	x	x	
Infrastructure Based Water Management Strategies	Infiltration Basins			x			x		x
	San Antonio Spreading Grounds	x	x	x	x	x	x	x	x
	Scalping Plant			x			x		x
Consumer Based Water Management Strategies	Rate Increases, CMWD to State Average				x			x	x
	50% Ocean Friendly Gardens				x			x	x
	50% Greywater				x			x	x

Table 2. 4: Summary of scenario combinations for the 8 suites.

2.9.1 Baseline and All Water Mater Management Strategies Implemented

The Baseline suite represents conditions with no temperature, precipitation, or land use change by 2099 and with no water resource management implementation. The All Water Management Strategies Implemented suite represents the upper 'book-end' in terms of water resource management, with all water management strategies except 'Pervious Streets' being implemented and with no climate or land-use change by 2099.

2.9.2 Worst Case: Climate and Land Use Change

The Worst Case suite along with the Worst Case Infrastructure and Worst Case Consumer suites model the potential for the water management strategies analyzed in this study to mitigate the effects of a 'worst case scenario'. The worst-case scenario includes increased temperatures, land use change and decreasing precipitation in the Ventura River Watershed. In the worst-case scenario, temperature warms by 4 degrees Celsius by the year 2099, precipitation decreases by 20%, and 50% of oranges are converted to raspberries. In Suite 1, no water resource management strategies are implemented other than the San Antonio Spreading Grounds Project, which is already underway in reality. In the Worst Case Consumer suite, consumer-based water resource management strategies are implemented on top of the San Antonio Spreading Grounds Project to offset the effects of climate and land use change. These consumer-based strategies are the ocean friendly gardens, greywater, and CMWD rate increase strategies discussed above. In Worst Case Infrastructure, infrastructure-based water resource management strategies are implemented on top of the San Antonio Spreading Grounds Project. These infrastructure-based strategies include a scalping plant near Ojai and decentralized infiltration basins.

2.9.3 Temperature Increase

The Temperature Increase suite modeled the potential for the water management strategies analyzed in this study to mitigate the effects of four degrees of warming in the Ventura River Watershed. This suite is represented by an increase of 4 °C in average temperature by 2099, no change in precipitation (from baseline), and no conversion of orange crops to raspberries. In the Temperature Increase suite, no water resource management strategies are implemented other than the San Antonio Spreading Grounds Project, which is already underway in reality. The Temperature Increase Consumer suite uses consumer-based water resource management strategies on top of the San Antonio Spreading Grounds Project to offset the effects of temperature change. These consumer strategies are the ocean friendly gardens, greywater, and CMWD rate increase water management strategies discussed above. In the Temperature Increase Infrastructure suite, infrastructure-based water resource management strategies are implemented on top of the San Antonio Spreading Grounds. The infrastructure strategies include the scalping plant, and infiltration strategies.

3. RESULTS

3.1 Water Budget

Model results show that the Ventura River Watershed receives roughly 346,000 AF of precipitation each year. Of this, 212,000 AF (61%) is lost from the system to evapotranspiration, 112,000 AF (32%) flows into the stream network, and 22,000 AF (7%) infiltrates to the groundwater system (Figure 3. 1).

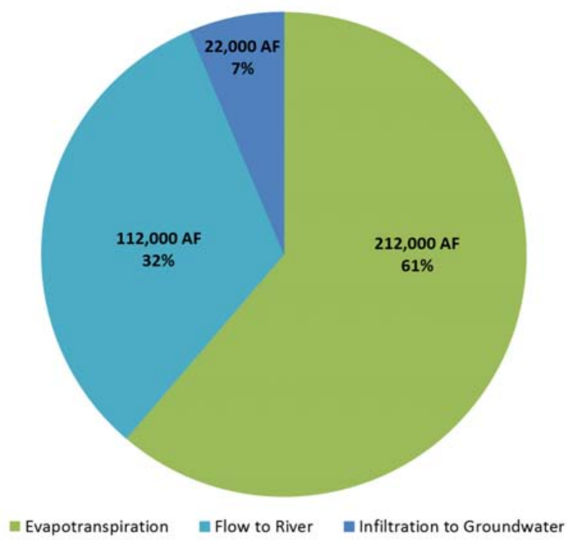

Figure 3. 1: Average annual water budget for the Ventura River Watershed.

Of the annual input from precipitation, only the water that flows to the river or that infiltrates into the groundwater system is available for human and environmental uses, around 134,000 AF annually. Of this, 35,000 AF (26%) is extracted for human uses, leaving 99,000 AF (74%) available for environmental uses (Figure 3. 2).

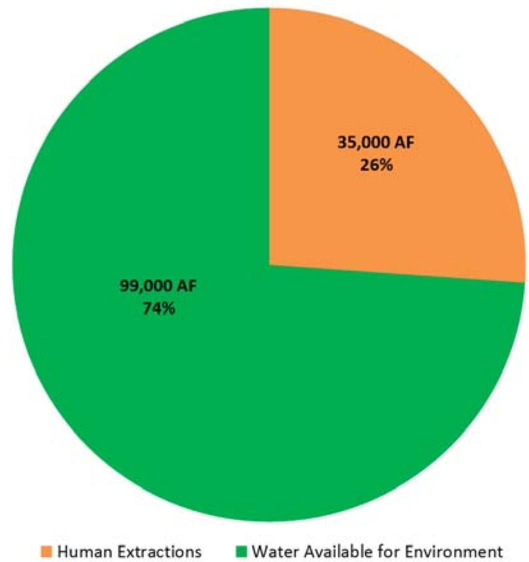

Figure 3. 2: Average annual available water.

Figure 3. 3 shows the sector-by-sector breakdown of human water uses. Agricultural uses account for 45% of demand, residential uses account for 37% of demand, and commercial uses account for 10% of demand (Figure 3. 3).

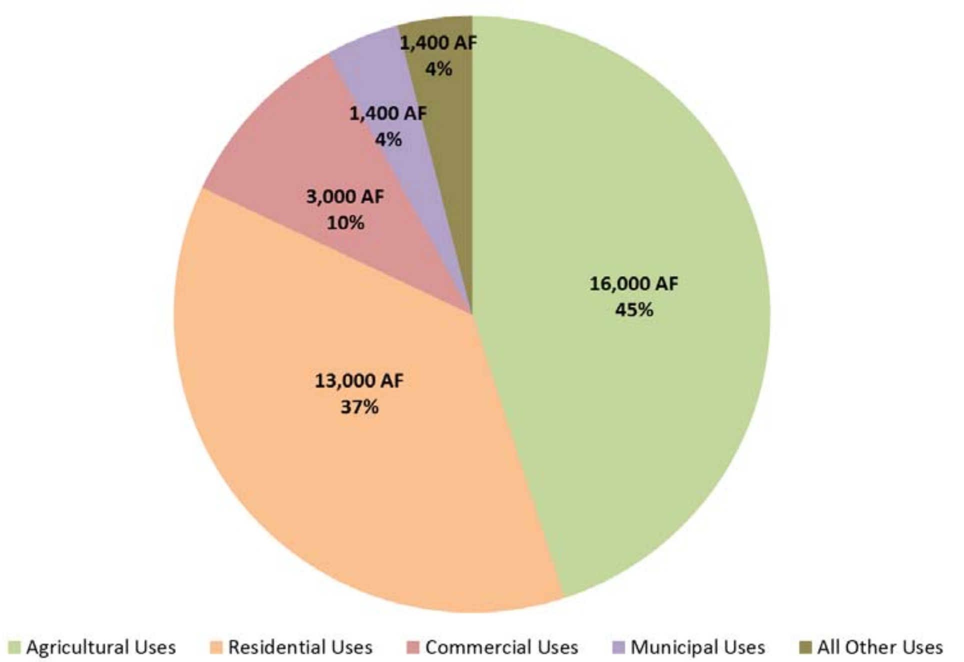

Figure 3. 3: Breakdown of human water uses in the Ventura River Watershed by sector.

3.2 Water Management Strategies

3.2.1 Ocean Friendly Gardens

Decreased Water Demand

Converting 25%, 50%, 75%, and 100% of lawns for 25%, 50%, 75%, and 100% of the single-family gardens in the watershed to ocean friendly gardens produced the estimated water reductions shown in Table 3. 1. Converting 50% of the lawn area for 50% of the single-family homes in the watershed, for example, reduced this sector's total water use by 10% or about 870 AF/yr. For a detailed breakdown of decreases in water demand throughout the watershed, see Appendix 2.

Conversion Factor	25%	50%	75%	100%
% water reduction for single-family accounts	2%	10%	21%	38%
Decreased Demand (AF/yr)	220	870	2000	3500

Table 3. 1: Single-family household water use reductions for the four ocean friendly garden scenarios. Each conversion factor represents both the percentage of lawn converted and the percentage of total gardens converted.

Increased Water Supply

Installing rain gardens in single-family homes in the watershed increased infiltration into the three groundwater basins as shown in Table 3. 2. Installing rain gardens to capture the roof runoff from 50% of the single-family homes in the watershed increased groundwater supply by an estimated 270 AF/yr. For a detailed breakdown of the increase in groundwater infiltration from installing rain gardens, see Appendix 2.

Increased Infiltration to Groundwater Basins (AF/yr)				
Conversion Factor	**25%**	**50%**	**75%**	**100%**
Ojai Valley Groundwater Basin	26	53	79	106
Upper Ventura Groundwater Basin	26	53	79	106
Lower Ventura Groundwater Basin	80	160	241	321
Watershed Groundwater Basin	130	270	400	530

Table 3. 2: Increased infiltration to groundwater basins in AF/yr due to conversion to ocean friendly gardens.

Cost-Effectiveness

Table 3. 3 shows the average cost-effectiveness estimates when the owner installs the garden and when a professional gardener installs it. Benefits are discounted over a 20-year period. Application of a $500 rebate is shown for comparison. Converting 50% of the lawn area of single-family homes for 50% of the watershed costs an average of $41 per AF of water saved over a 20 year time period if self-installed. For a detailed breakdown of the cost-effectiveness of ocean friendly gardens, see Appendix 2.

Scenario	$/AF saved with self-installation	$/AF saved with gardener-installation	$/AF saved with self-installation (with $500 rebate)	$/AF saved with gardener-installation (with $500 rebate)
25%	$(240)	$(1,170)	$120	$(810)
50%	$(41)	$(630)	$180	$(400)
75%	$53	$(370)	$220	$(210)
100%	$110	$(230)	$240	$(100)

Table 3. 3: Cost-effectiveness of conversion to ocean friendly gardens when installed and maintained by the owner or by a gardener. Cost-effectiveness is also shown when a $500 installation rebate is applied. Values in parentheses have a net cost over 20 years, while those without save the homeowners money.

Improved Ecosystem Health

Ocean friendly gardens improved stream flows in the Live Reach through a reduction in water demand in the City of Ventura. Table 3. 4 shows the number of positive events (see Section 2.4.1 for definition) for each ocean friendly garden scenario for the years 1992-2009. As more ocean friendly gardens are installed in the watershed the number of positive events increases. The reduced demand in the City of Ventura offsets pumping at the Foster Park Well Field, increasing stream flow in the Live Reach.

Scenario	Number of Additional Positive Events	Percentage of Possible Positive Events by Stopping Foster Park Pumping During Summer
25%	1	4%
50%	6	21%
75%	21	75%
100%	28	100%

Table 3. 4: Amount of positive events at the Live Reach caused by ocean friendly garden conversion scenarios.

Improved Water Quality

Installing rain gardens at 25%, 50%, 75%, and 100% of the single-family homes in the watershed can reduce total nitrogen and total phosphorous as shown in Table 3. 5.

Scenario	N Reduction (lb/yr)	P Reduction (lb/yr)
25%	140	1
50%	540	5
75%	1200	11
100%	2200	20

Table 3. 5: Total nutrient runoff pollution reduction for TN and TP in lbs/yr when installing rain gardens for the four ocean friendly garden scenarios.

Suitability for Proposition 84 Funding

Ocean friendly gardens met 4 of the 12 criteria for projects that are suitable for Proposition 84 funding. These gardens increase water use efficiency, capture and treat stormwater, reduce nonpoint source pollution, and increase groundwater recharge through infiltration.

Summary

The overall results for converting 50% of the lawn area for 50% of the single-family homes in the watershed to ocean friendly gardens are shown in Table 3. 6.

Criteria	Value
Decreased Demand	870 AF
Increased Supply	270 AF to Groundwater
Cost-Effectiveness ($/AF)	Cost of $41/AF to Consumers; Benefit of $180/AF to Consumers (no rebate; $500 rebate)
Improved Water Quality	1300 lbs/yr N; 140 lbs/yr P
Improved Ecosystem Health	14% of Dry Months
Suitability for Proposition 84 Funding	4

Table 3. 6: Summary of results for the six evaluation criteria for converting 50% of the lawn area of 50% of the single-family homes in the watershed to ocean friendly gardens.

3.2.2 Greywater

Decreased Water Demand

This water management strategy investigated the effect of 25%, 50% and 75% of customers in the watershed installing a greywater system. This strategy resulted in water savings of 180 AF/yr, 350 AF/yr and 520 AF/yr respectively (see Appendix 3).

Increased Water Supply

This water management strategy did not significantly increase supply.

Cost-Effectiveness

This water management strategy uses a greywater system cost of $200, representing a basic self-installed system. With a water rate of $2.5 per HCF the yearly benefit is $37 dollars per person per year. Assuming a 3% discount rate there is a 7-year return on investment. The NPV of a greywater system is $35. The average cost per AF of savings for the municipality can be considered to be 0. However, the individual households who utilized the systems will see an average benefit of $50/AF. If the household is located in an area which pays for sewer services based on water use the benefits can be significantly increased. For instance the NPV of a greywater system in the City of Ventura is $270 over 20 years. The summary of cost-effectiveness results can be found in Appendix 3.

Improved Ecosystem Health

Greywater improved stream flows in the Live Reach through a reduction in water demand in the City of Ventura. The 25% scenario saved 24 AF over the four dry months, the 50% scenario saved 48 AF, and the 75% scenario saves 72 AF. This equates to 1, 3, and 5 positive events, respectively, where flow with normal pumping would have been below 12 cfs but flow with reduced pumping would be above 12 cfs.

Improved Water Quality

This water management strategy does not directly impact water quality.

Suitability for Proposition 84 Funding

The establishment of a fund which could subsidize greywater projects within the watershed could be funded by Proposition 84 grants. Greywater would be a good candidate for 2 of the Proposition 84 criteria: Water supply reliability, water conservation and use efficiency, and Conveyance of reclaimed water for distribution to users.

Summary

The results for this water management strategy are summarized below in Table 3. 7.

Criteria	**Value**
Decreased Demand	350 AF/yr
Increased Supply	0
Cost-Effectiveness ($/AF)	Benefit of $51/AF to Consumers
Improved Ecosystem Health	3 Positive Events
Improved Water Quality	0
Suitability for Proposition 84 Funding	2

Table 3. 7: Summary of results for the six evaluation criteria for 50% of watershed customers installing a greywater system.

3.2.3 Scalping Plant in Ojai

Decreased Water Demand

The reclaimed water from scalping plant will reduce the demand for groundwater by 220 AF/yr.

Increased Water Supply

The model results do not show any change in groundwater recharge for this water management strategy. This is because it is assumed that the golf courses have turf grass and irrigation efficiency is 100%. Therefore all the water used for golf course irrigation is lost from the system.

Cost-Effectiveness

The cost-effectiveness value for scalping plants was calculated to be an average cost of $330/AF of water saved to municipalities.

Improved Ecosystem Health

The water management strategy has no significant impact on ecosystem health as defined in our criteria as it does not affect the water demand in City of Ventura. Consequently, the ecosystem health metric (flows in the Live Reach) will remain unchanged by this strategy.

Improved Water Quality

Design considerations for scalping plant require that the plant be located at a suitable site to minimize the risk of surface water and groundwater contamination. Since the scalping plant is a closed loop process there will be no discharge of treated water from this plant (AECOM, 2012). Although the scalping plant will reduce flow to the central WWTP by 200,000 gpd as well as decrease nutrient loading to the WWTP, it will also increase the concentration of the wastewater.

It is expected that the reduction in nutrient load to OVSD WWTP may result in the improved performance of the facility and a small decrease in nutrient discharge to Ventura River via treated effluent. However, since estimates of influent nutrient concentrations to OVSD WWTP could not be obtained it is difficult to quantify the reduction in nutrient load to WWTP.

Overall, there should be little to no effect on water quality as the OVSD treatment plant will be able to continue to provide the same level of water treatment.

Suitability for Proposition 84 Funding

To assess suitability for Proposition 84 funding, the water management strategy was evaluated using the checklist for Proposition 84 and was given 3 points as it satisfies three criteria for Prop 84 grants. These criteria are 'water supply reliability, water conservation and use efficiency', 'Contaminant removal through reclamation, desalting, or other treatment technologies', and 'Conveyance of reclaimed water for distribution to users.'

Summary

The results for this water management strategy are summarized below in Table 3. 8.

Criteria	Value
Decreased Demand	220 AF/ year
Increased Supply	0
Cost-Effectiveness ($/AF)	Cost of $330/AF to Municipalities
Improved Ecosystem Health	0
Improved Water Quality	0
Suitability for Proposition 84 Funding	3

Table 3. 8: Summary of results for the six evaluation criteria for constructing a scalping plant in Ojai.

3.2.4 Infiltration Basins

Decreased Water Demand

This water management strategy will have no impact on the behavioral practices of end consumers or influence the water conservation practices in the watershed. The model results showed no change in demand for this strategy.

Increased Water Supply

The model results for the 10% impervious area conversion scenario show increased groundwater recharge to the Ojai Groundwater Basin by 280 AF/yr on average.

Cost-Effectiveness

The cost-effectiveness value for the 10% impervious area conversion scenario was calculated to be an average cost of $85/AF of water saved to municipalities. (It is worth reiterating that the cost analysis did not include the land costs).

Improved Ecosystem Health

The water management strategy has no significant impact on ecosystem health as defined in our criteria as it does not affect the water demand in City of Ventura. Consequently, the ecosystem health metric (flows in the Live Reach) will remain unchanged as a result of this water management strategy.

Improved Water Quality

Calculations show that the 10% impervious area conversion scenario will result in 9 lbs/yr reduction for Total Phosphorus (TP) and 65 lbs/yr reduction for Total Nitrogen (TN).

Suitability for Proposition 84 Funding

To assess suitability for Proposition 84 funding, the water management strategy was evaluated using the checklist for Proposition 84 and was given 4 points as it satisfies four criteria for Proposition 84 grants. These criteria are 'Water supply reliability, water conservation and use efficiency', 'Stormwater capture, storage, treatment, and management', 'Non-point sources pollution reduction, management and monitoring', and 'Groundwater recharge and management projects.'

Summary

The results for this water management strategy are summarized below in Table 3. 9.

Criteria	**Value**
Decreased Demand	0
Increased Supply	280 AF/ yr to Groundwater
Cost-Effectiveness ($/AF)	Cost of $85/AF to Municipalities
Improved Ecosystem Health	0
Improved Water Quality	70 lbs/yr N; 10 lbs/yr P
Suitability for Proposition 84 Funding	4

Table 3. 9: Summary of results for the six evaluation criteria for constructing infiltration basins in the Ventura River Watershed.

3.2.5 Water Rate Increase to State Average

Decreased Water Demand

This water management strategy will save 1100 AF, 1500 AF, or 1800 AF depending on the price elasticity of demand.

Increased Water Supply

This water management strategy will not increase supply.

Cost-Effectiveness

As shown in Table 3. 10 the price elasticity of demand (PED) determines whether increasing the cost of water will result in a loss to consumers or to producers. For the first two scenarios, -0.15 and -0.2 price elasticity of demand, the cost falls on the consumers. However, if the PED is -0.25 then the cost will fall on the water purveyors. This is because under this assumed price elasticity, consumers will lower their water demand so far that they will spend less per year on water even with an increase in price. For example, under the -0.2 PED scenario, the cost of saving 1500 AF of water per year will cost about $296,000 or an average cost of $160/AF over 20 years. Changes in the price elasticity of demand will change which group bears the cost of the rate changes as well as the magnitude of the costs (see Appendix 6).

Price Elasticity	Average Reduction in Water Use	Average Cost-Effectiveness for Consumers
-0.15	35%	$520/AF
-0.2	46%	$160/AF
-0.25	58%	($63/AF)

Table 3. 10: Average cost to Casitas and Meiners Oaks customers incurred by raising water rates to $2.5 per HCF at the 15 HCF tier. For this analysis a linear price scheme was assumed. Costs vary depending on the price elasticity of demand. For the 0.25 price elasticity of demand the cost to consumers is negative. This will become a benefit for consumers and a cost to producers.

Improved Ecosystem Health

This water management strategy does not directly impact ecosystem health.

Improved Water Quality

This water management strategy does not directly impact water quality.

Suitability for Proposition 84 Funding

This project is not suitable for Proposition 84 funding.

Summary

The results for this water management strategy are summarized below in Table 3. 11.

Criteria	Value
Decreased Demand	1500 AF/yr
Increased Supply	0
Cost-Effectiveness ($/AF)	Cost of $160/AF to Consumers
Improved Ecosystem Health	0
Improved Water Quality	0
Suitability for Proposition 84 Funding	0

Table 3. 11: Summary of results for the six evaluation criteria for increasing water rates (using PED of -0.2) in the Ventura River Watershed to the State average.

3.2.6 Water Rate Increase to Full Cost Pricing

Decreased Water Demand

Increasing Casitas revenues by 20% required a 33% increase in the water rate. This resulted in a 10% decrease in water demand. Using a price elasticity of demand of -0.03 this increase in water rates will result in an average water savings of about 200 AF/yr. This increase will both decrease demand as well as increase revenue for CMWD which currently implements a land tax to subsidize low water prices. In order to make this strategy more cost-effective for consumers, the land tax could be removed, effectively lowering the cost of water without undervaluing the resource. Casitas also depends on other sources of income including the Clean Water Act surcharge, Mira Monte assessment, and Oak View availability charge. All of these non-operation based revenue streams effectively subsidize the cost of water. This rate increase will allow CMWD to move away from these non-operating revenues and toward a more sustainable pricing structure.

Increased Water Supply

This project will not increase the water supply.

Cost-Effectiveness

The average cost increase per household per year for a 33% increase in water rates is $58.56. The total cost of this project will be $159,200 per year and will save about 200 AF. The cost per AF for this project is an average of $280/AF over 20 years. This number could be lower because land taxes that currently subsidize cheap water could be lowered or removed due to the increased revenue from water sales. Currently Casitas charges $1,959,800 in property taxes. However, it is unclear how much of this tax is charged to single family homes. It is possible that all of the cost associated with increasing rates could be negated by eliminating the land tax for single-family users. This will also result in a more equitable and economically efficient scenario where low water users are not subsidizing high water users.

Improved Ecosystem Health

This project has no direct effects on ecosystem health.

Improved Water Quality

This project will not significantly affect water quality. There may be some benefits to water quality due to the addition of 200 AF/yr to the natural system, but these benefits cannot be adequately quantified.

Suitability for Proposition 84 Funding

This project will not qualify for Proposition 84 funding.

Summary

The results for this water management strategy are summarized below in Table 3. 12.

Criteria	Value
Decreased Demand	200 AF/yr
Increased Supply	0
Cost-Effectiveness ($/AF)	Cost of $280/AF to Consumers
Improved Ecosystem Health	0
Improved Water Quality	0
Suitability for Proposition 84 Funding	0

Table 3. 12: Summary of results for the six evaluation criteria for increasing Casitas water rates to full cost pricing.

3.2.7 Conversion to Pervious Streets

Decreased Water Demand

Conversion of residential streets to pervious asphalt will not decrease water demand within the watershed.

Increased Water Supply

This water management strategy will increase recharge to groundwater by 58 AF/yr within the Ventura River Watershed.

Cost-Effectiveness

Given that we expect 58 AF per year of recharge to groundwater resulting from the installation of pervious streets, summing the total recharge over the expected lifetime of a street (20 years) yields an average cost-effectiveness of $10,900/AF of recharge for this water management strategy.

Improved Ecosystem Health

This water management strategy will have no effect on stream flow levels within the Live Reach of the Ventura River during the summer months.

Improved Water Quality

Using average nitrogen and phosphorus concentrations for residential runoff of 4.57 mg/L and 0.54 mg/L, respectively, from the Algae TMDL, a reduction of 58 AF per year in runoff amounts to a reduction of 720 lbs/yr of nitrogen and 85 lbs/yr of phosphorus.

Suitability for Proposition 84 Funding

This water management strategy was found to meet 3 of the 12 criteria for projects that are suitable for Proposition 84 funding: stormwater capture, storage, treatment, and management; non-point sources pollution reduction, management and monitoring; and groundwater recharge and management projects.

Summary

The results for this water management strategy are summarized below in Table 3. 13.

Criteria	Value
Decreased Demand	0
Increased Supply	58 AF/yr
Cost-Effectiveness	Cost of $10,900/AF to Municipalities
Improved Ecosystem Health	0
Improved Water Quality	720 lbs/yr N ; 90 lbs/yr P
Suitability for Proposition 84 Funding	3

Table 3. 13: Summary of results for the six evaluation criteria for converting to pervious streets in the Ventura River Watershed.

3.2.8 San Antonio Spreading Grounds

Decreased Water Demand

The San Antonio Spreading Grounds Rehabilitation Project will not decrease water demand within the Ventura River Watershed.

Increased Water Supply

The San Antonio Spreading Grounds Rehabilitation Project is expected to increase groundwater recharge in the Ojai Valley Groundwater Basin by an average of 225 AF/yr, 80% of which would be available for local extraction (Padre Associates, Inc, 2011). WEAP model results support this estimation, indicating that an average increase in recharge to the Ojai Valley Groundwater Basin of 380 AF/yr would occur following construction of the San Antonio Spreading Grounds, assuming no change in precipitation in the coming decades. Assuming a 10% and 20% increase in precipitation by 2099, the WEAP model predicts increased recharge rates and assuming a 10% and 20% decrease in precipitation by 2099, the WEAP model predicts decreased recharge rates. These changes in recharge rates are summarized in Table 3. 14.

Climate Scenario	Recharge Rates (AF/yr)
Baseline Climate Conditions	380
10% Increased Precipitation	400
20% Increased Precipitation	410
10% Decreased Precipitation	360
20% Decreased Precipitation	340

Table 3. 14: Increases in water supply due to the San Antonio Spreading Grounds under different climate scenarios.

Cost-Effectiveness

The San Antonio Spreading Grounds Rehabilitation Project is expected to cost $1,315,000 (Padre Associates, Inc, 2011). Given our calculated increases in water supply of 380, 400, 410, 360, and 340 AF/year with no precipitation change, a 10% increase in precipitation, a 20% increase in precipitation, and 10% decrease in precipitation, and a 20% decrease in precipitation, respectively, the average cost-effectiveness of the San Antonio Spreading Grounds Rehabilitation Project is $170/AF, $170/AF, $160/AF, $180/AF, and $190/AF (Table 3. 15).

Climate Scenario	Cost-Effectiveness ($/AF)
Baseline Climate Conditions	Cost of $170/AF to Municipalities
10% Increased Precipitation	Cost of $170/AF to Municipalities
20% Increased Precipitation	Cost of $160/AF to Municipalities
10% Decreased Precipitation	Cost of $180/AF to Municipalities
20% Decreased Precipitation	Cost of $190/AF to Municipalities

Table 3. 15: Cost-effectiveness of the San Antonio Spreading Grounds under different climate scenarios.

Improved Ecosystem Health

The San Antonio Spreading Grounds Rehabilitation Project will not result in increased flow levels within the Live Reach under any future precipitation scenario.

Improved Water Quality

The San Antonio Spreading Grounds Rehabilitation Project is expected to have 'less than significant' impacts on surface water quality (Padre Associates, Inc, 2011).

Suitability for Proposition 84 Funding

The San Antonio Spreading Grounds Rehabilitation Project has already received funding under Proposition 50. While the project is no longer eligible for funding under Proposition 84 given that it has already been funded, we ranked it to provide a basis for comparison with our other water management strategies. This strategy was found to meet 2 of the 12 criteria for projects that are suitable for Proposition 84 funding: water supply reliability, water conservation and use efficiency; and groundwater recharge and management projects.

Summary

The results for this water management strategy are summarized below in Table 3. 16.

Criteria	Value
Decreased Demand	0
Increased Supply	380 AF/yr
Cost-Effectiveness	Cost of $170/AF to Municipalities
Improved Ecosystem Health	0
Improved Water Quality	0
Suitability for Proposition 84 Funding	2

Table 3. 16: Summary of results for the six evaluation criteria for the San Antonio Spreading Grounds Rehabilitation Project in the Ventura River Watershed.

3.3 Land Use Change (Crop Conversions)

The WEAP model was used to simulate the effects of converting 25%, 50%, and 75% of orange cropland to raspberries. The model was run for a 100-year period under baseline climate conditions.

Evapotranspiration

Converting oranges to raspberries leads to a decrease in potential evapotranspiration in all months Figure 3. 4, and a decrease in actual evapotranspiration in all months except September and October in which there is an increase Figure 3. 5. This increase results from the fact that K_c values for raspberries are highest in September and October. Combined with irrigation rates that are higher than baseline, actual evapotranspiration increases even though potential evapotranspiration decreases.

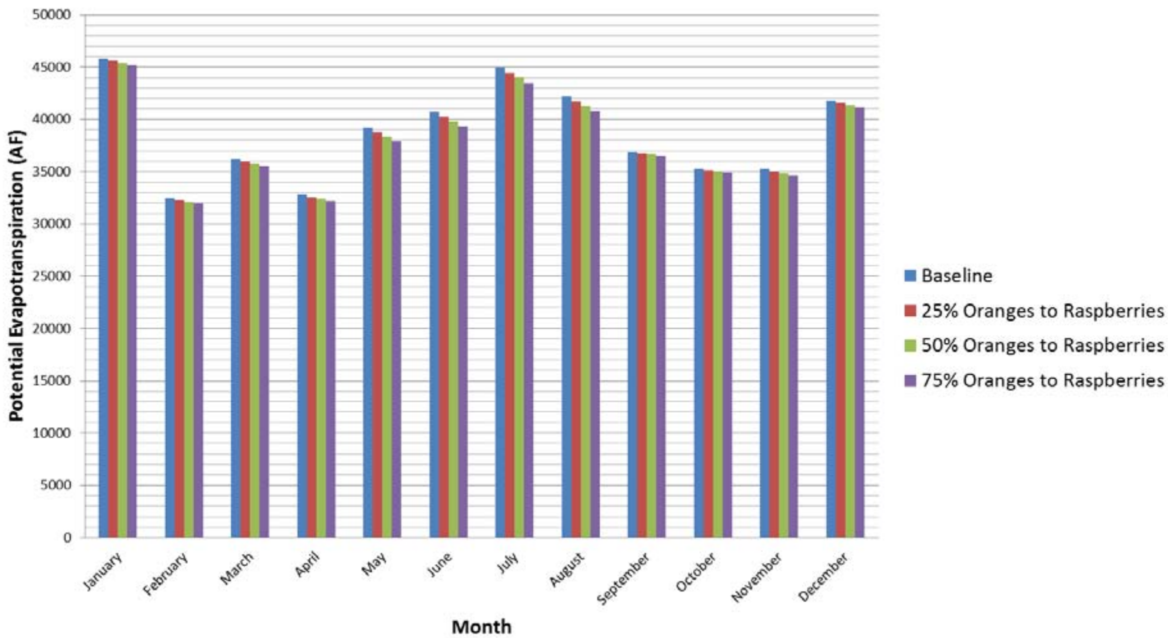

Figure 3. 4: Potential Evapotranspiration, 100-year monthly averages (see Appendix 10 for values).

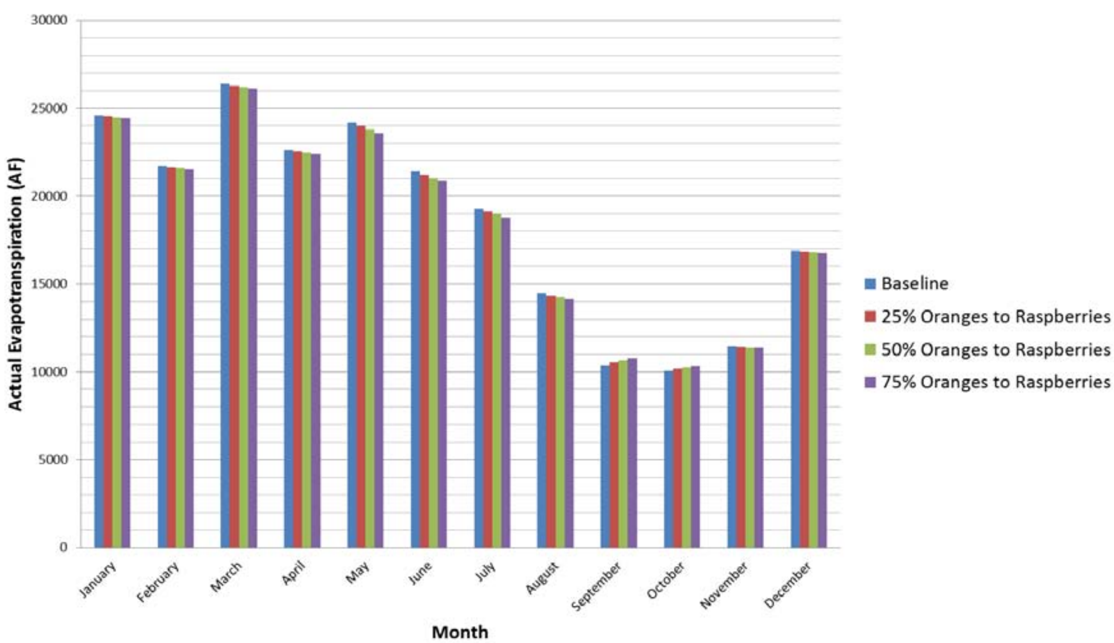

Figure 3. 5: Actual evapotranspiration, 100-year monthly averages (see Appendix 10 for values).

Streamflow

Converting oranges to raspberries leads to increased streamflow in the Live Reach of the Ventura River in all low flow months (Figure 3. 6). These increases are the result of increased runoff to the river due to the increased irrigation and decreased evapotranspiration associated with raspberries relative to oranges. Because all increases in streamflow are minimal (<1.5 cfs), they are insignificant.

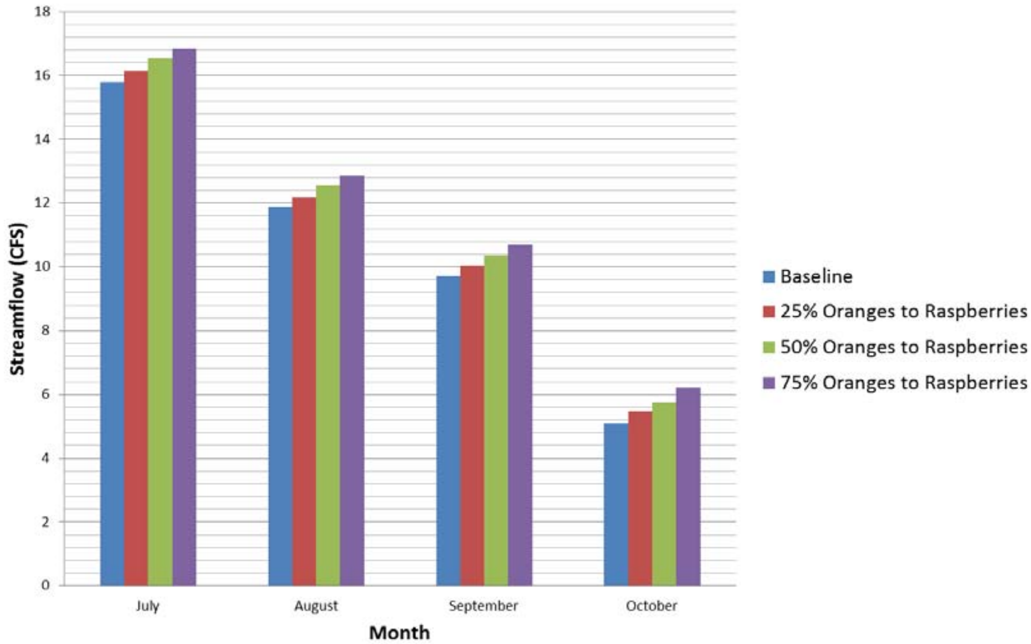

Figure 3. 6: Ventura River Live Reach streamflow, 100-year monthly averages (see Appendix 10 for values).

Lake Casitas Storage

Converting oranges to raspberries leads to decreases in the volume of water stored in Lake Casitas in all months Figure 3. 7. This is a result of increased water demand on CMWD to meet the irrigation needs of raspberries which require more water than oranges.

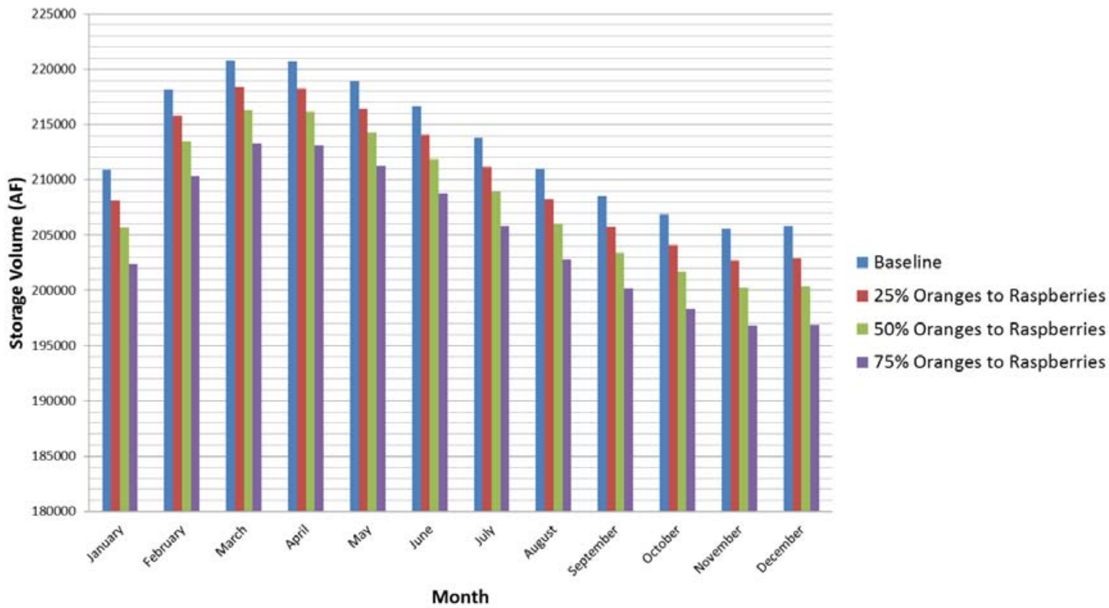

Figure 3. 7: Lake Casitas storage volume, 100-year monthly averages (see Appendix 10 for values).

Groundwater Storage

Converting oranges to raspberries leads to a decrease in the volume of water stored within the Ojai Groundwater Basin Figure 3. 8 and the Upper Ventura River Groundwater Basin in all months Figure 3. 9. This is a result of increased water demand on the groundwater basins to meet the irrigation needs of raspberries which require more water than oranges.

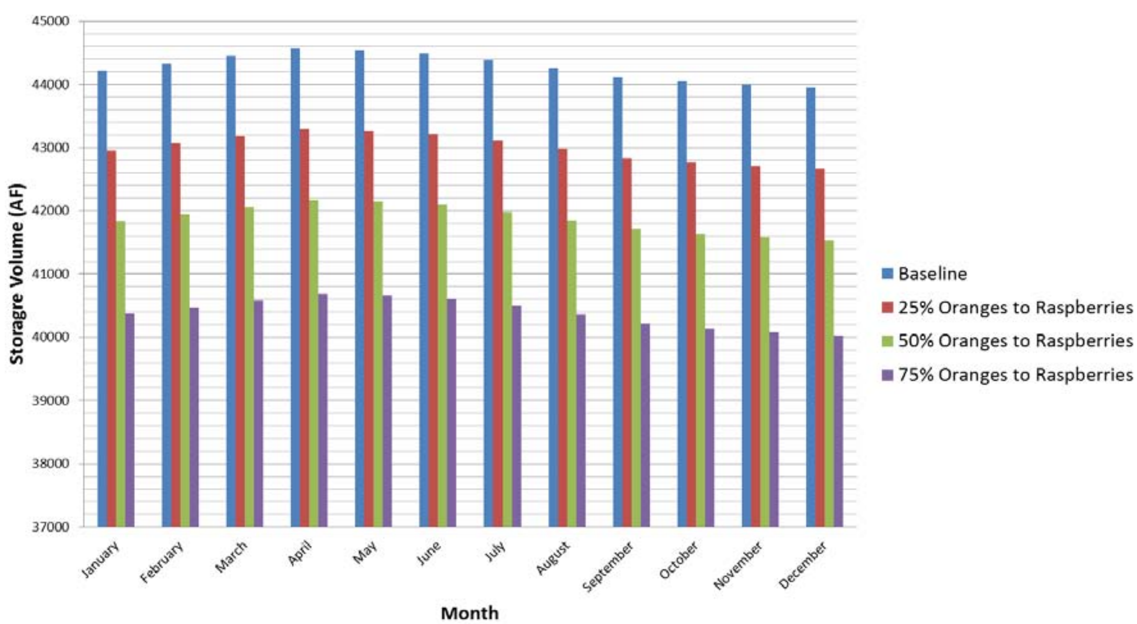

Figure 3. 8: Ojai Groundwater Basin storage volume, 100-year monthly averages (see Appendix 10 for values).

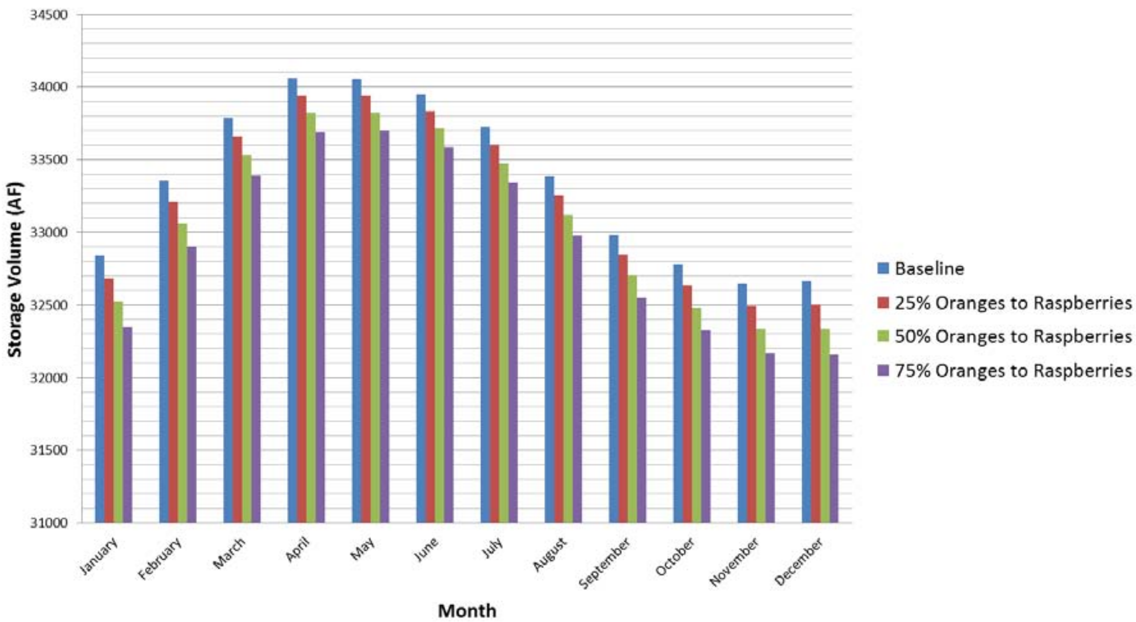

Figure 3. 9: Upper Ventura River Groundwater Basin storage, 100-year monthly averages (see Appendix 10 for values).

3.4 Climate Change

Water Demand

Human water demand in the Ventura River Watershed grew from 36,000 AF in 2010 to 40,000 AF in 2099 (Figure 3. 10). Demand during these years grew due to the projected increase of population in the watershed. Annual population growth in the watershed is projected to be 0.7% out to the year 2035 and we extrapolated this growth rate out to the year 2099 (Wickstrum & Merckling, 2011).

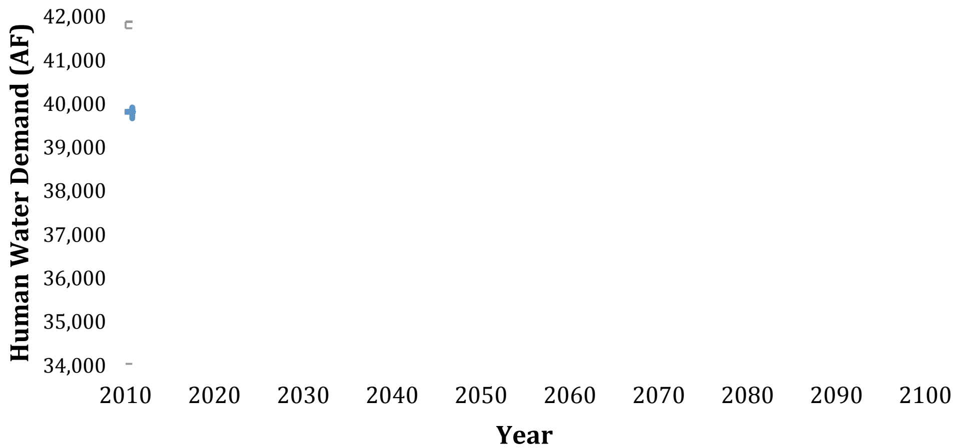

Figure 3. 10: Modeled human demand in the Ventura River Watershed for the years 2010-2099 (note: y-axis does not begin at zero).

Potential Evapotranspiration

In all five of the T4 climate change scenarios, excluding the baseline scenario, the annual potential ET increases in magnitude out to the year 2099 compared to the baseline scenario as shown in Figure 3. 11. The increase in potential ET was the same for all five scenarios: T4-20, T4-10, T4, T4+10, T4+20. This rise in potential ET is caused by the uniform increase in mean annual temperature, 4 °C by 2099, as modeled in our study.

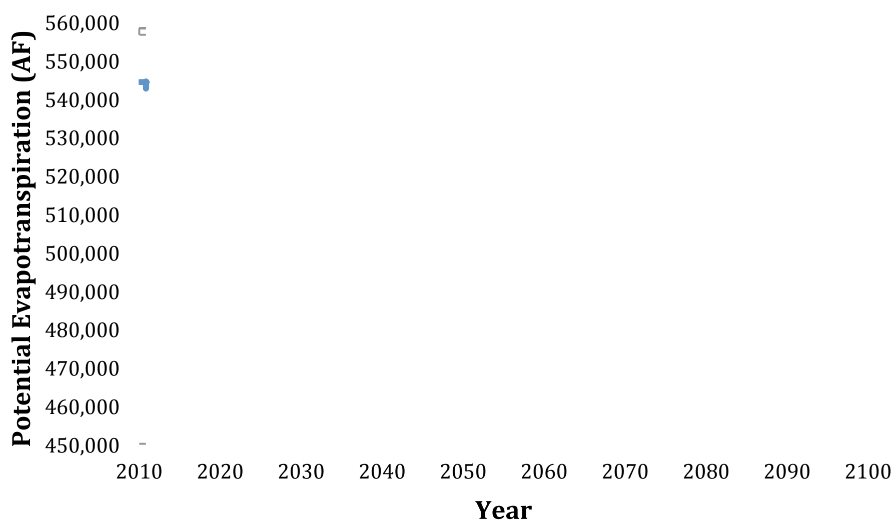

Figure 3. 11: Modeled potential evapotranspiration in the Ventura River Watershed under five climate change scenarios: T4-20, T4-10, T4, T4+10, and T4+20 (note: y-axis doesn't begin at zero).

Actual Evapotranspiration

Actual ET during the modeled years of 2010-2099 varied for each of the six climate scenarios and these differences tended to increase in magnitude in the later years of the model run. Mean annual actual ET (MAAET) of the T4, T4+10, T4+20, and T4-10 scenarios was higher than the baseline scenario while the MAAET of the T4-20 was less than baseline (Figure 3. 12). MAAET was higher in the T4+10 and T4+20 scenarios due to the combination of increased potential ET and increased precipitation (compared to baseline) in both of these scenarios. While there was less precipitation in the T4-10 scenario, there was still a higher potential ET and enough precipitation available to be evapotranspired so that MAAET in this case was higher than baseline. For the T4-20 scenario there was so much less precipitation available for evapotranspiration that despite increased potential ET the MAAET was lower than the baseline MAAET.

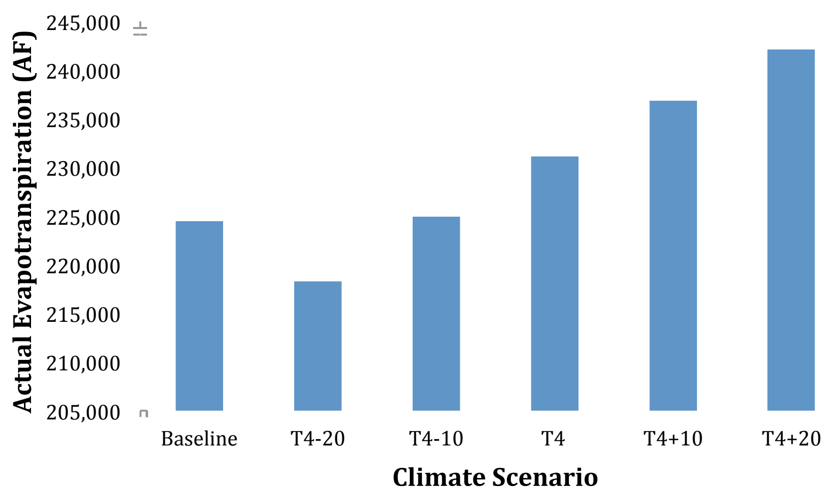

Figure 3. 12: Modeled mean annual actual evapotranspiration in the Ventura River Watershed under six climate scenarios averaged over the 2010-2099 time period (note: y-axis doesn't begin at zero).

Changes in actual evapotranspiration can have varying influences on watershed processes. When actual ET increases without a change in precipitation than there would be less water available in the system for groundwater recharge or surface flow. When actual ET increases and precipitation decreases there would be less water available in the system for two reasons, the increased ET and the decreased precipitation. When actual ET increases and precipitation increases, depending on the magnitude of both factors, there could be more or less water available in system. The interplay between precipitation and actual ET will directly impact the volume of water available for human and environmental uses but other factors such as human demand will also influence local water resources.

Mean Monthly Flow in the Live Reach

To analyze monthly flow in the Live Reach we looked at mean monthly flows from July-October, dry months that are critical for Steelhead Trout that are over-summering in the perennially flowing reaches and pools of the river. Specifically we summed the number of months with an average flow above 12 cfs, a threshold flow that has been identified as one that supports over-summering habitat in the Live Reach. In each of the climate change scenarios the number of months with an average flow above 12 cfs decreased compared to baseline (Figure 3. 13).

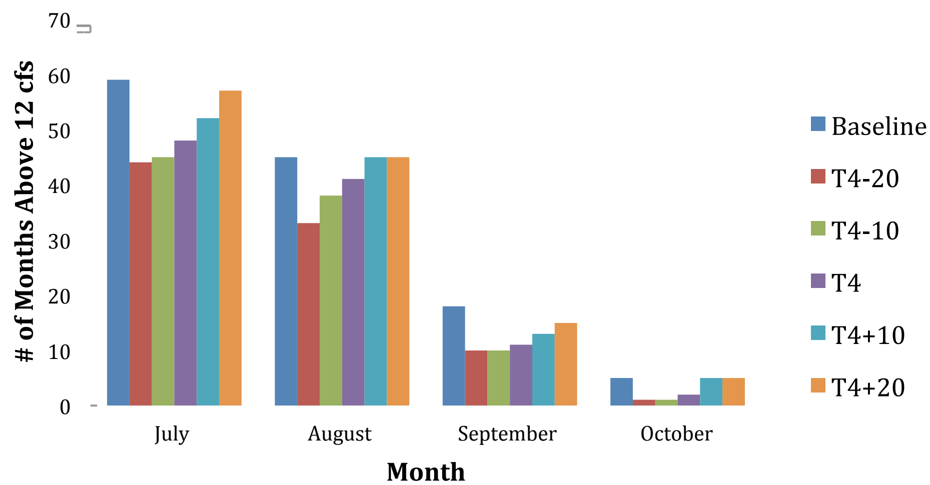

Figure 3. 13: The number of modeled months in which the mean monthly flow was above 12 cfs in the Ventura River Live Reach in July-October from 2010-2099.

Additionally, we examined how average monthly flow changed in each of the climate scenarios. The average flow fluctuated across the six scenarios. The stream flow at the Live Reach for each of these potential future climate scenarios is shown in Figure 3. 14 for the dry months, July through October. The modeled stream flows for all five of the climate change scenarios were lower compared to the baseline scenario. This was also true for the number of months in which stream flow was above 12 cfs (Figure 3. 13). In the T4-10, T4, T4+10, and the T4+20 scenarios this was primarily caused by higher rates of actual ET (see Figure 3. 12). In the T4-20 scenario, the lower flows during the dry months was primarily caused by the 20% decrease in annual precipitation.

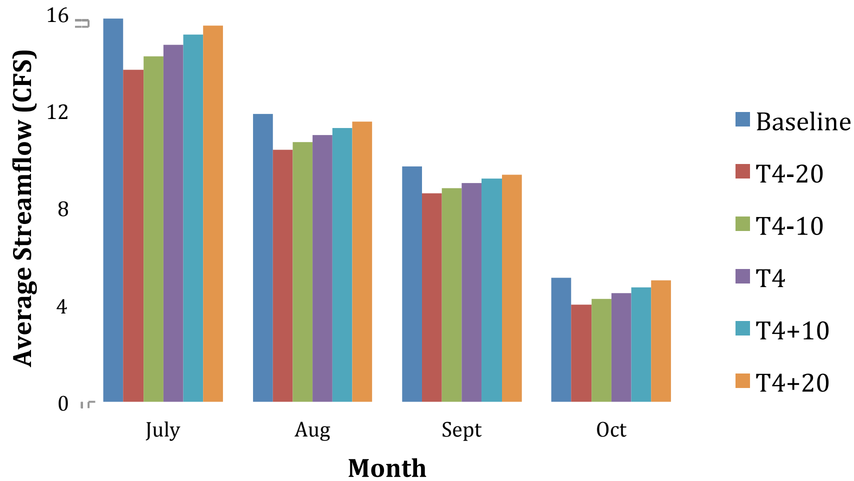

Figure 3. 14: Average monthly flow in the Live Reach during dry months modeled under six climate change scenarios from 2010-2099.

Groundwater Storage

In the Ojai Groundwater Basin, storage during the modeled years showed a general trend of decline in four of the five T4 scenarios (Figure 3. 15). The only scenario in which storage in this aquifer increased relative to baseline was the T4+20 scenario. Human water demand, changes in precipitation, and changes in actual ET all influenced the average groundwater storage in the Ojai GW Basin over this 90-year period.

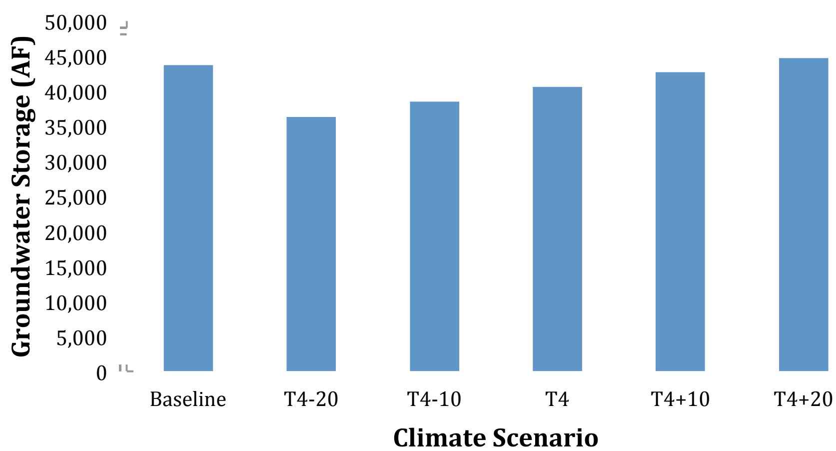

Figure 3. 15: Modeled Ojai Groundwater Basin mean storage under six climate scenarios averaged over the 2010-2099 time period.

In the Upper Ventura Groundwater Basin the T4, T4+10, T4-10, and T4-20 scenarios all predicted lower mean groundwater levels compared to the baseline scenario (Figure 3. 16). Only under T4+20 conditions were groundwater levels in this aquifer higher than the baseline conditions. As in the case of Ojai GW Basin, these changes in average groundwater storage in the Upper Ventura GW Basin were influenced by a combination of changes in actual ET and changes in precipitation. For instance in the T4-10 scenario actual ET increased and precipitation decreased. Those two trends both drove the annual groundwater storage down. Whereas for the T4+20 scenario actual ET increased and precipitation increased. The precipitation increase in this scenario was enough to overcome the increase in actual ET that alone would have decreased groundwater storage.

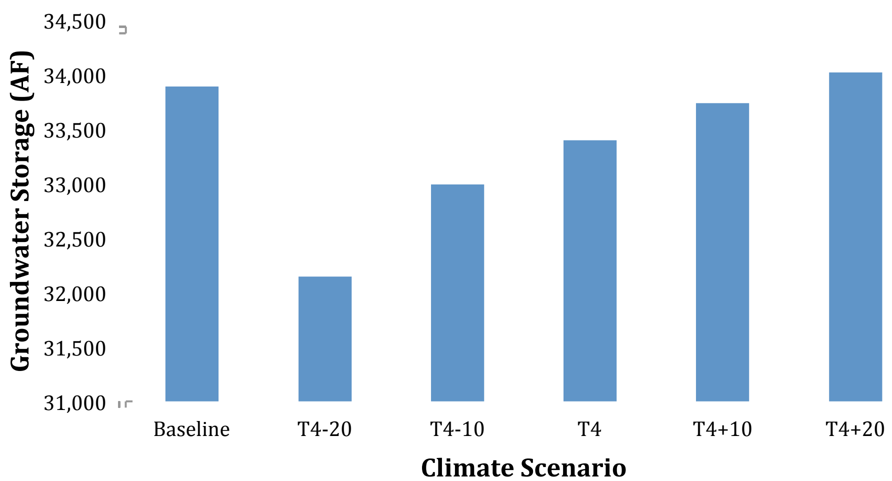

Figure 3. 16: Modeled Upper Ventura Groundwater Basin mean storage under six climate scenarios averaged over the 2010-2099 time period (note: y-axis doesn't begin at zero).

Lake Casitas Storage

In the T4, T4-10, and T4-20 scenarios mean storage in Lake Casitas decreased compared to the baseline scenario. The T4+10 and T4+20 scenarios both indicated that Lake Casitas storage would be slightly higher under these climatic conditions than under baseline conditions (Figure 3. 17). In the T4-20 scenario, decreased precipitation and increased pan evaporation drove lake levels down. In the T4-10 and the T4 scenarios increased actual ET, increased pan evaporation, and decreased precipitation (not in the T4 scenario) drove modeled lake volume down. In the T4+10 and T4+20 scenarios the increased precipitation was enough to overcome increase in actual ET and pan evaporation off the lake, therefore lake storage in these scenarios increased.

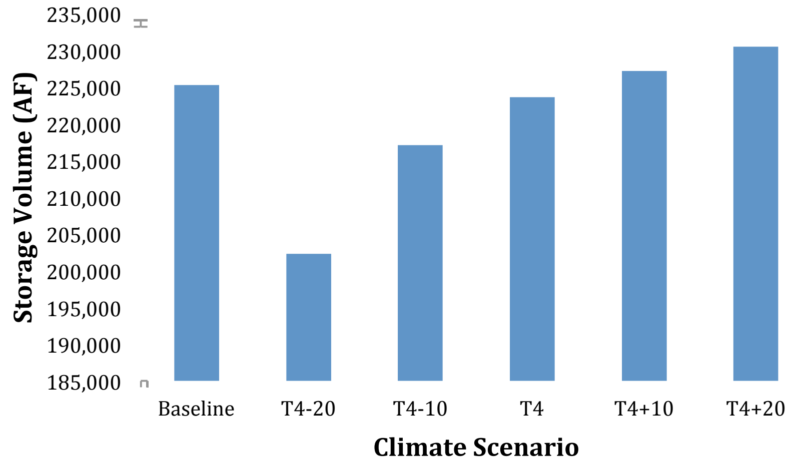

Figure 3. 17: Modeled Lake Casitas mean storage under six climate change scenarios averaged over the 2010-2099 time period (note: y-axis doesn't begin at zero).

3.5 Scenario Suites Results

3.5.1 Baseline and All Water Management Strategies Implemented

The Baseline suite models the effects of implementing only the San Antonio Spreading Grounds Project under projected baseline climate conditions out to 2099 with no land use change. The All Water Management Strategies Implemented suite models the potential for the water management strategies analyzed in this study to benefit the watershed under baseline climate conditions with no land use change out to 2099. The average monthly flow in the Live Reach during the dry months, June through December, under Baseline conditions and Baseline conditions with all strategies implemented is shown in Figure 3. 18. Average monthly storage volume in all groundwater basins for these two suites is shown in Figure 3. 19.

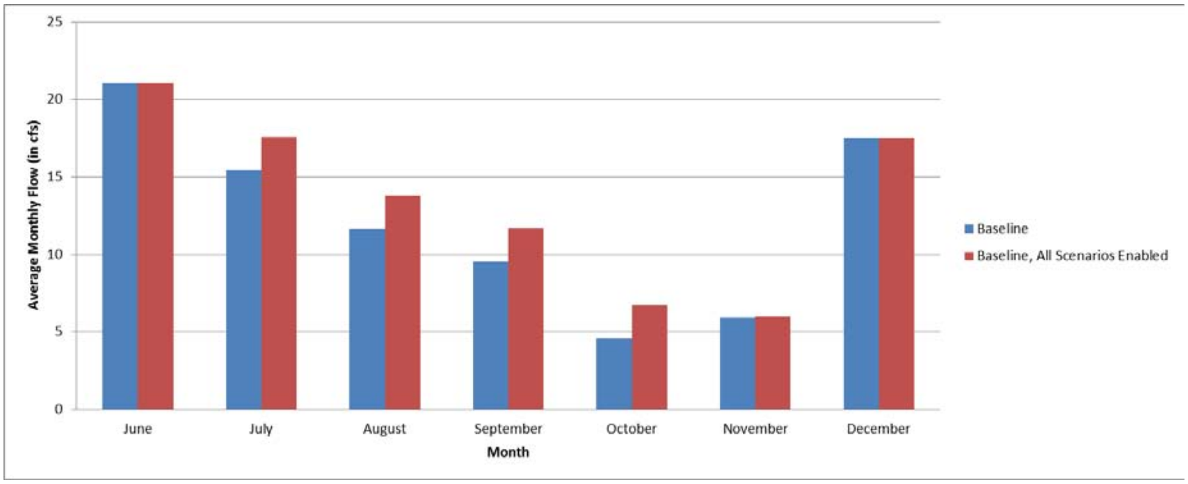

Figure 3. 18: Average monthly flow in the Live Reach during dry months for the Baseline and Baseline with All Water Management Strategies Implemented Suites.

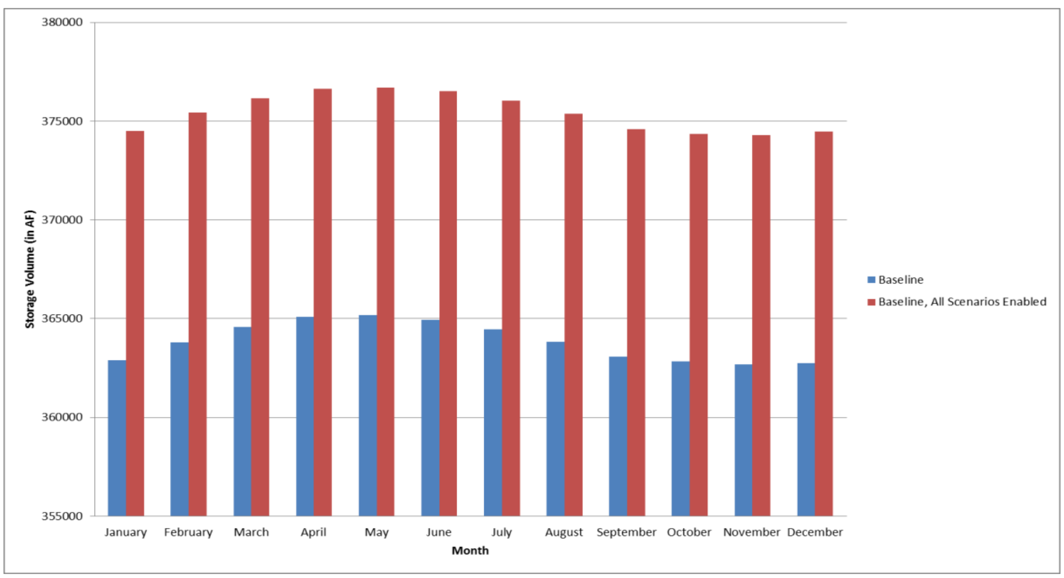

Figure 3. 19: Average monthly storage volume in all groundwater basins for the Baseline and Baseline with All Water Management Strategies Implemented Suites.

3.5.2 Worst Case: Climate and Land Use Change

The Worst Case suite models the impact of a 4 degree Celsius temperature increase out to 2099 as well as a 20% decrease in precipitation and a 50% land use change. We also ran two more suites, Worst Case Infrastructure and Worst Case Consumer, to compare possible mitigation strategies. Modeled results for these three suites show that the individualized strategies represented by the Worst Case Consumer suite increase the streamflow in the Live Reach, especially in the dry months (Figure 3. 20). Consumer solutions also increase groundwater storage levels, but the infrastructure-based strategies are slightly more effective at increasing groundwater storage volumes (Figure 3. 21).

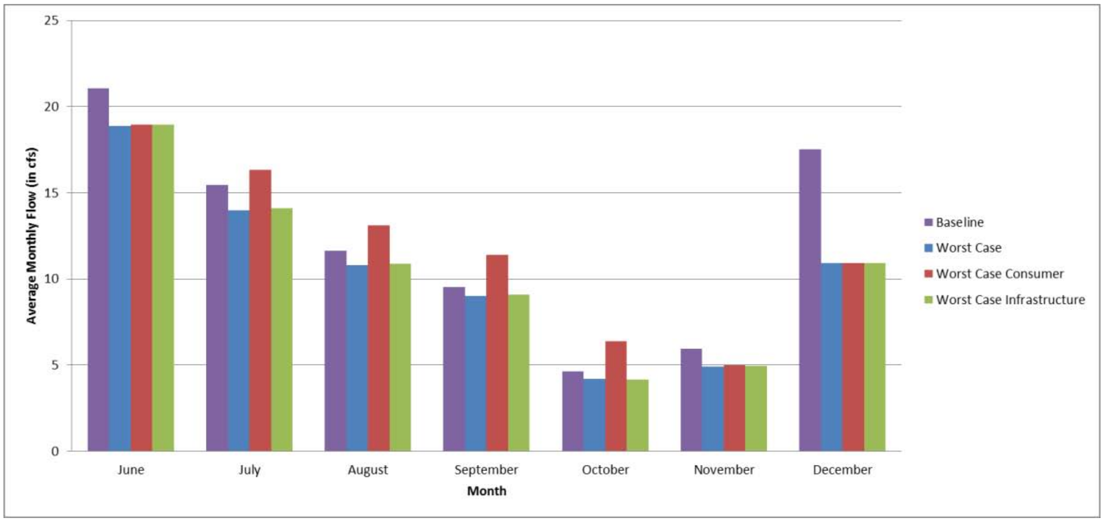

Figure 3. 20: Modeled average monthly flow in the Live Reach during the dry months for Worst Case Suites with a 4-degree temperature increase, a 50% land use change, and a 20% decrease in precipitation.

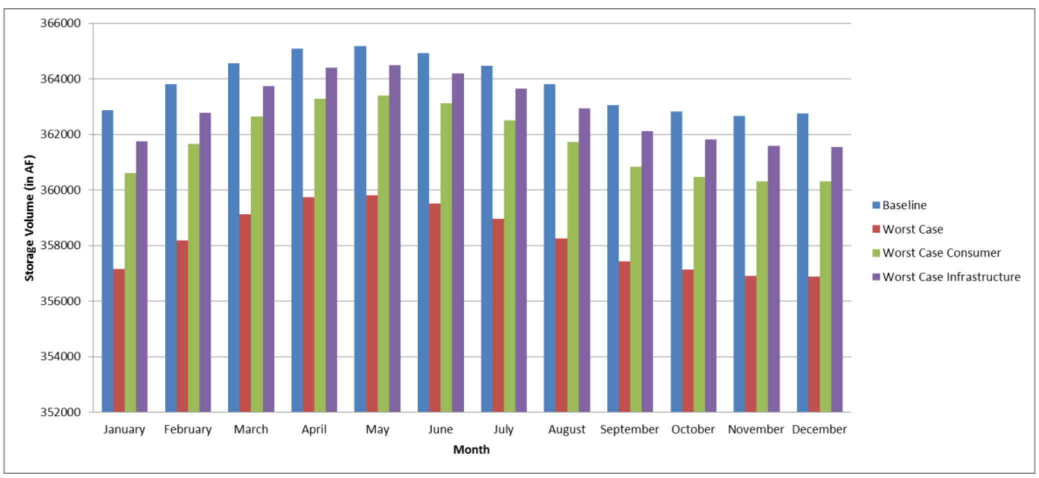

Figure 3. 21: Modeled average monthly storage volume of all groundwater basins (AF) for Worst Case suites with a 4-degree temperature increase, a 50% land use change, and a 20% decrease in precipitation.

3.5.3 Temperature Increase

Again, model results for these three suites show that the consumer based strategies represented by the Temperature Increase Consumer suite are more effective at increasing streamflow in the Ventura River Live Reach (Figure 3. 22) while the 'infrastructure' strategies represented by Temperature Increase Infrastructure are more effective at increasing groundwater storage volumes (Figure 3. 23). The consumer driven strategies result in increases in both streamflow and groundwater storage.

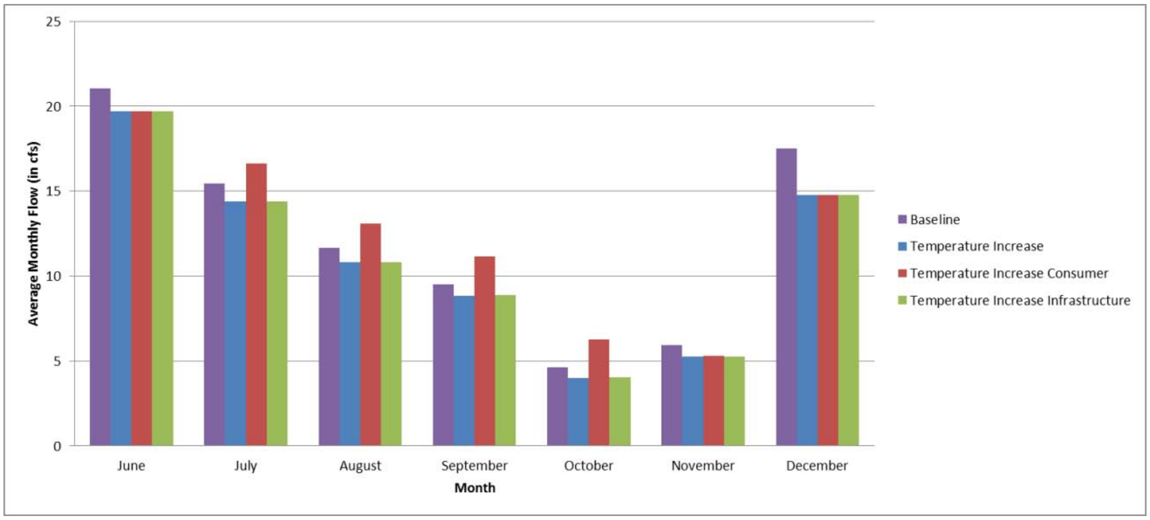

Figure 3. 22: Modeled average monthly flow in the Live Reach during the dry months for suites with a 4-degree temperature increase and no precipitation or land use changes.

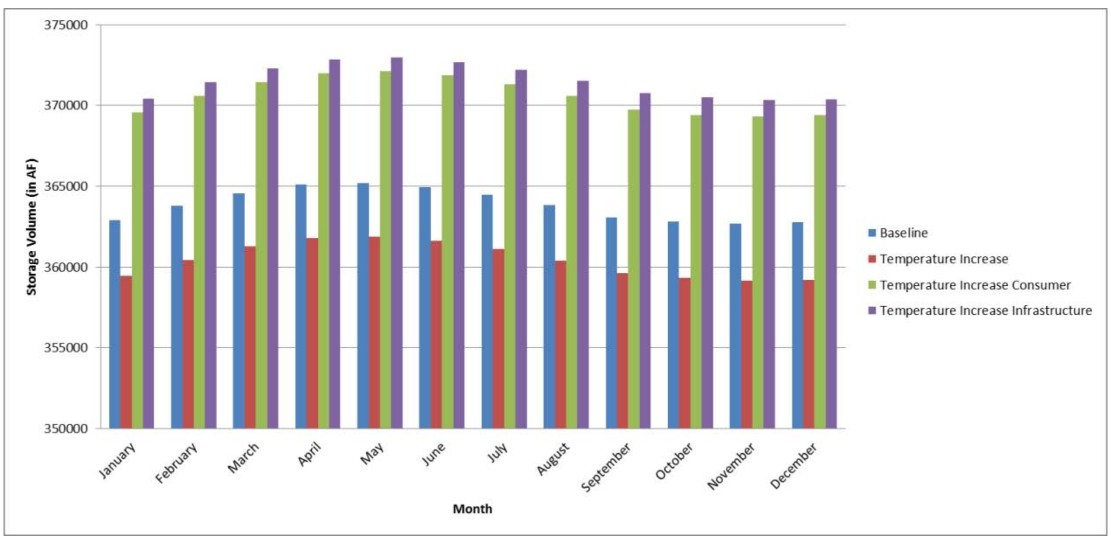

Figure 3. 23: Modeled average monthly storage volume in all groundwater basins for suites with a 4-degree temperature increase and no precipitation or land use changes.

4. DISCUSSION

4.1 Water Management Strategies

4.1.1 Ocean Friendly Gardens

Implications of Results

Ocean friendly gardens produced benefits for all six of the evaluation criteria. Capturing rainwater and using native vegetation reduced irrigation requirements for single-family homes. The overall water demand for the sector was also reduced, lowering demands on domestic water supply sources such as Lake Casitas. The installation of rain gardens further improved water supply in the watershed by capturing and infiltrating rainwater that would otherwise have flowed into stormwater sewer systems and into the river. The rain gardens instead direct volume into the groundwater basins making it available for pumping at a later time.

The reduced demand in the City of Ventura decreases the need for pumping at Foster Park. Under the assumption that less pumping can occur at Foster Park during the summer months if the City of Ventura reduces its yearly demand, the 50/50 conversion scenario to ocean friendly gardens allows flows at the Live Reach to go above a monthly average of 12 cfs 6 more times for those 4 months over a 20 year period than if no conversion occurred. This increase improves steelhead ability to use the reach for over-summering habitat and benefits the species' overall recovery.

The use of rain gardens lowers the Total N and Total P loading during storm events by reducing the need for fertilizer. Rain gardens also reduce or eliminate the runoff caused by over-irrigation, which can be a substantial portion of runoff during dry weather. The algae and nutrient TMDL for the Ventura River requires a reduction of 9,240 pounds of Total N and an 86.2-pound reduction in Total P from the City of Ventura's MS4 system (CRWQCB, 2012). The calculations for the dry weather reductions from the 50/50 scenario only reduce dry weather loading from the City of Ventura by 215 pounds for N and 2 pounds for P. These calculations use a conservative estimate of nutrient concentrations in runoff and they do not include reductions in fertilizer by switching from lawns to native plants. Both of these factors may result in estimates that substantially underestimate the dry weather loading reduction achieved by ocean friendly gardens.

Although ocean friendly gardens require an upfront conversion cost to homeowner's, the homeowner will benefit from reduced water, sewage, and lawn-maintenance costs. In addition, the native landscaping can provide curb appeal while creating an environment that attracts wildlife, including birds and butterflies. The analysis of cost-effectiveness for ocean friendly gardens also suggest the return on investment is higher if the homeowner converts the entire yard instead of half of the yard. Encouraging wide-scale adoption of full-yard conversion will provide substantial benefits to the homeowner, as well as water supply and water quality improvements for the entire watershed. In addition, the costs of ocean friendly gardens are generally offset by the benefits, and as water prices rise in the future, the benefits will outweigh the costs by a greater margin.

Because ocean friendly gardens qualify for so many Proposition 84 categories, it is possible that a wide-scale conversion could be partially funded by the Proposition. Proposition 84 funding, or funding from another source, could provide rebates for turf conversion to significantly reduce the upfront installation costs and even make the consumer money over time through the water and maintenance savings. One limitation of this water management strategy is that it is up to the consumers to make the change; conversion from turf to a rain garden and native landscaping on private property cannot be mandated. Thus, providing promotional rebates can help motivate property owners to commit to a conversion to more sustainable landscape.

Uncertainties

Several numbers in this analysis were estimates derived in other research papers. Some of the largest uncertainties surrounded how much the conversion to rain gardens and native landscaping would reduce nutrient loading during dry weather. Tetra Tech estimates that 80% of water used outdoors for landscaping is consumed, with 20% either infiltrating or running-off. Our analysis assumes that 5% of outdoor water use runs off with the other 15% infiltrating. We assumed that ocean friendly gardens will reduce pollutant loading in dry weather runoff by decreasing the volume by this 5% of household used outdoors. This assumes the gardens will capture water from over irrigation. Because it is so difficult to estimate how much of dry weather runoff is from over irrigation, and how much the conversion to ocean friendly gardens will reduce it, the dry weather pollution reductions have a high level of uncertainty.

Other major uncertainties dealt with the surface to groundwater interaction. We assumed that 90% of the first inch of rain that falls on rooftops is captured and infiltrated into the groundwater basin. The 10% reduction accounts for water that stays on the impervious surfaces and does not runoff into the rain garden. We allowed 90% of all rainfall 1 inch and below to contribute to the overall infiltration yet very light rainfall might not infiltrate at all if it stays on surfaces and evaporates. Thus, our results for increased groundwater supply due to ocean friendly gardens may be oversimplified.

Factors Not Included

While we tried to incorporate as many elements as possible into our analysis of how an implementation of ocean friendly gardens throughout the watershed would affect water demand and supply, some considerations were omitted. In our water management strategies, we only considered water demand for the single-family household sector, yet rain gardens and xeriscaping can be effectively used for other sectors such as multi-family households, landscape, government, and commercial development. In addition, for our calculations of water saving benefits over 20 years, we discounted benefits but assumed a constant water rate through time. It is highly likely that the cost of water will increase for the different sectors over the next twenty years, but we kept the potential water cost savings from reducing water demand conservative and held rates the same. Another factor we did not include was the reduction in nutrient loading runoff caused by the reduced fertilizer requirements for nonnative plants. Thus, our water quality estimates were very conservative, and likely underestimate the reduction in nutrient loading from ocean friendly gardens.

4.1.2 Greywater

Implications of Results

The greywater management strategy has benefits associated with two of the evaluation criteria. The strategy resulted in a decrease in demand as well as ecosystem health benefits of decreasing demand specifically within the City of Ventura. By reusing laundry water, households using greywater can reduce their outdoor water use. The greywater system can also be implemented in conjunction with ocean friendly gardens to lower outdoor water use to near zero while still providing water for trees or shrubs that require water.

Households within the City of Ventura not only pay per HCF of water, but also for wastewater. Wastewater is billed per HCF of water that goes into the house. Therefore, any reduction in demand will hold benefits of both water and wastewater reduction. In Ventura, the cost per HCF of wastewater is $2.78 per HCF. This increases the yearly benefit of a greywater system to $79.2 a year or a 20-year NPV of benefits of $500. Thus, within the City of Ventura, a greywater system that can be installed for less than $500 will have a positive economic benefit.

The average cost of materials for a simple greywater system costs $200 dollars. For this water management strategy, we assume a $35 NPV of installing a greywater system over 20 years. However, as long as the total cost of installing the greywater system is lower than $235, the project will have a positive net present value and will be economically beneficial to those who install it. However, if a household needs to hire someone to install their system they can expect to add a few hundred dollars on top of the $200 dollar material cost. Installation costs could decrease the net present value to a negative number. Some cities choose to subsidize this cost by providing a rebate for greywater systems. San Francisco provides a $112 rebate on a $117 greywater system (San Francisco Water and Power, 2011), increasing the NPV of the system for its customers. This project would be a good candidate to be funded by revenues raised by a rate increase in the Ventura River Watershed.

A large-scale greywater conversion project could be implemented with proposition 84 funding. Greywater projects meet several prop 84 criteria and could also be bundled with an ocean friendly garden project to maximize water conservation. Greywater systems could also be incorporated into new building codes, which would decrease the installation costs significantly. Installing a greywater system before walls have been completed makes running pipes easier and less expensive.

The ecosystem benefits of the greywater system are derived by lowering demand in the City of Ventura during the dry months. We use the assumption that pumping at Foster Park would decrease by the same amount that the greywater systems decrease demand. Outputs from the WEAP model show that the 25% greywater scenario results in one positive event, the 50% scenario produces 3 of these events, and the 75% scenario produces 5. Combining these results with other water management strategies that reduce pumping at Foster Park, such as ocean friendly gardens, can create additive effects. By installing greywater and ocean friendly gardens in 75% of the houses in the City of Ventura, demand could be reduced enough to stop pumping in the dry months, maximizing ecosystem benefits to steelhead within the Live Reach.

Uncertainties

There are several uncertainties underlying the greywater scenarios. One of the major problems with any greywater system is that increasing the efficiency of water using fixtures essentially decreases the benefit of your greywater system. For example we assumed an average washing machine efficiency of 35 gallons of water per load. This is the average for washing machines currently in use, but current energy star washing machines can use as little as 15 gallons per load (DWR, 1995). Conversion to high efficiency washing machines would cut our benefits by more than half, but the net water-savings to the consumer would be the same. The same would hold true for more complicated multi branch greywater systems. As the efficiency of toilets, showers, and faucets continue to increase, the value of harvesting greywater decreases. The installation of large, centralized greywater systems for large development projects may become more effective than many small, decentralized installations.

The greywater scenarios assumed a price of $2.5 per HCF of water, the current the state average price for water at the 15 HCF tier. Water prices are higher than the state average in some parts of the watershed and lower in others. Estimates of savings will be accurate on average across the watershed, but may not reflect exact savings a homeowner will experience for a particular water purveyor. In addition, water prices will likely climb higher. In Santa Barbara, for example, water prices can be over $5 per HCF. At these rates, the benefits of a greywater system over 20 years can be up to $500. If water prices continue to rise at a rate greater than inflation, the value of greywater systems will continue to rise as well.

Factors Not Included

One factor that was not included in our analysis was the cost associated with changing the detergent used for clothes washing. It is necessary to use biodegradable, non-toxic laundry soap when using a greywater system. GreywaterAction.org also points out that its important to choose a detergent that does not have borax or high levels of salts, as those ingredients are safe for people but can be toxic to plants. They also encourage using a detergent which is pH neutral, as some plants cannot withstand the more acidic conditions created by the soap. Greywater Action has a good list of landscape friendly detergents on their website (Greywater Action, 2012).

4.1.3 Scalping Plant in Ojai

Implications of Results

In Ventura River Watershed, reclaimed water produced from a scalping plant can potentially be used for landscape irrigation or industrial use such as for oil extraction using steam injection procedures (Alvarado & Manrique, 2010). However, considering that groundwater use is not strictly regulated in the watershed and many users are currently using groundwater to meet their irrigation needs it is important that the reclaimed water be priced to encourage users to buy reclaimed water from the scalping plant instead of pumping groundwater.

The results illustrate overall feasibility of installing a scalping plant upstream of the Ojai Valley Sanitary District (OVSD) treatment system. Reclaimed water rates are generally priced below the cost of production to encourage use (American Water Works Association, 2003). Assuming the reclaimed water from the scalping plant in Ojai is sold at a price of $2.5/ unit (HCF) (where $2.5 is close to average state price for potable water but lower than some of other agencies' who currently supply potable water in the Ventura River Watershed), it was found that over 20 years the scalping plant has an average cost of $330/AF of water saved or $1/HCF of water saved (Appendix 4). Given the uncertainties and costs associated with imported water supplies (such as from the State Water Project) the popularity of scalping plants in arid regions like Southern California is expected to increase despite the fact that the unit costs for these systems are typically higher than for centralized systems (Byrne, 2012). Because scalping plants are applicable for Proposition 84, these funds could be used to meet some of the costs for scalping plant.

Uncertainties

The cost estimates for this water management strategy were obtained from a case study in Texas (AECOM, 2012). Factors such as net installation and overhead costs may be different for California. Additionally, the irrigation amount of 250 AF each for the two golf courses in Ojai is an estimate derived from the water use rates for golf courses in Ventura County (Miller, 1991). Another uncertainty is the irrigation efficiency for the golf courses. Although the annual irrigation water use for golf courses in California is estimated to fall in range of 80% to 100% of well watered conditions (Green, 2006) 100% irrigation efficiency was assumed for the scalping plant strategy because golf course managers are increasingly using water management techniques to increase irrigation efficiency and conserve water (Frame, 2009).

Factors Not Included

The cost-effectiveness analysis did not compare costs of installation of a scalping plant with the costs of upgrading the current treatment system or installing the reclamation infrastructure at the current facility. Additionally, the analysis did not include land costs for scalping plant, site suitability analysis to identify a location that would be the most appropriate for siting this plant, and conveyance costs for transporting reclaimed water to the end users. Since the scalping plant is a much smaller unit than a centralized treatment system, associated land costs are expected to be relatively small. If the scalping plant is sited in an area within Ojai Valley Sanitary District's right-of-way, the land costs can be reduced to zero.

Wastewater flow rates were not included in this analysis, and the rates can impact the operating costs of scalping plants. Low flow rates can significantly decrease their cost-effectiveness by increasing costs of producing reclaimed water (Byrne, 2012) Additionally this study only considers the costs and benefits for a scalping plant using Activated Sludge Process and having a treatment capacity of 200,000 gpd. Depending on the intended reuse type, the scalping plants can use different technology, such as Membrane Bioreactors, and have different capacities. Choosing a different technology or altering the treatment capacity may change the cost-effectiveness of this solution.

4.1.4 Infiltration Basins

Implications of Results

Infiltration Basins have been used in various regions in California with varying degrees of success (California Stormwater Quality Association, 2003). Although this water management strategy has no direct monetary benefits, by promoting groundwater recharge and enabling better management of groundwater; an infiltration basin will augment water supply in the long term. Moreover, the water management strategy meets several of the requirements needed to qualify for Prop 84 grants. Although improved water quality is often cited as a key benefit of infiltration basins; a conservative score of '1' was given to this criteria for water quality owing to the fact that calculation of N and P removal estimates were simplified.

Although the infiltration basins were modeled as a single large basin that could capture runoff from 59 acres, smaller and dispersed stormwater control structures within the watershed may allow for more feasible and cost-effective implementation. Some infiltration based BMPs that can be considered to capture drainage from 59 acres include biofilters (swales and filter strips), constructed wetlands, grass swales (US EPA, 1999), and planter boxes (US EPA, 2013).

Uncertainties

The major uncertainty in the evaluation of this water management strategy concerns the cost estimates. The cost estimates are based on literature research and can vary a lot based on factors such as labor costs, location, and design of the basin (US EPA, 2012). Other uncertainties relate to model parameters. The values for soil characteristics such as depth and conductivity are estimates, and there is uncertainty associated with infiltration rates. Although these uncertainties are general to the model as a whole, they are particularly important when evaluating potential benefits of this water management strategy, since the primary benefit of these basins is groundwater recharge and this would be influenced greatly by the onsite soil characteristics.

Factors Not Included

Although infiltration basins scored well on many of the criteria, analysis was not conducted to determine how much total area is available for decentralized solutions. It may be possible to construct decentralized infiltration basins to capture substantial runoff than possible from the 59 acres of drainage area examined in this study. Land cost is a major factor that was not included in the cost-effectiveness analysis of the modeled infiltration basin. The cost of acquiring land is the variable that most significantly affects the overall costs for these structures and the land costs differ widely from state to state as well as regionally and depend on zoning and surrounding land use (US EPA, 1999). Additionally, although soil types and topography are critical components of infiltration basins, the analysis does not include relative suitability of specific locations for constructing the infiltration basins (US EPA, 2012).

4.1.5 Water Rate Increase to State Average

Implications of Results

CMWD and Meiners Oaks rates are 284% and 181% below the state average of $2.50 per HCF at the 15 HCF tier. This low price encourages over consumption of the resource and may require water imports in the future. It would be in the best interest of the Ventura River Watershed to increase their rates to a more reasonable level in order to decrease demand and avoid the need for even more expensive water in the future. This water management strategy saved the most water in AF of any of the strategies that were evaluated. Raising rates is also the most technically feasible water management strategy; there is no need to encourage people to adopt a strategy or even a need to build infrastructure. Because of these reasons rate increases are the most efficient way to increase water conservation. Although increasing rates to state average was not the most cost-effective strategy, it is still much cheaper than the possible alternative of utilizing the State Water Project. Even using the state average cost of $2.50, 10,000 AF/year will cost only $400 per AF to consumers. Compare that to the estimated $1445/AF for state water and the cost of rate increases seems much less expensive. Reducing demand now by increasing local prices to the state average could avoid the need to import expensive water. While the average cost to consumers of this strategy is $160 per AF/yr, it is a benefit to water purveyors. The increased revenue could then be used to create a rebate system for installing ocean friendly gardens or greywater systems. Increasing water rates also encourages conservation measures and increases the cost-effectiveness of these and many water saving projects.

Uncertainties

The main source of uncertainty in this water management strategy is the price elasticity of demand. As discussed in the methods section, there is no clear answer to how a specific region will respond to increases in the price of water. A range of price elasticity values was examined in this study to address the uncertainty associated with this factor. Further exploration of the specifics of price elasticity in this region may help to address the uncertainty.

Factors Not Included

A major factor not included in this analysis is how other factors may change demand in conjunction with rate increases. Changes in demand could be caused by climate change or a decrease in demand as a result of water conservation techniques such as greywater and ocean friendly gardens.

Decreased demand coupled with increased rates may result in changes not predicted by this analysis. A sufficient decrease in demand could cause a decrease in water purveyor revenue.

4.1.6 Water Rate Increase to Full Cost Pricing

Implications of Results

This water management strategy investigates the results of increasing CMWD single-family water rates by 33%, which would increase revenue by 20%. If CMWD implemented this 33% rate increase across all of their sales they would increase their total revenue by 20%, enough to make operational costs equal operational income. Increasing water rates remains one of the most efficient ways to lower water use in the Ventura River Watershed.

Uncertainties

Much like in the "increase to state average" water management strategy, a major uncertainty is the price elasticity of demand. Further study could help determine the true price elasticity of demand for the watershed and would be a major benefit for further water rate planning.

Factors Not Included

The factors not included are the same as the Rate Increase to State Average water management strategy.

4.1.7 Conversion to Pervious Streets

Implications of Results

Conversion of impervious streets to pervious streets is costly and provides only marginal water supply and water quality benefits. While it is likely that the reductions in nitrogen and phosphorus loading associated with this water management strategy have been underestimated, it is also likely that different stormwater best management practices (BMPs) would be more cost-effective in this watershed and would lead to similar or increased nitrogen and phosphorus loading reductions.

Pervious street conversion results in an average of 58 AF per year of increased groundwater recharge in the Ojai Groundwater Basin. This amount of increased infiltration could be achieved with a more distributed approach to stormwater management within the watershed, as discussed in the Infiltration Basins water management strategy. Curb cuts and curb extensions, coupled with the construction of bioswales, have been effective methods of reducing runoff and increasing infiltration in other watersheds (City of Portland Oregon, 2012). These approaches are far less costly than construction of a pervious street (~$2/sq-ft catchment area compared with ~$7/sq-ft catchment area) and could easily be completed on a watershed-wide scale.

This water management strategy leads to a yearly reduction of 719 lbs of nitrogen loading and 85 lbs of phosphorus loading to the stream network. Because this strategy only accounts for wet-weather runoff reductions, it is likely that the water quality benefits associated with an impervious-to-pervious street conversion would be higher than predicted. However, these same reductions could be achieved with a more decentralized approach to stormwater management using curb cuts and curb extensions throughout the watershed. This approach would also be less costly.

In general, stormwater BMPs seem to be good candidates for Proposition 84 funding. They address both water quality and water quantity issues and, depending on how they are implemented, could also create open spaces for recreation. While the installation of pervious streets would require a large amount of funding to be economically feasible, curb cut and curb extension programs could succeed even with smaller grants.

Uncertainties

As discussed above, a major uncertainty in this strategy is the magnitude of dry-weather infiltration and consequent runoff reduction that would result from the installation of pervious streets. This has the potential to increase annual infiltration rates and decrease nutrient loading to the stream network.

Factors Not Included

Factors not included in this analysis include the suitability of streets within the Ventura River Watershed for an impervious to pervious conversion, suitability of soils within the Ventura River Watershed for pervious street cover, and willingness of Ventura River Watershed residents to undergo extensive street construction projects. In addition, nutrient reduction estimates do not take into account decreases in runoff during dry-weather months. Runoff from lawn and garden irrigation often contains fertilizer and is a significant source of nitrogen and phosphorus loading in the Ventura River Watershed. All of these factors could alter the results of this water management strategy.

4.1.8 San Antonio Spreading Grounds

Implications of Results

The largest benefit of the San Antonio Spreading Grounds would be the increase in groundwater supply made possible through this project. By diverting water from San Antonio Creek into the spreading grounds, infiltration of water into the Ojai Groundwater Basin would be increased. This would increase the supply of water available to be extracted from the aquifer for municipal and agricultural uses. While this project would not decrease water demand, improve water quality or aquatic ecosystem health, it would increase local water supply cost-effectively when this project is compared to ocean friendly gardens or water rate increases. Additionally, while this particular project is not eligible for Prop. 84 funding (because it has already been funded), projects like it would be excellent candidates for funding through this water project-funding source.

The amount of groundwater recharge provided by this project was dependent on future precipitation patterns. In a wetter future this project would provide more groundwater recharge and in a drier future this project would provide less. While larger volumes of water could be diverted during wetter periods, the benefit of increasing potential groundwater recharge would be higher during periods of water scarcity. Municipal and agricultural users in the basin wouldn't be as concerned about water scarcity during years of above average rainfall. However, during dry years the spreading grounds will increase the total storage of groundwater in the aquifer in a period when water demand would be high due to the scarcity of the resource.

Uncertainties

The quantity of water that infiltrates to the groundwater is an estimate. The volume of aquifer recharge from this project could be higher or lower than current projections, and this uncertainty has implications for the cost-effectiveness of this project. In addition, the initial estimates for the cost of this project may be below the actual final costs of the San Antonio Spreading Grounds. If the price of this project increases, the cost-effectiveness of this project will go down.

Evaporative losses of water diverted to the spreading grounds were set at a standard 20% for all model runs. However, in a future warmer climate evaporative losses from this project could increase compared to this value.

The diversions from San Antonio Creek to the spreading grounds were modeled in WEAP using regression equations that were created by plotting local precipitation versus the historic water diversions of the previous San Antonio Spreading Grounds. The highest R-squared value was 0.10, indicating that these regressions poorly predict actual diversions to the spreading grounds (Appendix 9). Improvements in these equations would improve the accuracy of diversion volumes to the infiltration basin.

Factors Not Included

By increasing water infiltration into the Ojai Groundwater Basin this project would increase the amount of groundwater available to be extracted by both local municipal and agricultural wells. Many wells in the region usually go dry at some point during the year and then those users must buy more expensive water from Lake Casitas MWD or other local water purveyors. This project could potentially decrease the volume of relatively more expensive water these users would have to purchase. This possible monetary savings was not included in our analysis.

4.2 Land Use Change (Crop Conversions)

Implications of Results

Model results for crop conversions relating to evapotranspiration align with expectations. Although raspberries require significantly more irrigation than oranges, oranges have a higher crop coefficient value, indicating that they have the potential to evapotranspire more water than raspberries. This explains why potential evapotranspiration rates decrease in all months following the crop conversion (Figure 3.5). The crop coefficient values and water demand for raspberries are highest at the beginning of their growing season, which falls in September and October in the WEAP model. The crop coefficient value for oranges during these months is still higher than that of raspberries. The increased amount of irrigation to raspberry crops leads to a higher actual evapotranspiration rate (Figure 3.6).

The modeled effects of crop conversions on monthly streamflows in the Live Reach of the Ventura River are minimal. Results show very slight increases in streamflow in the low flow months, July-October (Figure 3.7). Changes in irrigation runoff volumes or precipitation runoff volumes could alter streamflow in this scenario. Raspberries require more irrigation than oranges, so we would expect more water to reach the stream network as irrigation runoff following crop conversions. Also, raspberries consume less water than oranges so we would expect more water to reach the stream network during precipitation events as a result of decreased interception and evapotranspiration following crop conversions. Model results confirm these expectations. In all months, the magnitude of changes in streamflow are insignificant and do not affect any conclusions in this analysis.

Model results for Lake Casitas storage volumes following crop conversions indicate that crop conversions lead to decreased storage levels in Lake Casitas (Figure 3.8). This is a result of the increased water-demand on CMWD following conversion from oranges to raspberries, which require more irrigation annually. Increased demand on Lake Casitas may lead to increased diversions from the stream network by CMWD in order to keep lake volumes high. This could lead to reduced water availability for ecosystem needs within the watershed.

Groundwater basin storage levels decrease within the watershed following the modeled crop conversions, with both the Ojai Groundwater Basin (OGWB) and the Upper Ventura River Groundwater Basin (UVRGWB) experiencing a decrease in storage in all months (Figures 3.9 and 3.10). This decrease is caused by an increased in water demand. Although some additional water reaches the groundwater basins as the result of increased irrigation, the increased infiltration is just a fraction of the increased extractions. The decreases in groundwater storage will lead to increases in demand on Lake Casitas earlier in the season, further stressing this water supply.

Uncertainties

One major uncertainty in this analysis is the actual crop coefficient values for raspberries. Crop coefficient values reflect the quantity of water that a crop will consume through evapotranspiration. For our analysis, we used the crop coefficient values of strawberries as a surrogate for raspberries, as no published crop coefficient values could be found for raspberries. While several sources noted that strawberries and raspberries have similar crop coefficients values, small differences in these values could translate to large differences in total evapotranspiration when applied at a watershed scale. Furthermore, the crop coefficients for strawberries correspond to the strawberry growing season. Because the raspberry growing season is slightly different from the strawberry growing season, assumptions had to be made about how to translate the values across months. This could also have led to inaccuracies in the model results.

Another uncertainty in this analysis is the source of the additional irrigation water required to grow raspberries. In the model, this demand was divided proportionately between groundwater basins and Lake Casitas based on relative pre-conversion demand. The reality may be very different, with more or less water coming from Lake Casitas or from groundwater sources, and this could have a large effect on water resources within the watershed.

Factors Not Included

The main factors not considered in this analysis were (1) the effect of the spatial distribution of crop conversions within the watershed on the water budget, (2) the effect of the temporal distribution of demand on the water budget, and (3) the impacts of changing fertilization requirements on water quality within the watershed. In the current model setup, the increased water demand associated with switching from oranges to raspberries was distributed proportionately across the six different agricultural demand sites based on their relative pre-conversion demand. In reality, these crop conversions may be concentrated over a single groundwater aquifer rather than all three, and this would change how much water was being withdrawn from the aquifers and how much excess water was infiltrating back into the aquifers. Also, the increases in demand resultant from the crop conversions are not distributed according to the irrigation schedule for raspberries but for agriculture as a whole. Making this change in the model would affect the timing of increases and decreases in Lake Casitas and groundwater levels throughout the watershed. The last major factor not considered in this analysis was the impact of nutrient loading to the stream network from crop changes. It is likely that the conversions would have some effect on the water quality within the stream network and determining the magnitude of this effect would be relevant to the current TMDL.

4.3 Climate Change

Implications of Results

Modeling of the six climate scenarios indicate that the effects of climate change on the environmental and human uses of water in the basin will be dependent on increased future temperature, changes in the amount of precipitation, and changes in future water demand. While none of these scenarios accurately predict the meteorological future in the region, they give an indication of the trends of water availability as a result climate change. Long-term fluctuations in weather patterns such as the El Niño and La Niña oscillations have always made predicting future climatic conditions difficult. In the past and currently most water planning was based on stationarity, a belief that meteorology and hydrology remain, on average, relatively stable over periods of time relevant for water planning (~10-100 years). Climate change and the possibility of rapid alterations in local hydrology could destroy the paradigm of stationarity, adding additional complexity to the process of water resource planning.

If the climate warms but has the similar precipitation to current levels (the T4 scenario), water resources in the basin would be reduced as a result of increased evapotranspiration and increased human demand (Figure 3. 12 & Figure 3. 10). Groundwater storage in this case would decline in both the Ojai and Upper Ventura aquifers (Figure 3. 15 & Figure 3. 16). This would reduce the water supply available for extraction by municipal and agricultural wells. Average Lake Casitas storage would also decline, which would decrease the volume of water Casitas MWD could deliver to its customers (Figure 3. 17). The number of months, during times of low flow, when flow in the Live Reach was above 12 cfs would be reduced from 127 months to 102 over a one hundred year period (Figure 3. 13). Average flow in the Live Reach was modeled to decrease in dry months under this warming scenario (Figure 3. 14). This would negatively impact the over-summering steelhead populations in this reach. In order to mitigate the potential impacts of reduced supply and streamflow caused by a warming world, managers would have to reduce local demand or find additional water resources such as recycled wastewater.

In the future if the climate both warms and precipitation decreases (T4-10 & T4-20), water resources may decrease even more than in the warming-only scenario. These cases represent the worst case scenarios for water managers and water resource stakeholders. The number of dry months when flow in the Live Reach was above 12 cfs would be reduced from 127 months to 94 months in the T4-10 scenario and to 88 months in the T4-20 case (Figure 3. 13). Average streamflow in the Live Reach was projected to decline in every dry month in both of these scenarios, especially in the T4-20 case compared to baseline (Figure 3. 14). The mean storage in the Ojai Groundwater Basin may decline 12% in the T4-10 case and 17% in the T4-20 case, while mean storage in the Upper Ventura Basin would decline 3% and 5% respectively (Figure 3. 15 & Figure 3. 16). Lake Casitas storage may also decline under both of these climate regimes (Figure 3. 17). The main causes for these declines of water supply and streamflow in the T4-10 and T4-20 scenarios were decreased precipitation and increased water demand. To meet future human and ecosystem water needs under these climatic conditions, water resource managers may have to aggressively reduce (compared to T4 conditions) local demand or find new sources of water.

If there were an increase in both temperature and precipitation (T4+10 & T4+20), water resources would be impacted in both positive and negative ways. In the T4+20 scenario the number of months with average flow greater than 12 cfs was 122 and in the T4+10 scenario this number declined to 115 compared to 127 months in the baseline scenario (Figure 3. 13). Because the increased precipitation mostly falls in the winter, flow during the dry months still declined. These results indicate that these climate scenarios may not positively benefit steelhead populations. Groundwater storage in the Ojai aquifer may only slightly decline in the T4+10 scenario and somewhat increase in the T4+20 scenario, this same relationship was true for the Upper Ventura aquifer (Figure 3. 15 & Figure 3. 16). Storage in Lake Casitas may increase in both cases (Figure 3. 17). These outcomes show that human water resources in a future that is both warmer and wetter may be only slightly reduced or even increased depending on the magnitude of precipitation increase. Water resources in these cases may not be nearly as stressed compared to the T4, T4-10, and T4-20 scenarios. Despite the negative impacts on over-summering steelhead habitat and the possible reductions in groundwater storage these scenarios predict, the T4+10 and T4+20 cases may represent a future that will not require significant change from current management strategies in order to remain at baseline levels of water supply and ecosystem function.

Understanding how potential meteorological trends could impact water resources in the Ventura River watershed should inform current water planning in the basin so the impacts modeled in the climate change scenarios could be proactively addressed. Most scenarios indicate water shortages in the Ventura River watershed in the future, especially if local demand continues to rise or precipitation declines. The scenarios also indicate possible declines in aquatic ecosystem health. To avoid these negative effects, programs and projects that improve current water use-efficiency, increase resiliency to drought, and improve ecosystem health should be implemented. Planning to mitigate the possible impacts of climate change through water conservation and reuse could reduce the need for expensive supply solutions such as ocean desalination or importing state water.

Uncertainties

The globe has been warming on average due to the anthropogenic release of greenhouse gasses and this has been well quantified on a global scale (IPCC, 2007). However, both the timing and magnitude of global and local temperature changes is very uncertain. A four-degree temperature increase is within the range of current climate change projections. It is uncertain if temperature changes of this size will occur in the Ventura River watershed.

Temperatures may not rise uniformly as they have been modeled in this analysis. Climate projections indicate that more warming may occur in the summer months versus the winter months due to differences in both atmospheric and terrestrial water content during these seasons (California Energy Commission, 2012). Our climate change scenarios did not consider the possibility of differing changes in seasonal temperature.

Historical temperature data from one station in Ojai was used as a proxy for temperature throughout the entire watershed. This watershed varies dramatically topographically from sea level to 6,000-foot mountain ranges. Where the watershed is near the Pacific Ocean, daily temperatures are relatively stable, versus inland areas where daily temperature fluctuates more dramatically. The use of more temperature records distributed throughout the watershed would improve the accuracy of the climate change scenarios.

Each of the climate change scenarios was compared to the baseline scenario in order to qualify whether these scenarios might positively or negatively impact the human and environmental water needs in the future. This implies that the baseline scenario is the climate that would have persisted if climate change were not occurring. This is a major assumption and certainly a source of uncertainty in the analysis.

The future storage of Lake Casitas was modeled using regression equations that correlated rainfall measured at the dam with historic diversions of water from the Ventura River into the reservoir. These regressions had very low r-squared values of 0.43 or less and therefore any extrapolation done with them would be uncertain.

Increased concentrations of carbon dioxide in the atmosphere may improve the water use efficiency of vegetation thereby reducing water loss from plants due to transpiration (Islam, Ahuja, Garcia, Ma, & Saseendran, 2012). If transpiration is reduced in the future due to increased carbon dioxide concentrations than ET in the watershed would be reduced compared to the scenarios modeled in this analysis and streamflow in local streams may cease.

In the scenario with increased precipitation, changes to precipitation patterns and the magnitude of storm events were not factored into the analysis. Increases in precipitation could occur as large storms that rapidly run off, possibly increasing storm damage. If increased precipitation is part of larger storm events, the water available for both human and ecosystem needs may not actually increase. Instead, rapid runoff to the ocean could occur.

The projections of future precipitation are much less certain than the projections of future temperature. For the Los Angeles area, projections of future precipitation range from -40% of the annual average rainfall to +20% (California Energy Commission, 2012). While we have investigated a range of possible precipitation changes, the magnitude of future changes in precipitation may fall outside of that range.

Factors Not Included

Important factors not included in the climate change analysis were: seasonal variability in temperature change, increased frequency of extreme events such as heat waves and wildfires, changes in precipitation timing, changes in relative humidity, wind speed, or the cloudiness factor, and possible declines or increases in future per capita water use.

4.4 Scenario Suites

4.4.1 Comparing Baseline, Temperature Increase, and Worst Case Suites

Comparing the "baseline", "temperature increase" and "worst case" scenario suites highlights the differences in water availability under the following three sets of conditions:

1. **Baseline**: climate conditions identical to the past (1990-2009 meteorological data) with no land-use change.
2. **Worse case**: climate and land-use change with a 4-degree increase in temperature, 20% decrease in precipitation, and conversion of 50% of orange cropland to raspberries.

3. **Temperature increase**: a 'possible future' scenario with a 4 degree temperature increase and no land-use change.

Climate and land use change modeled in both temperature change and worst case suites reduce the water supply and increase demand within the Ventura River Watershed compared to the baseline. The temperature increase scenario examines the changes to streamflow and groundwater storage as temperature increases by 4 degrees. In the worst case suites, these temperature increases are then magnified by precipitation decreases and land use changes that require additional water, leading to further reductions in streamflow and groundwater storage. These suites show that, although the magnitude of climate change is unknown, a warmer climate will result in real changes in water availability. Unless water resource managers plan for these possible futures, water resources in the basin may become increasingly scarce, threatening the lifestyles of the local population and the health of local ecosystems.

4.4.2 Comparing Baseline, Worst Case, Worst Case Consumer, and Worst Case Infrastructure

Results for the worst-case scenario suite suggest that the combination of temperature increases, precipitation decreases, and increased water demand from land use changes may have a substantial negative impact on water supply volumes. Storage levels in Lake Casitas and the groundwater basins within the watershed are predicted to decline dramatically if no water management strategies are implemented. Worst Case Consumer and Worst Case Infrastructure indicate that both the consumer and infrastructure solutions discussed in this study can improve groundwater levels relative to the Worst Case suit. The Worst Case Consumer suite was more cost-effective and had benefits associated with ecosystem health, but was not as effective as Worst Case Infrastructure at increasing groundwater supplies. However, neither suite could bring water levels back to those modeled under baseline. In this worst case climate change scenario, more aggressive water conservation efforts, such as increased conversion to ocean friendly gardens, would be needed to mitigate these reductions in water supply.

4.4.3 Comparing Baseline, Temperature Increase, Temperature Increase Consumer and Temperature Increase Infrastructure Suites

In the Temperature Increase Suites the temperature increases by four degrees by 2099, but there are no precipitation or land use changes. Although the temperature decreases ground water supply within the watershed, both consumer and infrastructure solutions increase the average monthly groundwater levels to greater than the baseline. These results suggest that using either consumer or infrastructure solutions can mitigate the water shortages caused by increased temperatures associated with climate change. The consumer solutions are more cost-effective, and unlike the infrastructure options, they have the potential to also increase streamflow during the dry summer months, resulting in improved ecosystem health for steelhead trout.

4.4.4 Comparing Baseline and All Water Management Strategies Implemented

Comparing results from Baseline and All Water Management Strategies Implemented shows what it is possible to achieve by implementing all soft- and infrastructure water resource management strategies outlined in this study. Results suggest that significant demand reductions and supply increases can be achieved. Because flow increases within the Ventura River are only modeled by decreasing pumping at Foster Park, the model indicates modest flow increases in the Ventura River Live Reach during low flow months.

4.5 Suites Synopsis

Comparisons between scenario suites show that, even with significant warming, significant decreases in precipitation, and increased demand from widespread land-use change, the Ventura River Watershed should be capable of maintaining its independence from imported water. This will require implementation of several water conservation and water use efficiency projects but, whether planners choose infrastructure or consumer-driven strategies, it will be far less costly than connecting to and importing State Water. Our suite analysis suggests that both infrastructure and consumer-driven water resource management strategies have potential for increasing groundwater infiltration. Consumer-driven strategies have a greater potential for increasing streamflow in the Ventura River Live Reach during low flow months. Both approaches to water conservation could mitigate the effects of climate change, land use change, and population growth, though the consumer strategies could do so in a more cost-effective manner. The cost-effectiveness of consumer projects plus the associated ecosystem health benefits, make consumer strategies a preferable way of increasing water conservation in the Ventura River Watershed.

5. RECOMMENDATIONS

5.1 Comparison of Water Management Strategies

Water management strategy results for each of the evaluation criteria are summarized in Table 5. 1.

	Decreased Demand	Increased Supply	Cost-Effectiveness	Improved Ecosystem Health	Improved Water Quality	Prop. 84 Criteria
Ocean Friendly Gardens	870 AF/yr	270 AF/yr	Cost of $40/AF to Consumers	6 Positive Events	1,300 lbs N/yr; 140 lbs P/yr	4
Greywater	350 AF/yr	Insignificant	Benefit of $50/AF to Consumers	3 Positive Events	Insignificant	2
Scalping Plant	220 AF/yr	None	Cost of $330/AF to Municipalities	Insignificant	Insignificant	3
Infiltration Basins	None	280 AF/yr	Cost of $90/AF to Municipalities	Insignificant	60 lbs N/yr; 10 lbs P/yr	4
Rate Increases to State Average	1400 AF/yr	None	Cost of $160/AF to Consumers	None	None	N/A
CMWD 33% Rate Increase	210 AF/yr	None	Cost of $280/AF To Consumers	None	None	N/A
Pervious Streets	None	60 AF/yr	Cost of $10,900/AF to Municipalities	Insignificant	720 lbs N/yr; 90 lbs P/yr	3
SA Spreading Grounds	None	380 AF/yr	Cost of $160/AF to Municipalities	Insignificant	Insignificant	2

Table 5. 1: Summary of water management strategy results for each evaluation criteria.

Based on these results, each strategy was assigned a score of 0 to 3 to reflect its ability to meet each of the six evaluation criteria. The following table (Table 5. 2) shows the normalized scores given to each of the strategies under the six different evaluation criteria. A score of 3 was given to strategies that performed well for a criterion, while a score of 0 was given to strategies that performed poorly or had insignificant results under a criterion. Under any given criteria, multiple water management strategies could receive the same normalized score.

		Cost Effectiveness	Decreased Demand	Increased Supply	Water Quality	Ecosystem Health	Proposition 84
Infrastructure Based Water Management Strategies	Infiltration Basins	3	0	3	1	0	3
	Pervious Streets	0	0	1	2	0	2
	Scalping Plant	2	1	0	0	0	2
	San Antonio Spreading Grounds	2	0	1	0	0	1
Consumer Based Water Management Strategies	Ocean Friendly Gardens	2	2	3	3	3	3
	Greywater	3	2	0	0	3	1
	Rate Increases to State Average	2	3	0	0	0	0
	CMWD 33% Rate Increase	1	1	0	0	0	0

Table 5. 2: Normalization results for each water management strategy for each of the six evaluation criteria.

Following the normalization of the results of each strategy, it was clear that ocean friendly gardens, greywater, and infiltration basins were the top overall performers. However, different water management strategies may rise to the top depending on the priorities of different watershed planners. A set of different priorities is reflected in the weighting schemes outlined below.

After normalizing the results of each strategy we applied each weighting scheme (Table 2. 3) to determine how differences in priorities influenced the relative effectiveness of each strategy. The normalized result (0-3) from each strategy was multiplied by the weight given to the criteria in the five weighting schemes. The weighting schemes are Cost Focus, Ecosystem Health Focus, Water Quality Focus, Water Supply Focus, and Neutral. The results were then summed across criteria for each strategy. The strategies are shown in Table 5. 3 and the corresponding weighted sums are shown in Table 5. 4. In this table, each strategy was ordered from highest to lowest scoring under each weighting scheme, with the highest scoring water management strategies shown at the top.

Ocean Friendly Gardens
Infiltration Basins
Greywater
Pervious Streets
Rate Increases to State Av.
Scalping Plant
SA Spreading Grounds
CMWD 33% Rate Increase

Table 5. 3: Color-coded legend for the eight water management strategies being evaluated under the different weighting schemes.

	Weighting Schemes				
	Cost Focus	Ecosystem Health Focus	Water Quality Focus	Water Supply Focus	Neutral
Best	2.6	2.8	2.7	2.6	2.7
|	2.2	2.0	1.6	2.5	1.7
|	1.7	1.3	1.2	1.2	1.5
|	1.3	0.7	1.1	1.1	0.8
|	1.0	0.7	0.7	0.9	0.8
|	0.9	0.6	0.7	0.9	0.8
V	0.9	0.6	0.6	0.8	0.7
Worst	0.4	0.3	0.3	0.4	0.3

Table 5. 4: Color-coded, weighted score for each of the evaluated water management strategies under the five analyzed weighting schemes.

Application of our hypothetical weighting schemes revealed several water management strategies that outperform the rest regardless of the relative priorities of watershed planners. Ocean Friendly Gardens scored the highest under every weighting scheme, with Infiltration Basins and Greywater scoring second or third highest under every weighting scheme. While our five weighting schemes do not comprise an exhaustive list of the exact priorities of watershed planners, they represent a wide range of potential weighting schemes.

Our strategy results, normalization scores, and weighting scheme analyses revealed the water resource management strategies that were most effective in terms of each of the six different evaluation criteria: decreased demand, increased supply, cost-effectiveness, improved ecosystem health, improved water quality, and suitability for Proposition 84 funding. Increasing CMWD and Meiners Oaks water rates to the state average has the greatest potential to decrease demand within the watershed. Installation of ocean friendly gardens in single-family homes and construction of infiltration basins throughout the watershed have the greatest potential to increase water supply by increasing infiltration to groundwater. Installation of ocean friendly gardens and greywater systems achieve water conservation in the most cost-effective manner. Both ecosystem health and water quality (as defined in this study) receive the most benefits from the installation of ocean friendly gardens. Finally, ocean friendly gardens and infiltration basins were found to be the most suitable strategies for receiving Proposition 84 funding.

5.2 Recommendations Derived from the Analysis

The homeowner driven solutions, including ocean friendly gardens and greywater systems, are the most cost-effective mechanisms for decreasing demand and increasing water supply. These solutions can also improve water quality, and enhance ecosystem health within the Ventura River. Therefore, emphasis should be placed on widespread adoption of ocean friendly gardens and greywater systems. Both mechanisms can save homeowners money by decreasing water demand while increasing water supply and improving water quality throughout the watershed. Over the next century, climate change threatens to reduce water availability. Land use change and population growth could increase demand. The homeowner driven solutions are able to offset much of the reduced supply, even in the worst-case scenario examined in the study. Adopting these solutions can also reduce water demand, allowing reduced pumping from near-stream wells during the dry months. Reduced pumping can help preserve important over-summering habitat for steelhead and generally improve instream ecosystem health.

Infiltration basins provide a strong approach for increasing groundwater supply while improving water quality. Because of the potentially high cost of acquiring large land parcels to build infiltration basins, we recommend a more decentralized approach. Street-side planters and bioswales capture runoff from surrounding impervious surfaces, serving the same function as larger infiltration basins by capturing stormwater runoff. Local municipalities should adopt the aforementioned best management practices that emphasize increasing infiltration around impervious surfaces such as streets and parking lots. Although the installation of decentralized infiltration basins would take time, the net result would be beneficial to local water supply and water quality.

Raising CMWD and Meiners Oaks water rates to the state average would significantly reduce demand by encouraging more efficient water use. Even though they employ a tiered-rate structure, current water rates for these two organizations are so low that they fail to incentivize efficient water use by consumers. Raising water rates to reflect the true value of water within the Ventura River Watershed will help to avert even higher rate hikes in the future, which will occur if water purveyors are forced to purchase costly State Water to meet consumer demand. The significant demand reductions that would result from increased water rates would strengthen the independence of the Ventura River Watershed and leave more water available for agricultural and environmental needs.

5.3 Opportunities for Future Studies

Though our analysis strongly suggests that the strategies outlined above will improve the state of water resources in the Ventura River Watershed, the potential benefits associated with each could be better quantified with a better understanding of certain aspects of the watershed. These opportunities for future studies, which are discussed in detail below, include in-depth analysis of each water management strategy outlined above, detailed groundwater modeling, creation of a water quality model, characterization of steelhead habitat needs, and reassessing removal options for the Matilija Dam.

5.3.1 Groundwater Modeling

In order to build the WEAP model of the Ventura River Watershed, we relied on three main sources to quantify the characteristics of groundwater resources in the basin (Ojai Basin Groundwater Management Agency, 2010); (Daniel B. Stephens & Associates, Inc., 2010); (Wickstrum & Merckling, 2011). These studies have greatly improved the understanding of the three main aquifers in the watershed - the Ojai, the Upper Ventura River, and the Lower Ventura River Groundwater Basins. Further studies should evaluate the location of all wells in the watershed, the timing and rates of extraction of these wells, the depth of the wells, and the use of the water (domestic or agricultural). Not only would this information help accurately characterize these important local water resources, this information could help inform future water planning. Knowing the quantity of water that is pumped from those aquifers, the timing of extraction, and when wells are running dry would enable water managers to more accurately anticipate future demand on Lake Casitas and improve the accuracy of any water budget analysis.

Understanding the relationship between groundwater levels and surface flows would help to quantify the ecosystem benefits of projects that increase surface water flow through groundwater recharge. Our analysis of ecosystem health focused only on the Foster Park area, where the connection between pumping and streamflow is well understood. In many other regions of the watershed, groundwater pumping likely affects flow. Reducing pumping higher in the watershed may have numerous ecosystem benefits. The relationship between pumping and streamflow higher in the watershed is not sufficiently understood and could not be well quantified. As a result, we could not include ecosystem health benefits from reduced demand higher in the watershed in our analysis.

Understanding of the small Upper Ojai Groundwater Basin is currently limited. Our model relied on estimates made by the California DWR. A future study should quantify the extractions, recharge rates, and storage capacity of this aquifer as well as characterize its connectivity to nearby aquifers and local surface flow. Such a study would improve the accuracy of the WEAP model or any water balance model of the Ventura River Watershed.

5.3.2 Expanding on Water Management Strategies

Analysis of several of the water management strategies discussed in this study could be refined using area-specific data and modeling. For this study, scientific literature was reviewed and used to estimate the impacts of several strategies under each evaluation criteria. Infiltration rates to the groundwater, in particular, were generalized for the strategy evaluation. The values taken from this literature review were often ranges and were not specific to the local geology and climate of the Ventura River Watershed. A future study that performed a more detailed analysis of the water management strategy impacts specific to our study location in the Ventura River Watershed would strengthen analysis under each of the evaluation criteria. Water management strategies that would particularly benefit from a more detailed analysis include ocean friendly gardens, pervious streets, and infiltration basins.

5.3.3 WARMF/Water Quality

While this study ranked water resource management projects based on their ability to improve water quality, the lack of a sophisticated water quality model prevented thorough analysis of water quality. Given that a TMDL for algae already exists for the Ventura River Watershed and that fecal coliform concentrations are a concern in certain stream reaches, an in-depth water quality modeling study would be useful. As part of our study, we created a preliminary Water Analysis Risk Management Framework (WARMF) model with the intention of using it to assess the impacts of decreased nitrogen and phosphorus loading into the stream network. Due to time constraints, calibration of this model was never completed. Finishing calibration of this model or designing a new model using WARMF (the EPA-designated TMDL analysis model) would allow water resource planners to establish quantitative goals for nitrate and phosphorus loading to achieve desired reductions and could also facilitate improved fecal coliform mitigation planning.

5.3.4 Steelhead

The ecosystem health criteria of this study is based on a biological opinion stating that a flow of 12 cfs in the Ventura River Live Reach is recommended for steelhead survival. The minimum flow in the live reach allows steelhead to survive the dry months before the winter rains. However, this is only one of the habitat features that steelhead trout populations require. In order for a viable population of steelhead to be restored within the Ventura River stream network, other habitat features must be present as well. These include gravel beds to provide spawning habitat, large woody debris for rearing habitat, and overwintering habitat, which protects the fish from high flow events (Smith). A future study building on the work of the NMFS (NMFS, 2012) that investigated the Ventura River in greater detail would be very useful in advancing steelhead restoration efforts in the stream network. If steelhead habitat suitability was quantified on a reach-by-reach basis, the major barriers to population restoration in each reach could be identified. This could inform a more comprehensive analysis of the impacts of each of the water management strategies considered in this study on ecosystem health as it relates to steelhead trout.

5.3.5 Dam Removal

The Matilija Dam reservoir, located on Matilija Creek, has been rendered ineffective as a result of sediment accumulation. The US Bureau of Reclamation estimates that as much as 5.9 million cubic yards of sediment is trapped behind the dam (US Bureau of Reclamation, 2012). Consequently, the dam is unable to provide significant water storage or flood protection benefits. Removal of the dam is considered necessary to reverse the damage done to Ventura River ecosystems as a result of obstruction of the natural sediment flow to the downstream river reaches and coastal beaches. The dam also prevents steelhead migration to their upstream spawning habitat. The primary challenge associated with dam removal is the disposal of the trapped sediment. The Matilija Dam Technical Advisory Committee (TAC) and California Coastal Conservancy are involved in exploring feasible methods for dam removal and management of the released flow and sediment (Ventura River Ecosystem, 2012).

This project did not consider impacts Matilija Dam removal may have on water quality, supply, and steelhead habitat in Ventura River Watershed. Future studies evaluating both short term and long term impacts of the dam removal on the water management strategies analyzed in this project would be useful for informing water resources management and planning in Ventura River Watershed.

6. CONCLUSION

The Ventura River Watershed is one of the few watersheds in Southern California where residents, farmers, businesses, and ecosystems rely solely upon local water. Increasing water demand resulting from population growth, land use change, and climate change are stressing water supplies within the basin and degrading the function of riparian ecosystems. In order to ensure that local water supplies meet both human and ecosystem needs, this study sought to identify water resource management strategies that could take advantage of the funding available through Proposition 84. To accomplish this, the WEAP System was used to create a hydrologic model of the watershed. In conjunction with relevant literature and economic analysis, this model was used to assess the impacts of a set of water management strategies, land use change, and climate change scenarios on water resources within the basin. Water management strategies were evaluated based on six criteria: ability to decrease demand, ability to increase supply, cost-effectiveness, benefits to ecosystem health, benefits to water quality, and suitability for Proposition 84 funding.

Results from the analysis suggest that, while climate and land use change have the potential to severely impact water availability within the watershed, implementing water resource management strategies can offset the impacts. Consumer-based strategies such as ocean friendly gardens and greywater systems in single family homes were shown to be very cost-effective options for reducing water demand and increasing water supply, benefiting riparian ecosystem health. Although they are less cost-effective than consumer-based strategies, infrastructure-based solutions such as decentralized infiltration basins were shown to be viable pathways towards increasing water supplies and improving water quality. Results further suggest that the most effective option for decreasing demand within the watershed is by increasing water rates, thereby incentivizing conservation.

Other water management strategies explored in this study include impacts from rehabilitation of the San Antonio Spreading Grounds, installation of pervious streets to manage stormwater runoff, construction of a scalping plant in Ojai to irrigate two golf courses, and a more modest increase of CMWD water rates for residential consumers. These strategies were all found to have benefits under our six evaluation criteria, but none performed as well as the four previously mentioned strategies. The San Antonio Spreading Ground Rehabilitation Project is currently underway. It is interesting to note that, while our model likely over-predicted the water supply benefits associated with the project, it still ranked in the bottom half of strategies considered in this study.

Our final recommendations to watershed planners in the Ventura River Watershed are: (1) implement programs encouraging the increased installation of ocean friendly gardens and greywater systems in single-family homes, (2) construct decentralized infiltration basins throughout the watershed, and (3) increase CMWD and Meiners Oaks water rates to the state average. Implementation of these strategies, coupled with responsible groundwater pumping, has the potential to increase water availability for human needs, improve ecosystem health, and improve water quality even in the face of climate change, land use change, and population growth.

APPENDIX 1: WEAP MODEL PARAMETERS

The FAO Soil Moisture Model is used to calculate surface runoff and infiltration to groundwater. The Table A1.1 below shows a schematic representation of the model (WEAP Web Help, 2012).

Parameter	Description	Source	Effect on Model
K_c	Crop coefficient for each crop type; Native/Non-native Vegetation	(Snyder, Orang, Bali, & Eching, 2007); (Snyder R. L., Orang, Matyac, Sarrashteh, & Kadir, 2009)	Controls Evapotranspiration
Soil Water Capacity	Soil Depth from Ventura County Cooperative Extension	(UCCES, 2012)	Controls amount of water available for evapotranspiration; greater depth reduces runoff; greater depth increases infiltration to groundwater
Runoff Resistance Factor	Speed of water runoff. The values vary monthly: low values have fast runoff. Factors that influence runoff are vegetation type, slope, and moisture.	DEM and land cover Data from (USGS, 2006)	Higher resistance slows down runoff, increases evapotranspiration and groundwater infiltration.
Root Zone Conductivity	The rate at which soil conducts water to deeper levels and groundwater.	Soil data maps, (Natural Resource Conservation Service, 2012)	Higher values increase groundwater infiltration, decrease runoff.
Preferred Flow Direction	Apportions the flow in the soil between interflow and flow to deeper layers. Based on soil type, depth, and slope.	(UCCES, 2012) and (Natural Resource Conservation Service, 2012)	Higher values flow horizontally, zero indicates vertical flow to groundwater. Impervious cover increases values.
Initial Z1	Relative moisture storage in the top soil layer at the start of the simulation.	Based on meteorological data from previous year	Higher values result in higher runoff in beginning of simulation.

Table A1. 1: Description of values for each parameters for the soil moisture model.

Table A1.2 shows the equations that relate two-month average precipitation at the Lake Casitas precipitation gage to monthly diversion at the Robles Diversion Dam from 1959 to 2010. The equations generated for each month were used to estimate diversions in future scenarios where diversions were unknown but precipitation was estimated or modeled.

Month	**Equation (y = diversion in cfs, x= precipitation in inches)**
January	**y = 9.1923x - 3.6067**
February	**y = 12.134x - 3.0146**
March	**y = 9.8893x + 10.814**
April	**y = 13.463x + 3.2852**
May	**y = -2.6264x + 5.8799**
June	**y = 30.021x + 1.6837**
July	**y = 28.025x + 0.4987**
August	**y = 1.3811x + 0.263**
September	**y = 0.5125x + 0.2869**
October	**y = 5.895x - 5.2497**
November	**y = 8.3406x - 12.075**
December	**y = 11.897x - 6.6878**

Table A1. 2: Equations relating two-month average precipitation at the Lake Casitas precipitation gage to monthly diversion at the Robles Diversion Dam from 1959-2010.

APPENDIX 2: OCEAN FRIENDLY GARDENS

Calculating Decreased Demand

Each ocean friendly garden scenario included the variables of what percent of the outdoor landscape was converted from lawn to ocean friendly gardens and what percent of the watershed did this conversion. The four scenarios inputted into the model looked at a 25% lawn conversion for 25% of the watershed, a 50% lawn conversion for 50% of the watershed, a 75% conversion for 75% of the watershed, and a 100% conversion for 100% of the watershed. Assuming there is a 76% reduction in water requirements for the area converted from lawn to an ocean friendly garden, the % reduction in water use for each household's outdoor water use was found. Then, assuming 50% of the household water use is used outdoors, the total percent water use reduction per household that converts that proportion of their lawn was found. Finally, the percent of the single-family sector water use reduction was found using the percent of the watershed that would convert under that scenario. Table A2.1 summarizes these calculations under each reduction scenario.

	25%/25%	50%/50%	75%/75%	100%/100%
% water reduction for all the landscape	19.00%	38.00%	57.00%	76.00%
% individual household water reduction	9.50%	19.00%	28.50%	38.00%
% water reduction for sector	2.38%	9.50%	21.38%	38.00%

Table A2. 1: Water Reductions for the four ocean friendly gardens scenarios.

The WEAP model uses an annual water use per account rate as an estimation of water demand in the watershed. Each water purveyor has a different baseline water use rate found in the Urban Water Management Plans by dividing the total annual water use per sector by the number of accounts in that sector for each water purveyor. We used the estimated percent water reduction per sector (Table A2.1) to reduce the annual use rates in each district. We reduced the water use for single-family homes in each water district by the same percent, assuming a percent conversion of the entire watershed to ocean friendly gardens would involve a conversion in each water district by that percent. Table A2.2 summarizes the calculated final annual water use per account rates under each of the water purveyors in the watershed.

Single-family annual water use rates for each conversion scenario				
Water Purveyor	**25%/25% (AF/Account)**	**50%/50% (AF/Account)**	**75%/75% (AF/Account)**	**100%/100% (AF/Account)**
City of Ventura	0.320	0.297	0.258	0.203
Golden State Water Company (Ojai)	0.566	0.525	0.456	0.360
Casitas (non-resale)	0.746	0.691	0.601	0.474
Casitas Springs	0.433	0.402	0.349	0.275
Oak View	0.433	0.402	0.349	0.275
Mira Monte	0.511	0.473	0.411	0.324
Meiners Oaks	0.562	0.521	0.453	0.357
Casitas (Ojai)	0.411	0.381	0.331	0.261

Table A2. 2: Single-family annual water use rate inputs for the four ocean friendly gardens scenarios.

Table A2.3 shows the WEAP model outputs for the number of AF per year saved by decreasing demand in each of the water districts.

Water Savings in AF/yr				
Water Purveyor	25%	50%	75%	100%
City of Ventura	90	348	786	1403
Golden State Water Company (Ojai)	35	137	309	548
Casitas (non-resale)	49	199	444	789
Casitas Springs	10	38	87	154
Oak View	15	57	129	229
Mira Monte	0	1	3	5
Meiners Oaks	20	77	171	304
Casitas (Ojai)	4	16	36	64
Watershed	222	872	1963	3496

Table A2. 3: Water savings results for the four ocean friendly gardens scenarios.

Calculating Increased Supply

To calculate how much water could be infiltrated into groundwater basins due to the installation of a rain garden at a specified number of single-family homes in the watershed, we used data from the 2002/2003 water year identified as having an average total precipitation over the 30-year period from 1980-2010. Used daily precipitation data for this year from the Casitas precipitation gage we isolated only up to the first inch of rain per day and then assumed only 90% of this daily amount would make it to the rain gardens. Table A2.4 shows the estimates for the average annual precipitation that would run into the rain gardens.

Total precipitation over average year	25.45 inches
Taking only first inch	15.07 inches
90% of first inch (account for runoff loss)	13.56 inches

Table A2. 4: Average annual precipitation calculations using the 2002/2003 water year.

We calculated the recommended size of a rain garden to capture runoff from the first inch of rainfall on a 1,000 sq-ft rooftop, assuming a 6-inch depth for the capture basin. This came to a 150 sq-ft rain garden.

To find the amount of increased infiltration, we multiplied the estimated average annual rainfall on a 1,000 sq-ft rooftop that would runoff into the rain garden (13.56 inches * 1,000 square feet). This volume was assumed to be able to infiltrate each year at the single-family home in the watershed that convert to ocean friendly gardens. Thus, we found the increased infiltration at each water district for the four conversion scenarios by multiplying by the percent of the watershed that would convert. Table A2.5 shows the breakdown of the calculated average volume of runoff that could infiltrate into groundwater basins in each water district under the four conversion scenarios.

Increased Infiltration (AF/yr)				
Water Purveyor	25%	50%	75%	100%
City of Ventura	73	147	220	293
Golden State Water Company (Ojai)	16	32	48	64
Casitas (non-resale)	18	35	53	71
Casitas Springs	6	12	18	24
Oak View	9	18	26	35
Mira Monte	0	0	0	1
Meiners Oaks	9	18	27	36
Casitas (Ojai)	2	4	7	9
Watershed	133	266	399	533

Table A2. 5: Results for increases in water supply under the four ocean friendly gardens scenarios.

We estimated what groundwater basin would receive the infiltrated water for each water district to calculate how much increased volume could infiltrate into the individual groundwater basins. The Casitas breakdown was estimated by overlaying the Casitas sector map over the groundwater basins. Table A2.6 shows our estimation of the groundwater basin breakdown between water purveyors and Table A2.7 shows the combined estimated volumes entering each basins. We then input these annual infiltration volumes into WEAP as a return flow to the groundwater basin from each demand site.

Water District	Groundwater Basin
City of Ventura	Lower Ventura
Golden State Water Company (Ojai)	Ojai Valley
Casitas (non-resale)	46% Ojai Valley, 39% Lower Ventura, 15% Upper Ventura
Casitas Springs	Upper Ventura
Oak View	Upper Ventura
Mira Monte	Upper Ventura
Meiners Oaks	Upper Ventura
Casitas (Ojai)	Ojai Valley

Table A2. 6: Breakdown of which groundwater basin receives water from the different water districts.

Increased Infiltration to Groundwater Basins (AF/yr)				
Groundwater Basin	**25%**	**50%**	**75%**	**100%**
Ojai Valley	26	53	79	106
Upper Ventura	26	53	79	106
Lower Ventura	80	160	241	321
Watershed Total	133	266	399	533

Table A2. 7: Calculated increases in infiltration to the groundwater basins due to the four ocean friendly gardens scenarios.

Calculating Cost-Effectiveness

To calculate the money saved from reductions in water use we used the water rates found in the Urban Water Management Plans for the different purveyors as shown in Table A2.8.

Water Purveyor	Avg Water Rate ($/100cfs)
City of Ventura	2.92
Golden State Water Company (Ojai)	3.52
Casitas (non-resale)	1.31
Casitas Springs	2.25
Oak View	2.25
Mira Monte	1.47
Meiners Oaks	1.47
Casitas (Ojai)	1.47

Table A2. 8: Water rates for the different water purveyors in the Ventura River Watershed.

To estimate the cost-effectiveness of ocean friendly gardens, we calculated the total cost to convert 25%, 50%, 75%, and 100% of a 2600 sq-ft lawn to native plants and one 150 sq-ft rain garden. We then estimated the cost benefits from water savings and yard maintenance savings for converting the lawn, discounted the benefits over a 20-year period with a 3% discount rate and subtracted these from the upfront installation costs. Finally, we then divided this 20-year average cost by the estimated total water benefit over a 20-year period. This total water benefit was all decreases in demand plus any increases in supply over 20 years.

Installation costs and maintenance savings were estimated under 2 situations: The homeowner installs and maintains the garden and a professional gardener installs and maintains the garden. In addition, use of a $500 rebate to reduce upfront costs was analyzed. Tables A2.9 – A2.12 show the estimated average costs over 20 years and average cost per AF for each of the water districts for the 4 conversion scenarios. Each scenario includes average 20-year costs and cost-effectiveness for when the garden is installed and maintained by the homeowner, installed and maintained by a gardener. Tables A2.13 – A2.16 show these same calculation results after applying a $500 rebate on the initial installation costs.

25% of Watershed Converts 25% of their Lawn				
Water Company	20-year Cost ($) Self-install	20-year Cost ($) Gardener-install	Cost-Effectiveness ($/AF) Self-install	Cost-Effectiveness ($/AF) Gardener-install
City of Ventura	-636749	-4714675	-195	-1445
Golden State Water Company (Ojai)	-161735	-905792	-159	-888
Casitas (non-resale)	-352333	-1032058	-264	-774
Casitas Springs	-125390	-373844	-395	-1177
Oak View	-187010	-557433	-395	-1177
Mira Monte	-4113	-11070	-442	-1191
Meiners Oaks	-209662	-589119	-368	-1034
Casitas (Ojai)	-57671	-151631	-495	-1301
Watershed	-1734663	-8335622	-244	-1174

Table A2. 9: Cost-effectiveness results for the scenario where 25% of the watershed converts 25% of their lawn.

50% of Watershed Converts 50% of their Lawn				
Water Company	20-year Cost ($) Self-install	20-year Cost ($) Gardener-install	Cost-Effectiveness ($/AF) Self-install	Cost-Effectiveness ($/AF) Gardener-install
City of Ventura	739715	-8364312	75	-846
Golden State Water Company (Ojai)	136539	-1106963	40	-327
Casitas (non-resale)	-654138	-1790126	-140	-383
Casitas Springs	-242186	-657414	-242	-658
Oak View	-360739	-979806	-242	-657
Mira Monte	-8360	-19987	-257	-613
Meiners Oaks	-429830	-1063997	-227	-563
Casitas (Ojai)	-122091	-279123	-304	-696
Watershed	-941091	-14261728	-41	-626

Table A2. 10: Cost-effectiveness results for the scenario where 50% of the watershed converts 50% of their lawn.

75% of Watershed Converts 75% of their Lawn				
Water Company	20-year Cost ($) Self-install	20-year Cost ($) Gardener-install	Cost-Effectiveness ($/AF) Self-install	Cost-Effectiveness ($/AF) Gardener-install
City of Ventura	4233597	-10844709	211	-539
Golden State Water Company (Ojai)	925514	-572820	130	-80
Casitas (non-resale)	-926386	-2295174	-93	-231
Casitas Springs	-336768	-837090	-162	-402
Oak View	-502546	-1248481	-162	-402
Mira Monte	-13678	-27687	-208	-420
Meiners Oaks	-660507	-1424634	-167	-360
Casitas (Ojai)	-194668	-383880	-230	-453
Watershed	2524558	-17634474	53	-373

Table A2. 11: Cost-effectiveness results for the scenario where 75% of the watershed converts 75% of their lawn.

100% of Watershed Converts 100% of their Lawn				
Water Company	20-year Cost ($) Self-install	20-year Cost ($) Gardener-install	Cost-Effectiveness ($/AF) Self-install	Cost-Effectiveness ($/AF) Gardener-install
City of Ventura	9844897	-12155864	290	-358
Golden State Water Company (Ojai)	2175726	667171	178	54
Casitas (non-resale)	-1148869	-2526993	-67	-147
Casitas Springs	-416304	-920039	-117	-259
Oak View	-621753	-1372776	-118	-260
Mira Monte	-19130	-33235	-169	-294
Meiners Oaks	-895133	-1664473	-131	-245
Casitas (Ojai)	-275868	-466371	-190	-321
Watershed	8643567	-18472580	107	-229

Table A2. 12: Cost-effectiveness results for the scenario where 100% of the watershed converts 100% of their lawn.

25% of Watershed Converts 25% of their Lawn with Rebate				
Water Company	20-year Cost ($) Self-install w/ Rebate	20-year Cost ($) Gardener-install w/ Rebate	Cost-Effectiveness ($/AF) Self-install w/ Rebate	Cost-Effectiveness ($/AF) Gardener-install w/ Rebate
City of Ventura	776520	-3301405	238	-1012
Golden State Water Company (Ojai)	178015	-566042	175	-555
Casitas (non-resale)	-41958	-721683	-31	-542
Casitas Springs	-11941	-260395	-38	-820
Oak View	-17868	-388291	-38	-820
Mira Monte	-937	-7893	-101	-849
Meiners Oaks	-36394	-415852	-64	-730
Casitas (Ojai)	-14766	-108727	-127	-933
Watershed	830671	-5770289	117	-812

Table A2. 13: Cost-effectiveness results for the scenario where 25% of the watershed converts 25% of their lawn using a $500 rebate.

50% of Watershed Converts 50% of their Lawn with Rebate				
Water Company	20-year Cost ($) Self-install w/ Rebate	20-year Cost ($) Gardener-install w/ Rebate	Cost-Effectiveness ($/AF) Self-install w/ Rebate	Cost-Effectiveness ($/AF) Gardener-install w/ Rebate
City of Ventura	3566254	-5537773	361	-560
Golden State Water Company (Ojai)	816039	-427463	241	-126
Casitas (non-resale)	-33388	-1169376	-7	-250
Casitas Springs	-15288	-430517	-15	-431
Oak View	-22455	-641522	-15	-430
Mira Monte	-2007	-13634	-62	-418
Meiners Oaks	-83296	-717463	-44	-380
Casitas (Ojai)	-36283	-193315	-90	-482
Watershed	4189575	-9131061	184	-401

Table A2. 14: Cost-effectiveness results for the scenario where 50% of the watershed converts 50% of their lawn using a $500 rebate.

75% of Watershed Converts 75% of their Lawn with Rebate				
Water Company	20-year Cost ($) Self-install w/ Rebate	20-year Cost ($) Gardener-install w/ Rebate	Cost-Effectiveness ($/AF) Self-install w/ Rebate	Cost-Effectiveness ($/AF) Gardener-install w/ Rebate
City of Ventura	8473406	-6604901	421	-328
Golden State Water Company (Ojai)	1944764	446430	272	63
Casitas (non-resale)	4739	-1364049	0	-137
Casitas Springs	3579	-496743	2	-238
Oak View	4879	-741055	2	-239
Mira Monte	-4149	-18158	-63	-276
Meiners Oaks	-140705	-904832	-36	-229
Casitas (Ojai)	-65955	-255167	-78	-301
Watershed	10220558	-9938474	216	-210

Table A2. 15: Cost-effectiveness results for the scenario where 75% of the watershed converts 75% of their lawn using a $500 rebate.

100% of Watershed Converts 100% of their Lawn with Rebate				
Water Company	20-year Cost ($) Self-install w/ Rebate	20-year Cost ($) Gardener-install w/ Rebate	Cost-Effectiveness ($/AF) Self-install w/ Rebate	Cost-Effectiveness ($/AF) Gardener-install w/ Rebate
City of Ventura	15497975	-6502787	457	-192
Golden State Water Company (Ojai)	3534726	2026171	289	165
Casitas (non-resale)	92631	-1285493	5	-75
Casitas Springs	37491	-466243	11	-131
Oak View	54814	-696208	10	-132
Mira Monte	-6424	-20529	-57	-181
Meiners Oaks	-202063	-971404	-30	-143
Casitas (Ojai)	-104251	-294754	-72	-203
Watershed	18904900	-8211246	235	-102

Table A2. 16: Cost-effectiveness results for the scenario where 100% of the watershed converts 100% of their lawn using a $500 rebate.

Calculating Water Quality

The dry and wet weather total nitrogen and total phosphorous reductions are broken down by water district in Table A2.17.

25% of Watershed Converts 25% of their Lawn						
	Dry Weather			Wet Weather		
Water District	Reduced Irrigation Runoff	N Reduction (lb/yr)	P Reduction (lb/yr)	Increased Infiltration (AF/yr)	N Reduction (lb/yr)	P Reduction (lb/yr)
City of Ventura	4.49	55.6	0.5	73	409	75
Golden State Water Company (Ojai)	1.75	21.6	0.2	16	90	16
Casitas (non-resale)	2.45	30.3	0.3	18	98	18
Casitas Springs	0.50	6.2	0.1	6	33	6
Oak View	0.75	9.2	0.1	9	49	9
Mira Monte	0.02	0.2	0.0	0	1	0
Meiners Oaks	0.98	12.1	0.1	9	50	9
Casitas (Ojai)	0.18	2.2	0.0	2	12	2
Watershed	11.10	137.4	1.3	133	742	136

Table A2. 17: Dry and wet weather pollution reduction estimates for the different sectors.

APPENDIX 3: GREYWATER SYSTEMS

Methods

For the greywater strategy, a new average annual water use value was found for single-family homes within each demand site. This was calculated by determining the total number of single-family homes within the demand site and then finding 25%, 50% and 75% of those households. Next we calculated how much the average per person water use would decrease if 25%, 50%, or 75% of people adopted a greywater system. This was done by multiplying the number of adopters by the gallons saved per year. Gallons saved per year were then converted into AF saved per year. We then divided that number by the total number of AF used per year in that demand site. This gave us the percent reduction in use. The new per person water use was then calculated and was used as an input in the WEAP model. The parameters used in the WEAP model are shown in table A3.1 below under the Annual Household Use AF column.

Table A3. 1: The water savings per household per AF and the new average annual household use under each adoption percentage and at each demand site.

Percent Greywater Use		Savings Per Person AF	Average Annual Household Use AF
Oak View			
	25%	0.0084	0.4356
	50%	0.0169	0.4271
	75%	0.0253	0.4187
Meiners Oaks			
	25%	0.0084	0.5676
	50%	0.0169	0.5591
	75%	0.0253	0.5507
Mira Monte			
	25%	0.0084	0.5146
	50%	0.0169	0.5061
	75%	0.0253	0.4977
Casitas Springs			
	25%	0.0098	0.4342
	50%	0.0197	0.4243
	75%	0.0295	0.4145
Ventura Water			
	25%	0.0084	0.3196
	50%	0.0169	0.3111
	75%	0.0253	0.3027
Golden State Water			
	25%	0.0100	0.5700
	50%	0.0200	0.5600
	75%	0.0299	0.5501
CMWD			
	25%	0.0084	0.7556
	50%	0.0169	0.7471
	75%	0.0253	0.7387

Results

Figure A3.1 shows the water savings in AF per year for the greywater water management strategy. Table A3.2 shows the total cost to consumers as well as the average cost per AF. Costs are shown as negative to denote a benefit to consumers over the 20-year time frame. Table A3.2 shows the full cost-effectiveness results for all three greywater scenarios.

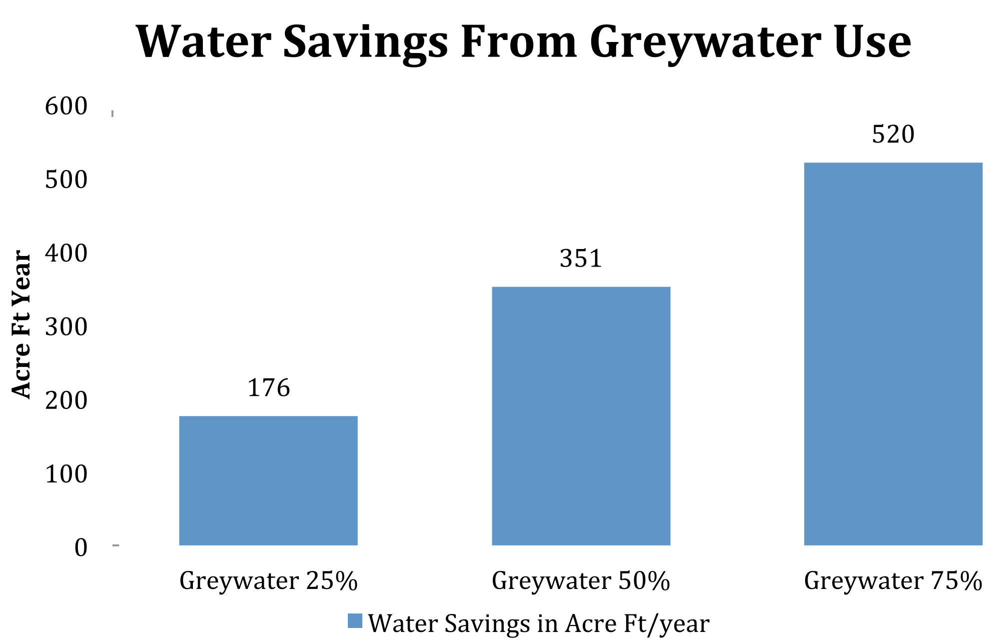

Figure A3. 1: Total AF/yr saved using the three greywater scenarios.

Percent adoption	Total Cost	Water Savings(AF)	Cost Per AF
25%	-3156.860981	176	-17.93671012
50%	-6313.721963	351	-17.98781186
75%	-9470.582944	520	-18.21265951

Table A3. 2: The total cost and cost per AF for each greywater scenario.

APPENDIX 4: SCALPING PLANT IN OJAI

WEAP Model Setup

For 'Ojai_Golf_Courses' branch (nested under the 'Demand Sites and Catchments' category, Annual Water Use Rate was changed from 500 AF/yr to 280 AF/yr.

In 'Return Flows' category, 'from OVSD WWTP' branch was chosen. This branch has a 'Return Flow Routing' field, which displays two branches 'to Return Flow Node 1' and 'to Ojai Groundwater Basin.' As a result of creating a transmission link from the OVSD WWTP to the Ojai Groundwater Basin in the Schematic view of WEAP, the 'to Ojai Groundwater Basin' branch was automatically created for this scenario in the model. The value for 'to Return Flow Node 1' a value of 90 Percent share was entered for 2001-2099 (The value is 100 percent share for the baseline year 2000). For 'to Ojai Groundwater Basin' a value of 10 Percent share was entered for 2001-2099. (The value was set to 0 for the baseline year 2000). This value of 10 Percent share was calculated as follows:

The wastewater output for OVSD treatment plant is ≈2240 AF/yr. Assuming the scalping plant strategy will provide 220 AF/yr the wastewater output should be decreased by a fraction of 220/2240 ≈ 0.098 or 10 %.

In 'Return Flows' category, 'from OVSD WWTP' branch was chosen. This branch has a 'Loss from System' field, which displays two branches 'to Return Flow Node 1' and 'to Ojai Groundwater Basin.' For this scenario, the value for 'to Return Flow Node 1' the default value of '0' for 2001-2099 was given which is same as for baseline year 2000 (since there is no loss from system from Return Flow Node 1 under this scenario. For 'to Ojai Groundwater Basin' a value of 99 Percent was entered for 2001-2099. (The value was set to 0 for the baseline year 2000), assuming the golf courses have turf grass with a crop coefficient of Kc=1 and the irrigation efficiency is nearly 100%. (*The choice of 100% irrigation efficiency is explained in the Discussion section of this report*).

Calculating Cost-Effectiveness

Tables A4.1-A4.3 show a cost-effectiveness analysis for the 'Scalping Plant in Ojai' water management strategy.

Treatment Capacity (Gallons per day)	**200,000**
Water savings in gallons/yr	730,000,00
AF saved/yr	224
AF saved/ 20 years	4480
Reclaimed water price (per unit)	2.5
One unit (gallons)	748
Water savings in units/yr	97593.6
Infrastructure costs of Scalping plant	$2,022,246
O&M costs	$ 210,000
Discount Rate	0.03

Table A4. 1: Parameters for calculation of cost-effectiveness.

Year	Cost Infrastructure '$'	Cost O&M '$'	Benefit from sale of Reclaimed Water '$'
0	2,022,246.00	210,000.00	243,983.96
1		203,883.50	236,877.63
2		197,945.14	229,978.28
3		192,179.75	223,279.88
4		186,582.28	216,776.59
5		181,147.84	210,462.70
6		175,871.69	204,332.72
7		170,749.22	198,381.28
8		165,775.94	192,603.19
9		160,947.51	186,993.39
10		156,259.72	181,546.98
11		151,708.47	176,259.20
12		147,289.77	171,125.44
13		142,999.78	166,141.20
14		138,834.74	161,302.14
15		134,791.01	156,604.02
16		130,865.06	152,042.74
17		127,053.45	147,614.31
18		123,352.87	143,314.86
19		119,760.07	139,140.64
20		116,271.91	135,088.00

Table A4. 2: Yearly NPV calculations.

	Cost '$'	Benefits '$'
20 year NPV	5,356,515.72	3,873,849.15
NPV of Costs- NPV of Benefits '$'	1,482,666.57	

Table A4. 3: NPV total.

Cost-Effectiveness = [NPV of Costs-NPV of Benefits]/Demand Decrease (AF saved in 20 years) = 1, 482, 666.57/4480 = $330.95/ AF

Comparison of $2.5/HCF (reclaimed water price) and $330/AF of water saved

1 AF= 325,851 gallons

Therefore at the cost of $330, 325,851 gallons of water can be saved

748 gallons = 1 HCF and 325,851 gallons = (1/748)* 325,851 = 435.6 HCF

Therefore at the cost of $330, 436 HCF of water can be saved or cost-effectiveness over 20 years is approximately equal to $1/HCF of water saved if reclaimed water is sold at a price of $2.5/HCF.

APPENDIX 5: INFILTRATION BASINS

To simulate this water management strategy in WEAP, a new branch called 'infiltration basins' was created in the urban category of four subcatchments: 449, 1082, 1083 and 442. An infiltration basin size of 20,000 m^2 or 4.94 acres was assigned in the four subcatchments and the equivalent amount of area deducted from low, medium, and high impervious branches. Table I shows the impervious area for all these catchments.

The scenario currently in WEAP, 'Infiltration_Basins' represents conversion of 10% of the impervious area of urban category in subcatchment 449, (the subcatchment containing Ojai), to infiltration basins. The model setup for this scenario is described below.

Additionally, although the water quality and cost estimates were calculated for both the scenarios mentioned above and these have been provided for comparison (Tables A5.4, A5.5, and A5.6) only the calculations for the 10% impervious area conversion scenario were considered for the criteria analysis (including cost- effectiveness (Table A5.7). The calculations for this scenario have been highlighted in green color in all the tables.

WEAP Model Setup

For the 'Infiltration_Basins' scenario a new branch called 'infiltration_basins' was created in the urban category of 'Catchment_ 449'. This catchment is nested under the main category 'Demand Sites and Catchments' in the WEAP model. Appropriate values were entered for four categories of 'Land Use' field in this catchment as described below.

The 'Area' category of the 'Land Use' field has the urban subcategory which is further subdivided into NoImperv, LowImperv,MediumImperv, HighImperv, Pervious branches. The 10% impervious area for this catchment is 236520 m2 (Table A5.4) and this value was entered in the created 'infiltration_basins' branch for years 2001-2099. (The value for this branch for baseline year 2000 was set to 0). An equivalent amount of area (10%) was deducted from each of the impervious categories. The resulting values are shown in Table A5.1.

Catchment_449	2000	2001-2099	Unit
Urban			m^2
NoImperv	334800	334800	m^2
LowImperv	1772100	1594890	m^2
MediumImperv	556200	500580	m^2
HighImperv	36900	33210	m^2
Pervious	0	0	m^2
Infiltration_Basins	0	236520	m^2

Table A5. 1: Pervious branch values.

In the 'Runoff Resistance Factor (RRF)' category under the 'Land Use' field, a runoff resistance factor of 10 was assigned to the 'infiltration basins' branch. The range of RRF is from 0.1 to 10 and a higher RRF indicates less runoff. It is assumed that all the water entering the infiltration basins is captured and eventually infiltrated and therefore a RRF of 10 was chosen for the 'infiltration basins' branch. For other branches of urban category, the RRF values from baseline year 2000 were used for 2001-2099.

In the 'Preferred Flow Direction' category under the 'Land Use' field, monthly preferred flow directions were assigned to the 'infiltration basins' branch as shown below. A preferred flow direction value can be in the range of 0 to 1.0. A value of 0 implies 100% vertical conductivity and a value of 1.0 implies 100% horizontal conductivity. This parameter partitions the flow out of the root zone layer between interflow and flow to the lower soil layer. Low preferred flow direction values were assigned to winter months assuming the soils have the capability to transmit a lot of water in the vertical direction during these months and little lateral flow is occurring. High values were given for summer months indicating little percolation to the lower soil layer. For other branches of urban category, the 'Preferred Flow Direction' values from baseline year 2000 were used for 2001-2099.

Month	Preferred Flow Direction Value
Jan	0.1
Feb	0.1
March	0.1
April	0.1
May	0.3
Jun	0.5
Jul	1.0
Aug	1.0
Sep	1.0
Oct	1.0
Nov	0.3
Dec	0.1

Table A5. 2: Monthly flow direction values.

In the 'K_c' category under the 'Land Use' field, monthly values for crop coefficient, 'K_c' were assigned using the Monthly Time-Series Wizard feature of WEAP model. K_c range is from 0 to 1 with 1 representing turf grass. Assuming that the drainage area for the infiltration basins is mostly impervious, K_c can be expected to be low. However since there is some evaporation even in impervious areas, values in the range of 0.1 to 0.3 were assigned depending on the season. Monthly K_c values are shown in table A5.3.

Month	Kc Value
Jan	0.0
Feb	0.0
March	0.0
April	0.1
May	0.1
Jun	0.2
Jul	0.3
Aug	0.3
Sep	0.3
Oct	0.2
Nov	0.1
Dec	0.0

Table A5. 3: K_c values for each month.

For other branches of urban category, the K_c values from baseline year 2000 were used for 2001-2099.

(Though RRF of 10 and monthly K_c values and monthly Preferred Flow Direction values were entered for both baseline year 2000 and for 2001-2099, in baseline year, infiltration basins have an area of 0 m2 so assigning RFF value and K_c values for year 2000 does not have any effect on the baseline scenario).

Catchment	**Extent of imperviousness (square meters)**				**Total Urban Area (square meters)**	**Percent of impervious area**	**Impervious Area (for 449) (square meters)**	**10% Impervious Area (for 449) (square meters)**
	Zero	Low	Medium	High				
442	428400	1535400	311400	45900	2320000	0.82		
449	344700	1772100	556200	36900	2700000	0.88	2365200	236520
1082	1241100	3841200	912600	131400	6110000	0.8		
1083	617400	1564200	810900	36000	13500000	0.18		

Table A5. 4: Impervious Cover 'I' Calculations for Different Catchments.

Table A5. 5 (a & b): Cost Calculations for Different Drainage Areas in Different Catchments.

a)

Catchment	**Drainage Area 'A' (m^2)**	**Drainage Area 'A' (acres)**	**Impervious Cover 'I'**	**Runoff Volume 'Rv'**	**Water Quality Volume/ Total Basin Volume (AF) 'V_{af}'**
		$0.00024711 * m^2$		$Rv = 0.05 + 0.9 (I)$	$P \cdot Rv \cdot A$ (acres)/12 (inch/feet)
442	20000	4.94	0.82	0.78	0.32
449	20000	4.94	0.88	0.84	0.35
1082	20000	4.94	0.8	0.77	0.32
1083	20000	4.94	0.18	0.21	0.09
10% of 449	236520	58.45	0.82	0.79	3.84

b)

Catchment	Water Quality Volume/ Total Basin Volume (cubic-feet) 'Vcf'	Construction Cost ($)	Typical Design Contingency & Other Capital Costs (30% of Construction Costs) ($)	Annual Maintenance Costs (8 % of Construction Costs) ($)	Total Cost ($)	Total Cost Adjusted for Rainfall Zone 6 ($)	Total Cost (from 1987) Adjusted for Inflation ($) [1]
	V_{af}*43560	$13.2V_{cf}^{0.69}$				Adjustment Factor = 1.24	
442	14069	9614	2884	769	13267	16451	33,247
449	15041	10067	3020	805	13892	17226	34,815
1082	13807	9489	2847	759	13095	16238	32,818
1083	3781	3882	1165	311	5358	6644	13,428
10% of 449	167183	53037	15911	4243	73191	90756	183,425

[1] Calculated from CPI Inflation Calculator from Bureau of Labor Statistics Website

Table A5. 6 (a, b, c): Water Quality Improvements Analysis for Different Catchments from Wet Weather Loadings Data.

a)

Catchment	Drainage Area 'A' for infiltration basin (acres)	Watershed Region from TMDL Document	Total Drainage Area for all Land Uses (acres) [1]	Drainage Area for Infiltration Basin as Percentage of Total Drainage Area (%)
442	4.94	Reach 4	13787	0.04%
449	4.94	San Antonio Creek Watershed	32745	0.02%
1082	4.94	Reach 4	13787	0.04%
1083	4.94	Reach 4	13787	0.04%
10% of 449	58.45	Reach 4	13787	0.42%

b)

Catchment	Wet Weather TN Load for total drainage area (lb/year)	Wet Weather TN Load for Infiltration Basin (lb/ year)	Removal Efficiency for TN (Lower Estimate) (lb/year)	Removal Efficiency for TN (Upper Estimate) (lb/year)
442	26168	9	5	6
449	27472	4	2	2
1082	26168	9	5	6
1083	26168	9	5	6
10% of 449	26168	111	61	67

c)

Catchment	Wet Weather TP Load for total drainage area (lb/year)	Wet Weather TP Load for Infiltration Basin (lb/ year)	Removal Efficiency for TP (Lower Estimate) (lb/year)	Removal Efficiency for TP (Upper Estimate) (lb/year)
442	3224	1	0.69	0.81
449	3470	1	0.31	0.37
1082	3224	1	0.69	0.81
1083	3224	1	0.69	0.81
10% of 449	3224	14	8.2	9.6

[1] Total Drainage Area for all Land Uses and, TN and TP Load information obtained from July 20, 2012 Draft Document: Algae, Eutrophic Conditions, and Nutrients Total Maximum Daily Loads For Ventura River and its Tributaries

Calculating Cost-Effectiveness

Table A5. 7 (a, b, c): Cost-effectiveness analysis for the infiltration basins water management strategy.

a)

Construction Costs of (Adjusted for Rainfall Zone 6)	In 1987 dollars	In 2012 dollars	Units
	65,766	132918	$
Other Capital Costs (Adjusted for Rainfall Zone 6)	In 1987 dollars	In 2012 dollars	
	19730	39876	$
Maintenance Costs (Adjusted for Rainfall Zone 6)	In 1987 dollars	In 2012 dollars	
	5,261	10633	$
Discount Rate	0.03		
AF saved/yr	281		AF
AF saved/ 20 years	5,620		AF
Gallons saved/yr	91,564,131		Gallons
Gallons saved/20 years	1831282620		Gallons

b)

Year	Cost Infrastructure '$'	Cost O&M '$'
0	172794	10633
1		10952
2		11281
3		11619
4		11968
5		12327
6		12696
7		13077
8		13470
9		13874
10		14290
11		14719
12		15160
13		15615
14		16083
15		16566
16		17063
17		17575
18		18102
19		18645
20		19204

c)

	Cost '$'	Benefits '$'
20 year NPV	477,711.07	0.00
NPV of Costs- NPV of Benefits '$'	477,711.07	

Cost-Effectiveness = [NPV of Costs-NPV of Benefits]/Supply Increase (Acre ft saved in 20 years) = 477,711.07/5620 = **$85/ AF**

APPENDIX 6: WATER RATE INCREASE TO STATE AVERAGE

Methods

Table A6.1 shows the data used to determine the percent reduction in water use under each price elasticity of demand due to a rate increase to state average. Percent reductions are calculated by multiplying the percent rate increase (181.6 or 284.2) by the price elasticity. This gives you the percent reduction in demand. Table A6.2 shows the associated decrease in average per household water use. The parameters shown in Table A6.2 were then used as inputs in WEAP.

	Meiners Oaks	CMWD
Current Price	$1.38	$0.88
% below state average	181.6	284.2
Percent reduction due to an increase in state average and PED of -0.15	27.24%	42.63%
Percent reduction due to an increase in state average and PED of -0.2	36.32%	56.84%
Percent reduction due to an increase in state average and PED of -0.25	45.4%	71.05%

Table A6. 1: The percent reduction in demand for both CMWD and Meiners Oaks water district customers at various price elasticity's of demand.

		New Annual Household Water Use (AF)		
Provider	Per Person Water Use (original)	0.15 PED	0.2 PED	0.25 PED
CMWD	0.764	0.438	0.330	0.221
Meiners Oaks	0.576	0.419	0.367	0.314

Table A6. 2: Annual water use per household in AF before and after a rate increase to state average. New water use values were input into the WEAP model for average household demand at both CMWD and Meiners Oaks demand sites.

Results

Results for all price elasticity of demands and both water purveyors are shown below in Table A6.3. Total cost is given on a per year basis. Table A6.3 shows the average reduction in water use and the total cost to consumers. Note that with the lowest price elasticity, there is a benefit to consumers and a cost to purveyors. Table A6.4 gives total costs per year for all price elasticity of demands given as well as the total cost over 20 years and the average price per AF over 20 years.

Casitas	Percent Reduction In use	New Water Use (HCF)	New Cost/YR	Difference From Old Cost/YR	Total Cost
-.15 Price Elasticity	42%	193	$483	$190	$515,591
-.2 Price Elasticity	56%	146	$ 366	$73	$199,000
-.25 Price Elasticity	71%	97	$241	$(52)	$(140,205)
Meiners Oaks					
-.15 Price Elasticity	27%	183	$456	$110	$201,570
-.2 Price Elasticity	36%	160	$399	$53	$97,341
-.25 Price Elasticity	45%	137	$342	$ (4)	$(6,887)

Table A6. 3: Full results for the increase to state average scenario showing all price elasticity's of demand. Difference from old cost per year column shows increase in price per person on average.

Year	Cost Per year -0.1 PED	Year	Cost Per year -0.15 PED	Year	Cost Per year -0.2 PED
0	$ 717,161.28	0	$ 296,341.47	0	$ (147,092.00)
1	$ 696,273.09	1	$ 287,710.16	1	$ (142,807.76)
2	$ 675,993.29	2	$ 279,330.26	2	$ (138,648.31)
3	$ 656,304.17	3	$ 271,194.42	3	$ (134,610.01)
4	$ 637,188.51	4	$ 263,295.56	4	$ (130,689.33)
5	$ 618,629.62	5	$ 255,626.75	5	$ (126,882.85)
6	$ 600,611.28	6	$ 248,181.31	6	$ (123,187.23)
7	$ 583,117.75	7	$ 240,952.73	7	$ (119,599.25)
8	$ 566,133.74	8	$ 233,934.69	8	$ (116,115.78)
9	$ 549,644.41	9	$ 227,121.06	9	$ (112,733.77)
10	$ 533,635.35	10	$ 220,505.88	10	$ (109,450.26)
11	$ 518,092.57	11	$ 214,083.38	11	$ (106,262.39)
12	$ 503,002.49	12	$ 207,847.94	12	$ (103,167.37)
13	$ 488,351.94	13	$ 201,794.12	13	$ (100,162.49)
14	$ 474,128.09	14	$ 195,916.62	14	$ (97,245.14)
15	$ 460,318.54	15	$ 190,210.31	15	$ (94,412.76)
16	$ 446,911.20	16	$ 184,670.21	16	$ (91,662.87)
17	$ 433,894.37	17	$ 179,291.46	17	$ (88,993.08)
18	$ 421,256.67	18	$ 174,069.38	18	$ (86,401.05)
19	$ 408,987.06	19	$ 168,999.40	19	$ (83,884.51)
20	$ 397,074.81	20	$ 164,077.09	20	$ (81,441.27)
Total Cost	$ 11,386,710.23		$ 4,705,154.21		$ (2,335,449.48)
Cost Per AF	518.3305572		160.4370692		-63.80221169

Table A6. 4: NPV and cost/AF calculation for all three price elasticity's of demand from the perspective of the consumer.

APPENDIX 7: WATER RATE INCREASE TO FULL COST PRICING

Methods

With a -0.3 price elasticity of demand, raising rates by 10% will result in a 3% decrease in demand. Following this logic, we would need to increase rates by 33% in order to increase revenue by 20% this calculation is shown through the following equations. All data was gathered through the Casitas Municipal Water District financial statement and the CMWD website.

Calculations for 20% increase in revenue for CMWD

*.33 rate increase * $.88 current rate = $.29 increase in rates*

$.29 increase in rate + $.88 current rate = $1.173 new rate

*2076 current water use AF * 0.9 new consumption rate = 1868.4 new water use AF*

1868.4 AF / 0.00229568411 HCF per AF = 813875.091 HCF

*813875.091 HCF * $1.173 = $954,964.64 new revenue*

$795,788.93 old revenue -$954,964.64 new revenue = $159,157.71 change in revenue

$159,157.71 change in revenue/$795,788.93 old revenue = 20%

APPENDIX 8: CONVERSION TO PERVIOUS STREETS

Methods

Table A8.1 displays the parameter and input values used in the WEAP model to simulate the conversion to pervious streets in catchment 449.

Parameter / Input	Value	Data Source
K_c	0.1	EPA, 1999
Runoff Resistance	8	City of Portland Green Streets Program

Table A8. 1: K_c and runoff resistance values used for the pervious streets scenario.

APPENDIX 9: SAN ANTONIO SPREADING GROUNDS

Methods

Table A9.1 displays the regression equations that were used to calculate monthly diversion volumes for the San Antonio Spreading Grounds.

Month	Regression Equation
Jan	y= 0.3744x-0.0888
Feb	y=0.2783x+0.1895
March	y=0.066x+0.3806
April	y=0.0261x+0.2433
May	y=0.0448x+0.001
June	y=0
July	y=0
Aug	y-0
Sep	y=0
Oct	y=0.0275x-0.0143
Nov	y=0.0225x-0.0141
Dec	y=0.1217x-0.0899

Table A9. 1: Regression equations used in the San Antonia Spreading Grounds scenario.

In the regression equations displayed in the table, y is equal to the monthly diversion in AF and x is equal to the amount of precipitation in millimeters in that month at Precipitation Gage 30D.

APPENDIX 10: LAND USE CHANGE (CROP CONVERSIONS)

Methods

Table A10.1 displays the K_c values assigned to raspberry cropland in each month. These values were derived from the 'BISe.xls' spreadsheet (Snyder R. L., Orang, Bali, & Eching, 2007).

Month	Kc Value
January	0.25
February	0.3
March	0.35
April	0.4
May	0
June	0
July	0
August	0
September	0.7
October	0.7
November	0.2
December	0.25

Table A10. 1: K_c values assigned to raspberry croplands in each month.

Based on the differences in water demand per acre between orange orchards and raspberry fields identified in ITRC, 2010, changes in annual demand at the six agricultural demand sites within the WEAP model were calculated (Table A10.2)

Demand Site	Annual Water Demand (AF) - Baseline	Annual Water Demand (AF) - 25% Crop Conversions	Annual Water Demand (AF) - 50% Crop Conversions	Annual Water Demand (AF) - 75% Crop Conversions
OGWB Ag from CMWD	3601	4002	4402	4803
UVRGWB Ag from CMWD	1177	1308	1439	1570
LVRGWB Ag from CMWD	3011	3346	3681	4016
OGWB Ag	2483	2759	3035	3312
UVRGWB Ag	1898	2109	2320	2531
LVRGWB Ag	522	580	638	696

Table A10. 2: Changes in annual demand at six agricultural demand sites.

Results

The following Tables A10.3-A10.8 display model results from the increases in water demand resulting from crop conversions from oranges to raspberries.

	January	February	March	April	May	June	July	August	September	October	November	December
Baseline	210953	218171	220798	220738	218956	216689	213840	211001	208535	206905	205577	205815
25% Oranges to Raspberries	208124	215789	218362	218249	216405	214089	211207	208295	205767	204084	202695	202873
50% Oranges to Raspberries	205698	213439	216294	216141	214245	211889	208948	205979	203421	201671	200225	200345
75% Oranges to Raspberries	202377	210349	213352	213141	211211	208795	205794	202768	200160	198349	196838	196905

Table A10. 3: 100-year Monthly Average Lake Casitas Storage Volumes (AF).

	January	February	March	April	May	June	July	August	September	October	November	December
Baseline	44223	44336	44455	44562	44544	44490	44387	44256	44118	44049	43996	43956
25% Oranges to Raspberries	42954	43065	43182	43286	43266	43210	43107	42975	42835	42763	42707	42664
50% Oranges to Raspberries	41842	41952	42067	42169	42147	42090	41985	41853	41711	41637	41578	41532
75% Oranges to Raspberries	40368	40476	40587	40686	40662	40603	40497	40363	40220	40142	40081	40032

Table A10. 4: 100-year Monthly Average Ojai Groundwater Basin Storage Volumes (AF).

	January	February	March	April	May	June	July	August	September	October	November	December
Baseline	32839	33356	33787	34057	34053	33951	33725	33386	32984	32782	32651	32666
25% Oranges to Raspberries	32685	33211	33660	33941	33939	33835	33602	33254	32845	32634	32494	32500
50% Oranges to Raspberries	32526	33063	33531	33825	33824	33715	33475	33120	32702	32483	32335	32332
75% Oranges to Raspberries	32351	32906	33390	33692	33701	33588	33341	32978	32552	32324	32167	32156

Table A10. 5: A10.3: 100-year Monthly Average Upper Ventura River Groundwater Basin Storage Volumes (AF).

	January	February	March	April	May	June	July	August	September	October	November	December
Baseline	45826	32484	36197	32806	39212	40687	44976	42216	36908	35279	35249	41771
25% Oranges to Raspberries	45595	32295	35949	32573	38756	40211	44451	41726	36760	35140	35016	41532
50% Oranges to Raspberries	45397	32135	35741	32379	38345	39780	43975	41284	36656	35039	34819	41327
75% Oranges to Raspberries	45183	31960	35512	32166	37912	39326	43475	40818	36530	34918	34603	41105

Table A10. 6: 100-year Monthly Average Potential Evapotranspiration (AF).

	January	February	March	April	May	June	July	August	September	October	November	December
Baseline	24597	21732	26400	22619	24211	21391	19275	14472	10387	10075	11455	16901
25% Oranges to Raspberries	24536	21659	26291	22536	23995	21204	19111	14354	10517	10162	11431	16861
50% Oranges to Raspberries	24484	21597	26201	22469	23793	21027	18957	14242	10651	10252	11411	16826
75% Oranges to Raspberries	24427	21527	26099	22390	23581	20842	18795	14125	10780	10339	11388	16788

Table A10. 7: 100-year Monthly Average Actual Evapotranspiration (AF).

	January	February	March	April	May	June	July	August	September	October	November	December
Baseline	293	429	267	81	60	22	16	12	10	5	7	19
25% Oranges to Raspberries	295	421	269	81	61	22	16	12	10	5	7	20
50% Oranges to Raspberries	296	415	268	81	61	22	17	13	10	6	7	20
75% Oranges to Raspberries	298	412	266	81	62	23	17	13	11	6	7	21

Table A10. 8: 100-year Monthly Average Ventura River Live Reach Streamflow (cfs).

APPENDIX 11: CLIMATE CHANGE

Temperature Data Sources

Only one weather station was used to simulate temperature throughout the entire watershed for the modeled years of 2010-2099. During our initial meteorological research we could only find one weather station with readily available and verifiable temperature data in the watershed. The temperature data was retrieved from the National Climatic Data Center (NCDC) maintained by the National Oceanic and Atmospheric Administration (NOAA). Maximum, minimum, and temperature at the time of observation data was retrieved for the Ojai, California station, for the time period starting on January 1, 1990 to December 31, 2010. The NCDC identification number for this station is, Global Historic Climatology Network Database (GHCND):USC00046399. This was the data set we used to extrapolate future temperature out to the year 2099.

Temperature Increase Procedure

First, we converted the temperature data from Fahrenheit to Celsius then we calculated daily mean temperature by averaging the daily maximum and minimum temperature values. Secondly, using the daily mean temperature values we converted these into mean monthly temperature values since we used a monthly time-step in the WEAP model. We extrapolated this data from the year 2010 to the year 2099 based on the empirical data from 1990-2009.

Average annual temperature was increased beginning in the modeled year 2010, using the extrapolated data described above. Starting in 2010 annual temperature was incrementally increased until the year 2099, the final year we choose to model in this scenario. By that year we increased the average annual temperature 4 °C higher than the historic temperature data obtained for the study. This incremental temperature increase was accomplished using the following equation.

$$T_2 = T_1 + \left(\frac{Tp}{90} \cdot 4\right)$$

Where: T_2 = Temperature new

T_1 = Temperature initial (empirical data)

T_p = Time period

Each year was assigned a time period beginning in 2010 which was assigned time period 1 and ending in 2099 which was assigned time period 90. Since we used monthly time-step in the WEAP model, each month was assigned the time period (T_p) pertaining to the year it occurred. For example January through December of 2010 were assigned a time period of 1 and January through December of 2011 were assigned a time period of 2. After these assignments and entering all the data in a table, the above equation was used to extrapolate new monthly average temperature values (T_2), based on empirical data (T_1) from 1990-2009. The result of this procedure was that by the final year, 2099, the mean monthly temperature for all months January through December was 4 °C higher than empirical data. The output of these data extrapolations was mean monthly temperature; this data was saved in a CSV file format and loaded into WEAP.

Precipitation Gauges Used

All precipitation data was obtained from the Ventura County Watershed Protection District Hydrologic (VCWPD) Data Webpage. Table A11.1 below lists the eleven precipitation gauges used to model future climate change. Daily precipitation from data from 1990-2009 was downloaded from each station.

Station Name	VCWPD Station ID
Casitas Dam	004A
Ventura River County Water District	020B
Ojai - County Fire Station	030D
Ojai - Thacher School	059
Upper Ojai Summit- County Fire Station	065
Canada Larga	085
Ventura - Kingston Reservoir	122
Matilija Dam	134B
Oak View - County Fire Station	140
Sulfur Mountain	163C
Wheeler Gorge	264

Table A11. 1: Precipitation gauges used to model climate change.

Precipitation Change Procedure

We converted all the daily precipitation values from inches to millimeters then we summed the values to obtain total monthly precipitation at each gauge station. This data was extrapolated from the year 2010 to 2099 using the 1990-2009 empirical dataset.

Monthly precipitation was increased or decreased incrementally beginning in the modeled year of 2010 using the extrapolated data described previously. Starting in the initial model year annual average precipitation was decreased by 10% or 20% and increased by 10% or 20% by the end of the modeled time period 2099. The monthly precipitation values were used to complete these four extrapolations; the following equation was used to obtain the modeled values of future monthly precipitation.

$$P_2 = P_1 \pm \left(\frac{Tp}{90} \cdot C\right)$$

Where: P_2 = Precipitation new

P_1 = Precipitation initial (empirical data)

T_p = Time period

C = Percentage Change (-0.20, -0.10, 0.10, 0.20)

Similar to the extrapolation of temperature data, each year was assigned a time period beginning in 2010 which was assigned time period 1 and ending in 2099 which was assigned time period 90. Since we used monthly time-step in the WEAP model, each month was assigned the time period (T_p) pertaining to the year it occurred. For example January through December of 2010 were all assigned a time period of 1 and January through December of 2011 were all assigned a time period of 2. After these assignments and entering all the data in a table, the above equation was used to calculate extrapolated monthly average precipitation (P_2), based on empirical data (P_1) from 1990-2009. This procedure was completed four times, once for each change in precipitation (±10% or ±20%). The result of this procedure was that by the final year, 2099, the monthly precipitation was either 10% or 20% higher or lower than the empirical data. The output of these data extrapolations was total monthly precipitation; this data was saved in a CSV file format and loaded into WEAP.

BIBLIOGRAPHY

ACOE, District, L. A., & VCWPD. (2004). *Matilija Dam ecosystem restoration feasibility study final report.*
AECOM. (2012). *Decentralized wastewater treatment in the City of Sugar Land and Sugar Land's extra territorial jurisdictions.* Texas Water Development Board.

Alvarado, V., & Manrique, E. (2010). Enhanced Oil Recovery Update. *Oil Recovery , 3* (9), 1529-1575.
American Water Works Association. (2003). *Water reuse rates and charges survey Results.*

BAIRWMP. (2012). *2013 Bay Area Integrated Regional Water Management Plan Frequently Asked Questions.* Retrieved December 2012, 2012, from Bay Area Integrated Regional Water Management Plan: http://bairwmp.org/content/frequently-asked-questions#15-where-does-california

Beckwith, D., Ciarametaro, C., Dehner, M., Rossiter, M., & Siew, R. J. (2007). *Evaluation of rainfall-runoff relationships to develop stormwater reduction approaches for watersheds in Southern California.* University of California, Santa Barbara, Bren School of Environmental Science & Management.

Bloomberg. (2013). *United States Government Bonds, U.S. Treasury Yields.* Retrieved February 10, 2013, from Bloomberg: http://www.bloomberg.com/markets/rates-bonds/government-bonds/us

Byrne, K. (2012). *Decentralized Scalping Plants.* Retrieved November 2012, from http://www.cwea.org/e-bulletin/images/ByrnePaper.pdf

CA Department of Transportation. (2012). *California Economic Forecast: California County-Level Economic Forecast 2012-2040.*

California Energy Commission. (2012). *Climate change and sea level rise scenarios for California vulnerability and adaptation assessment.*

California Stormwater Quality Association. (2003). *California Stormwater BMP Handbook - New Development and Redevelopment.* Retrieved from California Stormwater Quality Association: http://www.cabmphandbooks.com/Documents/Development/TC-11.pdf

California Water Code Division 6. (2013). Part 2.6 Urban water management planning. *Water Code Section 10610-10656* .

Cardno Entrix. (2012). *Ventura River Watershed Protection Plan Report.*
Chapter 4: Retention Basins. (n.d.). Retrieved November 2012, from Stormwater Management Guidebook Chapter 4: https://docs.google.com/viewer?a=v&q=cache:eXoJLYvHESEJ:www.michigan.gov/documents/deq/lwm-smg-04_202867_7.pdf+&hl=en&gl=us&pid=bl&srcid=ADGEESi5VoF0ounVO4arnOjPw4woQJrbnXFX8G6PzZ0yJOpM40-HqJnrh2E8-QXM0hXMiNoqpUFdJ-PSOM0npwUv52hSmC4zSopgpnZTdkThy9nqsgPRi5

City of Portland Oregon. (2012). *Green Streets*. Retrieved from Environmental Services: http://www.portlandoregon.gov/bes/44407

CMWD. (2012). *Annual Hydrology Reports, Years 2004-2009*.

CMWD. (2010). *Comprehensive Annual Financial Report.* Oak View, CA: Steve Wickstrum.

CRWQCB. (2012). *Algae, Eutrophic Conditions, and Nutrients Total Maximum Daily Loads for Ventura River and its Tributaries.* California Regional Water Quality Control Board, Los Angeles Region.

Dale, L., & Fujita, K. S. (2009). *Price impact on demand for water and energy in California residences.* California Climate Change Center.

Daniel B. Stephens & Associates, Inc. (2010). *Groundwater budget and approach to a Groundwater Management Plan Upper and Lower Ventura River Basin.* Ventura County Watershed Protection District.

Davis, A. P., Hunt, W. F., Traver, R. G., & Clar, M. (2009). Bioretention technology: Overview of current practice and future needs. *Journal of Environmental Engineering , 15* (3), 109-117.

Department of Water Resources. (2012). *Integrated Regional Water Management Grants.* Retrieved December 12, 2012, from California Department of Water Resources: http://www.water.ca.gov/irwm/grants/guidelines.cfm

Detention Ponds and Basins. (n.d.). Retrieved November 2012, from fg05_07_stormwaterman.pdf: https://docs.google.com/viewer?a=v&q=cache:o-k4LsA-iM0J:oa.mo.gov/fmdc/dc/fmdc_dip/10%2520Water%2520Quality/fg05_07_stormwaterman.pdf+&hl=en&gl=us&pid=bl&srcid=ADGEESjsZx-SJRyNTgLHaGcOg8C6NRdxAT7nbnq7UVIbz5rlUz21pYTg1BHG_bRS5DvjLj31f77Mco-52IzIg2zUxEaSCjX

Dettinger, M. D. (2005). From climate-change spaghetti to climate-change distributions for 21st century California. *San Fracisco Estuary and Watershed Science , 3* (1), Article 4.

DWR. (2000). *Agricultural Land Use Survey.* Retrieved 2012, from Department of Water Resources: http://www.water.ca.gov/landwateruse/lusrvymain.cfm

DWR. (1995). *Greywater guide.* Retrieved December 12, 2012, from California Department of Water Resources: http://www.water.ca.gov/wateruseefficiency/docs/graywater_guide_book.pdf

DWR. (2012, November). *IRWMP Guidelines.* Retrieved Decemeber 12, 2012, from CA Department of Water Resources: http://www.water.ca.gov/irwm/grants/guidelines.cfm

DWR Office of Water Use Efficiency. (2012). Retrieved December 12, 2012, from California Irrigation Management Information System: http://wwwcimis.water.ca.gov/cimis/welcome.jsp

DWR. (2013). *Senate Bill SB X7-7 2009: The Water Conservation Act of 2009*. Retrieved February 15, 2013, from California Department of Water Resources.

DWR. (2004). *South Coast Hydrologic Region Upper Ojai Valley Groundwater Basin Bulletin 118*. Retrieved 2012, from California Department of Water Resources: http://www.water.ca.gov/pubs/groundwater/bulletin_118/basindescriptions/4-1.pdf

Farm Bureau of Ventura County. (2012). *The Crop Report*. Retrieved December 12, 2012, from Farm Bureau of Ventura County: http://www.farmbureauvc.com/crop_report.html#

Frame, K. (2009). *Helping Californians Irrigate Efficiently.* Retrieved January 12, 2013, from California Irrigation Management Information System: http://wwwcimis.water.ca.gov/cimis/resourceArticleOthersHelpingIrrigate.jsp

Friends of Ventura River. (2012). *Watershed U*. Retrieved December 12, 2012, from Friends of Ventura River: http://friendsofventurariver.org/watershed-resources/watershed-u/

Golden State Water Company. (2011). *2010 Urban Water Management Plan - Ojai.*

Green, R. L. (2006). *Trends in Golf Course Water Use and Regulation in California.* University of California, Riverside, Department of Botany and Plant Sciences.

Greywater Action. (2012). Retrieved December 12, 2012, from Greywater Action: http://greywateraction.org

Hanak, E., & Davis, M. (2006). *Lawns and Water Demand in California.* San Francisco: Public Policy Institute of California.

Hoff, H., Bonzi, C., Joyce, B., & Tielborger, K. (2011). A Water Resources Planning Tool for the Jordan River Basin. *Water , 3* (3), 718-736.

Hopkins, C. J. (2006, June 26). Letter from Hopkins Groundwater Consultants to Karen Waln. Ventura, CA.

Idso, S. B., & Brazel, A. J. (1984). Rising atmospheric carbon dioxide concentrations may increase streamflow. *Nature , 312*, 51-53.

IPCC. (2007). *Climate change 2007 synthesis report.* Intergovernmental Panel on Climate Change (IPCC).

Islam, A., Ahuja, L. R., Garcia, L. A., Ma, L., & Saseendran, A. S. (2012). *Modeling the effect of elevated CO2 and climate change on reference evapotranspiration in the semi-arid central Great Plains.* St. Joseph, MI: American Society of Agricultural and Biological Engineers.

ITRC. (2010). Evaluation of Strengths and Weaknesses of the Existing FCGMA IE Program and Specific Suggestions for Improvement. Retrieved December 2012, from http://www.fcgma.org/news/FCGMA%20ITRC%20IE%20Report%20Task%202-2.pdf

Joyce, B., Kirschen, P., & Mitchel, D. (2008). *Evaluating the joint management of storm water, waste water, and water supply: Application of WEAP in Sharon, MA.*

Kear, J. (2012). (R. Gardner, Interviewer)

Kear, J. L. (2005). *Hydrogeology of the Ojai Groundwater Basin: Storativity and confinement, Ventura County, CA.* California State University, Northridge.

Kennedy/Jenks Consultants. (2011). *2010 Urban Water Management Plan - City of Ventura.* Ventura Water.

LeRoy, E. (2005). *A study of the development of water resources in the Olifants catchment, South Africa: Application of the WEAP model.* Imperial College, London.

LID Center. (2007). *Permeable Pavers Cost.* Retrieved January 21, 2007, from Low Impact Development Center: http:// www.lid-stormwater.net/permeable_pavers/permpaver_costs.htm

Long Beach Water Department. (2012). *Lawn-to-Garden Turf Replacement Program.* Retrieved November 15, 2012, from Long Beach Lawn-to-Garden: http://www.lblawntogarden.com

Matilija Coalition. (2012). Retrieved December 12, 2012, from Matilija Coalition: http://www.matilija-coalition.org

McCartney, M., & Arranz, R. (2009). Evaluation of Water Demand Scenarios for the Olifants River catchment, South Africa. *International Journal of River Basin Management , 7* (4), 379-390.

Miller, J. M. (1991, July 16). Study urges reclaimed water use. *Los Angeles Times* .
Ministry of Food and Fisheries. (2012). Water Conservation Factsheet. British Columbia, Canada.

Montgomery, J. M. (1987). *Feasibility of importing state project water into Ventura County.*
Monthly Weather for Ojai. (2012, December 12). Retrieved December 12, 2012, from The Weather Channel: http://www.weather.com/weather/wxclimatology/monthly/93023

Moore, M. R. (1980). *Factors influencing the survival of juvenile steelhead rainbow trout (Salmo gairdneri gairdneri) in the Ventura River, California.* Humboldt State University, Arcata, CA.

Nash, J. E., & Sutcliffe, J. V. (1970). River flow forecasting through conceptual models part 1 - A discussion of principles. *Journal of Hydrology , 10* (3), 282-290.

Nataraj, S. (2007). *Do Residential Water Consumers React to Price Increases? Evidence from a Natural Experiment in Santa Cruz.* Giannini Foundation of Agricultural Economics.

National Research Center. (2002). *A National Study of Water and Energy Consumption in Multifamily Housing.* Boulder, CO: Multi-housing Laundry Association.

Natural Resource Conservation Service. (2012). *Soil survey geographic database.*

NMFS. (2003). *Biological Opinion for steelhead.* National Marine Fisheries Service, Southwest Region.

NMFS. (2007). *Draft Biological Opinion on the issuance of Army Corps 404 permit authorization for City of Ventura's Foster Park Well Facility Repairs Project.* National Marine Fisheries Service, Southwest Region.

NMFS. (2012). *Southern California steelhead recovery plan.* National Marine Fisheries Service, Southwest Region, Protected Resources Division, Long Beach, CA.

Null, S. E., Viers, J. H., & Mount, J. F. (2010). Hydrologic Response and Watershed Sensitivity to Climate Warming in California's Sierra Nevada. *PLoS ONE , 5* (4), e9932.

Ojai Basin Groundwater Management Agency. (2010). *Annual Report.*

Ojai Valley Green Coalition. (2012). *Watershed Council.* Retrieved December 12, 2012, from Ojai Valley Green Coalition: http://ojaivalleygreencoalition.com/Watershed_Council.shtml
Ojai Valley Land Conservancy. (2012). Retrieved December 12, 2012, from Ojai Valley Land Conservancy: http://www.ovlc.org/

Ojai Valley Sanitary District. (2012). Retrieved December 12, 2012, from Ojai Valley Sanitary District: http://www.ojaisan.org/

Olmstead, S. M., & Stavins, R. N. (2007). *Managing Water Demand: Price vs. Non-Price Conservation Programs.* Pioneer Institute.

Orang, M., Bali, K., & Eching, S. (2007). *Basic irrigation scheduler excel worksheet.* Retrieved December 12, 2012, from BIS: http://biomet.ucdavis.edu/irrigation_scheduling/bis/BIS.htm

Padre Associates, Inc. (2011). *San Antonio Creek Spreading Grounds Rehabilitation Project Draft Mitigated Negative Declaration.* Ventura County Watershed Protection District.

Rodriguez, L. (2012). *Local and Statewide Water Efficiency Programs.* Watershed Coalition of Ventura County.

Roy-Poirier, A., Champagne, P., & Filion, Y. (2010). Review of bioretention system research and design: Past, present, and future. *Journal of Environmental Engineering , 136* (9), 878-889.

San Francisco Water and Power. (2011). *Graywater.* Retrieved December 12, 2012, from San Francisco Water and Power: http://www.sfwater.org/index.aspx?page=100

SEI. (n.d.). WEAP User Guide.

SEI. (n.d.). *Why WEAP?* Retrieved November 2012, from WEAP: http://www.weap21.org/index.asp?action=201

Smith, J. J. *Winter steelhead and chinook and coho salmon life cycles and habitat requirements.* San Jose University, Department of Biological Sciences.

Snyder, R. L., Orang, M. N., Matyac, J. S., Sarrashteh, S., & Kadir, T. (2009). *Delta evapotranspiration of applied water - DETAW.* Retrieved December 12, 2012, from California Water Plan Update: http://www.waterplan.water.ca.gov/docs/cwpu2009/0310final/v4c03a05_cwp2009.pdf

Snyder, R. L., Orang, M., Bali, K., & Eching, S. (2007, April). Basic Irrigation Scheduling (BIS). Retrieved December 2012, from http://biomet.ucdavis.edu/irrigation_scheduling/bis/BIS.htm

Sovocol, K. A. (2005). *Xeriscape conversion study final report.* Southern Nevada Water Authority.

Stream Team. (2012). Retrieved December 12, 2012, from Stream Team: http://stream-team.org/volunteer.html

Surfrider Foundation. (2012). *Ocean Friendly Gardens*. Retrieved February 3, 2013, from Surfrider Foundation: http://www.surfrider.org/programs/entry/ocean-friendly-gardens

Surfrider Foundation. (2012). *Ventura County Chapter*. Retrieved December 12, 2012, from Surfrider Foundation: http://ww2.surfrider.org/ventura/

Tetra Tech. (2009). *Baseline model calibration and validation report (Ventura River Hydrology Model).* San Diego, CA.

Tetra Tech. (2008). *Data Summary Report (Ventura River Watershed Hydrology Report).*

Tetra Tech. (2009). *Natural Condition Report (Ventura River Watershed Hydrology Model).* San Diego, CA.

The Groundwater Foundation. (2012). *Rain Gardens 101*. Retrieved November 15, 2012, from The Groundwater Foundation: http://www.groundwater.org/ta/raingardens.html

UCCES. (2012). *The environmental characteristics of Ventura County and its soils*. Retrieved December 12, 2012, from University of California Cooperative Extension Agriculture and Natural Resources Ventura County: http://ceventura.ucanr.edu/Com_Ag/Soils/The_environamental_characteristics_of_Ventura_County_and_its_soils_/General_Soil_Map/

University of Rhode Island. (2005). *Permeable Pavement: What's it doing on my street?* University of Rhode Island Cooperative Extension in partnership with the Rhode Island Department of Health Source Water Protection Program.

US Bureau of Reclamation. (2012). *Matilija Dam Ecosystem Restoration Project, California*. Retrieved January 12, 2012, from US Bureau of Reclamation: http://www.usbr.gov/pmts/sediment/projects/Matilija/MatilijaDam.html

US Department of Labor. (2012). *CPI Inflation Calculator*. Retrieved December 12, 2012, from Bureau of Labor Statistics: http://www.bls.gov/data/inflation_calculator.htm

US EPA. (2012). *Infiltration Basin*. Retrieved December 12, 2012, from National Pollutant Discharge Elimination System (NPDES): http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=69

US EPA. (1999). *Storm Water Technology Fact Sheet: Porous Pavement.* EPA 832-F-99-023, United States Environmental Protection Agency, Office of Water, Washington, DC.

US EPA. (1999). *Urban Stormwater Best Management Practices Study*. Retrieved December 12, 2012, from EPA Stormwater: http://water.epa.gov/scitech/wastetech/guide/stormwater/upload/2006_10_31_guide_stormwater_usw_d.pdf

US EPA. (2012). *Water & Wastewater Pricing*. EPA.

US EPA. (2012, December 12). *Watershed Assessment, Tracking & Environmental Results*. Retrieved December 12, 2012, from US Environmental Protection Agency: http://iaspub.epa.gov/tmdl_waters10/attains_watershed.control?p_huc=18070101&p_cycle=&p_report_type=T

US EPA. (2013). *What is Green Infrastructure?* Retrieved February 12, 2013, from US EPA: http://water.epa.gov/infrastructure/greeninfrastructure/gi_what.cfm#bioswales

USGS. (2006). *National Landcover Dataset.* Retrieved 2012, from The National Map Viewer: http://viewer.nationalmap.gov/viewer/

USGS. (2012). *USGS Hydrography Data.* Retrieved 2012, from USGS National Hydrography Data: http://nhd.usgs.gov/

VCWPD. (2006). *Hydrological Data Server.* Retrieved 2012, from Ventura County Watershed Protection District: http://www.vcwatershed.net/hydrodata/

VCWSQMP. (2012). Retrieved 2012, from Ventura Countywide Stormwater Quality Management Program: http://www.vcstormwater.org

Veatch, B. &. (2006). *California Water Rate Survey.* Los Angeles,CA.

Ventura Hillsides Conservancy. (2012). Retrieved December 12, 2012, from Ventura Hillsides Conservancy: http://venturahillsides.org/

Ventura River Ecosystem. (2012, December). *Matilija Dam 2012 Update*. Retrieved January 12, 2013, from Ventura River Ecosystem: http://www.venturariver.org/2012/12/matilija-dam-2012-update.html

VenturaRiver.org. (2011, April 28). *San Antonia Spreading Grounds*. Retrieved December 12, 2012, from Ventura River Ecosystem: http://www.venturariver.org/2011/04/san-antonio-creek-spreading-grounds.html

VRWC. (2012). *Mission & Priorities*. Retrieved December 12, 2012, from Ventura River Watershed Council: http://www.venturawatershed.org/mission-priorites

VRWC. (2012). *The Management Plan.* Retrieved January 12, 2013, from Ventura River Watershed Council: http://venturawatershed.org/the-watershed-plan

VRWC. (2012). *Ventura River Watershed News – OCT. 23, 2012*. Retrieved November 2012, from Ventura River Watershed Council: http://www.venturawatershed.org/blog/1497

Watershed Protection District. (2013). *San Antonio Spreading Grounds Rehabilitation Project*. Retrieved 2013, from County of Ventura: http://portal.countyofventura.org/portal/page/portal/PUBLIC_WORKS/Watershed_Protection_District/Programs_and_Projects/Prop%2050%20V-2%20San%20Antonio%20Creek%20Spreading%20Grounds%20Rehabilitati

WCVC. (2006). *IRWMP*. Retrieved December 12, 2012, from County of Ventura: http://portal.countyofventura.org/portal/page/portal/ceo/divisions/ira/WC/Library/IRWMP_Document

WCVC. (2012). *Proposition 84*. Retrieved December 12, 2012, from County of Ventura: http://portal.countyofventura.org/portal/page/portal/ceo/divisions/ira/WC/Prop84

WEAP Web Help. (2012). *Soil moisture method description.* Retrieved 2012, from WEAP Web Help: http://www.weap21.org/webhelp/two-bucket_method.htm

Wickstrum, S., & Merckling, R. (2011). *Casitas Municipal Water District 2010 Urban Water Management Plan.*

Wilson, P., Wheeler, D. P., & Kennedy, D. N. (1995). *Greywater Guide.* DWR.

World Bank. (2012). *Turn down the heat: Why a 4 degree C warmer world must be avoided.* Potsdam Institute for Climate Imapct Research and Climate Analytics.