APPENDIX K

Water Supply Assessment and Water Supply Verification

WATER SUPPLY ASSESSMENT
and
WATER SUPPLY VERIFICATION

for the Proposed

Section 31 Specific Plan

Prepared for:

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TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

This Water Supply Assessment and Water Supply Verification (WSA/WSV) is intended to document the sufficiency of the local water supply to meet the demand of development that could occur under the Section 31 Specific Plan (Project).

The Project consists of two parcels totaling approximately 618 acres of vacant land located south of Gerald Ford Drive, east of Bob Hope Drive, north of Frank Sinatra Drive, and west of Monterey Avenue in the City of Rancho Mirage, Riverside County.

At project buildout, the Project could accommodate approximately 75,000 square feet of Neighborhood Commercial; 50,000 square feet of Restaurants; 50,000 of Mixed-Use; 400 Hotel Rooms; 175,000 square feet of Hotel related Commercial Uses; 1,932 residential units and a 15,000 square foot residential beach clubhouse The proposed Project would also include a multi-use lake of approximately 34 acres, and 94.60 acres of open space comprised of a system of parks, paseos, sloped land, and landscaped areas.

The public water supplier is the Coachella Valley Water District (CVWD). The domestic water supply (potable) for the Project will be the Whitewater River (Indio) Subbasin in the Coachella Valley Groundwater Basin. Based on the grade elevations, the Project is located within the Mission Hills Pressure Zone (MHPZ) of CVWD's potable water distribution system.

Within the MHPZ, this Project proposes the development of the following building floor areas over a phased ten-year buildout:

- 1,932 Residential Units of Mixed Density and a 15,000 square foot Residential Clubhouse
- 400 Hotel Rooms and up to 175,000 square feet of Hotel related Commercial Uses
- 175,000 square feet of Mixed and Commercial Uses

Based upon this analysis, the estimated total domestic water demand for indoor and outdoor use is approximately 1,531.84 acre-feet per year (AFY), or 2.48 acre-feet per acre. The indoor use estimate is 388.90 AFY and the outdoor estimate is 1,142.94 AFY.

Estimates are based on the California Water Code performance use standards for indoor residential water demand, the American Water Works Association Research Foundation Commercial and Institutional End Uses of Water, and CVWD's Landscape Ordinance No. 1302.4 (AB 1881, Laird) which meets the water conservation goals of the California Department of Water Resources (DWR) Model Water Efficient Landscape Ordinance (MWELO).

This document examines the current condition of the Whitewater River (Indio) Subbasin of the Coachella Valley Groundwater Basin and finds the water supply from the Whitewater River (Indio) Subbasin, the State Water Project (SWP), the Colorado River, and other sources adequate to supply the Project in accordance with California Water Code Section 10910 et seq. This document also verifies the ability of the water supplies from the Whitewater River (Indio)

Subbasin, the SWP, the Colorado River, and other sources to serve the Project in accordance with the California Government Code Section (GCS) 66473.7.

The GCS defines the Project as a subdivision subject to the California Environmental Quality Act (CEQA). The GCS requires that a WSA be completed by the Public Water System (PWS) to ensure that adequate supplies exist to complete CEQA compliance. A written WSV is required pursuant to the Subdivision Map Act.

It is noted that this WSA/WSV addresses overall water supply available to CVWD to meet the demands of existing customers and other future demands. The WSA/WSV does not address the water delivery system within CVWD's system since the focus is on the overall water supply. Adequacy of the delivery system is addressed in CVWD's Water Master Plan. This WSA/WSV makes a finding of reasonable sufficiency of water supplies that either are or will be available to CVWD to meet future demands. The California Water Code requires a determination for a 20-year period from the start of the Project development. The Project will still be required to conform to all state, county, city, and local ordinances.

This document will be reviewed every five years, or if CVWD determines that the planning assumptions of this document are no longer valid in accordance with SB610, until the Project completes construction. The Project proponent shall notify CVWD when construction has begun. The review will ensure that the information included in this WSA/WSV remains accurate and no significant changes to either the Project of CVWD's water supply have occurred. If neither the Project proponent nor the lead agency contacts CVWD within five years of approval of this WSA/WSV, it will be assumed that the Project no longer requires the estimated water demand calculated and the WSA/WSV provided by this document will become invalid.

1.0 INTRODUCTION

The environmental review of the Section 31 Specific Plan (Project) is being prepared in compliance with the California Environmental Quality Act (CEQA) process. The City of Rancho Mirage (City) is the Lead Agency for the planning and environmental review of the proposed Project. The City has identified the Coachella Valley Water District (CVWD) as the Public Water System (PWS) that will supply water for the proposed Project. Because the Project is subject to CEQA and includes a subdivision as defined by the California Government Code Section 66473.7 it is required to secure approval of a Water Supply Assessment (WSA) and a Water Supply Verification (WSV).

The Project is a master planned mixed-use development comprised of 175,000 square feet of combined office, restaurant, and neighborhood commercial uses along with a total of 1,932 residential units, and up to 400 hotel keys on approximately 618 acres. For the purpose of calculating water demand, the WSA is also analyzing the water demand of the residential clubhouse and up to 175,000 square feet of commercial use for the hotel.

- 1,932 Residential Units of Mixed Density and a 15,000 square foot Residential Clubhouse
- 400 Hotel rooms and up to 175,000 square feet of Hotel related Commercial Uses
- 175,000 square feet of Mixed and Commercial Uses

1.1 PROJECT DESCRIPTION

1.1.1 Regional Setting

Section 31 is situated in the westerly portion of the Coachella Valley within the corporate limits of the City of Rancho Mirage, Riverside County. The Project community will be accessible from Interstate 10 by way of Bob Hope Drive and Monterey Ave as shown in **Figure 1: *Regional Location Map.***

1.1.2 Community Setting

Section 31 is an infill property surrounded on the north, west, and south by developed land within the City of Rancho Mirage, and on the east side by properties within the Cities of Rancho Mirage and Palm Desert. Section 31 is bounded by Gerald Ford Drive on the north; Bob Hope Drive on the west; Frank Sinatra Drive on the south; and Monterey Avenue on the east. **Figure 2: *Section 31 Vicinity Map***

1.1.3 Specific Plan Overview

The Section 31 Specific Plan ("Specific Plan") guides the development of the Project within an area comprised of approximately 618 acres of Section 31, a large undeveloped property within the City of Rancho Mirage, in the heart of the Coachella Valley.

The vision for the Specific Plan is to create a master-planned, mixed-use community oriented around a Grand Oasis, featuring a 34-acre multi-use Crystal Lagoon, with a wide range of water-based and other recreational opportunities. The proposed land use plan is presented in **Figure 3:** ***Section 31 Site Plan***. The proposed Project will feature up to 1,932 dwelling units consisting of various types of single-and multi-family residences. The Project also includes two resort hotels for a maximum of 400 hotel units on the site and a mixed-use town center on approximately 80 acres. The Project site would total approximately 618 acres as is shown in **Table 1.0-1: Land Use Summary.**

Total buildout of the Project is expected to take approximately 10 years following the construction of the Crystal Lagoon. Construction is set to begin in 2020 and end in 2030. The 20-year scenario is used to illustrate total Project demand within the required 20-year WSA time frame (2019-2039) established in Water Code Section 10910. All development within Section 31 will adhere to the standards of the Specific Plan.

Table 1.0-1
Specific Plan Conceptual Land Use Summary

Conceptual Land Use Summary

Planning Area	Land Use Category	Typical Permitted Uses												Gross Land Area (Acres)	Non Resi. Building (SF) [1]	Max. Dweling Units (DU)	Max. Hotel/ Resort (DU)
		Neighborhood Commercial	Restaurants	Office/Service	Resort Hotel	Mixed-Use	Commercial recreation	Open Space/ Parks	Multi-use Lagoon	Residential Estate	Residential Conventional	Residential Cluster	Multi-Family Residential				
PA TC	MU CORE													79.8	350,000	731	400
PA 1	LAG, RES													231.5	15,000	394	
PA 2	RES													145.8		260	
PA 3	RES													160.9		547	
TOTAL														618	365,00	1,932	400

1. Assumes 175,000 square feet of commercial retail space plus 175,000 square feet of resort serving commercial space for purposes of estimating water demand only. This differs from the Specific Plan Land Use Table and EIR which recognizes the resort serving commercial as ancillary to and accounted for within the 400 hotel units. Likewise, the 15,000 square feet residential beach clubhouse is assumed ancillary to the residential units.

1.2 REGULATORY REQUIREMENTS

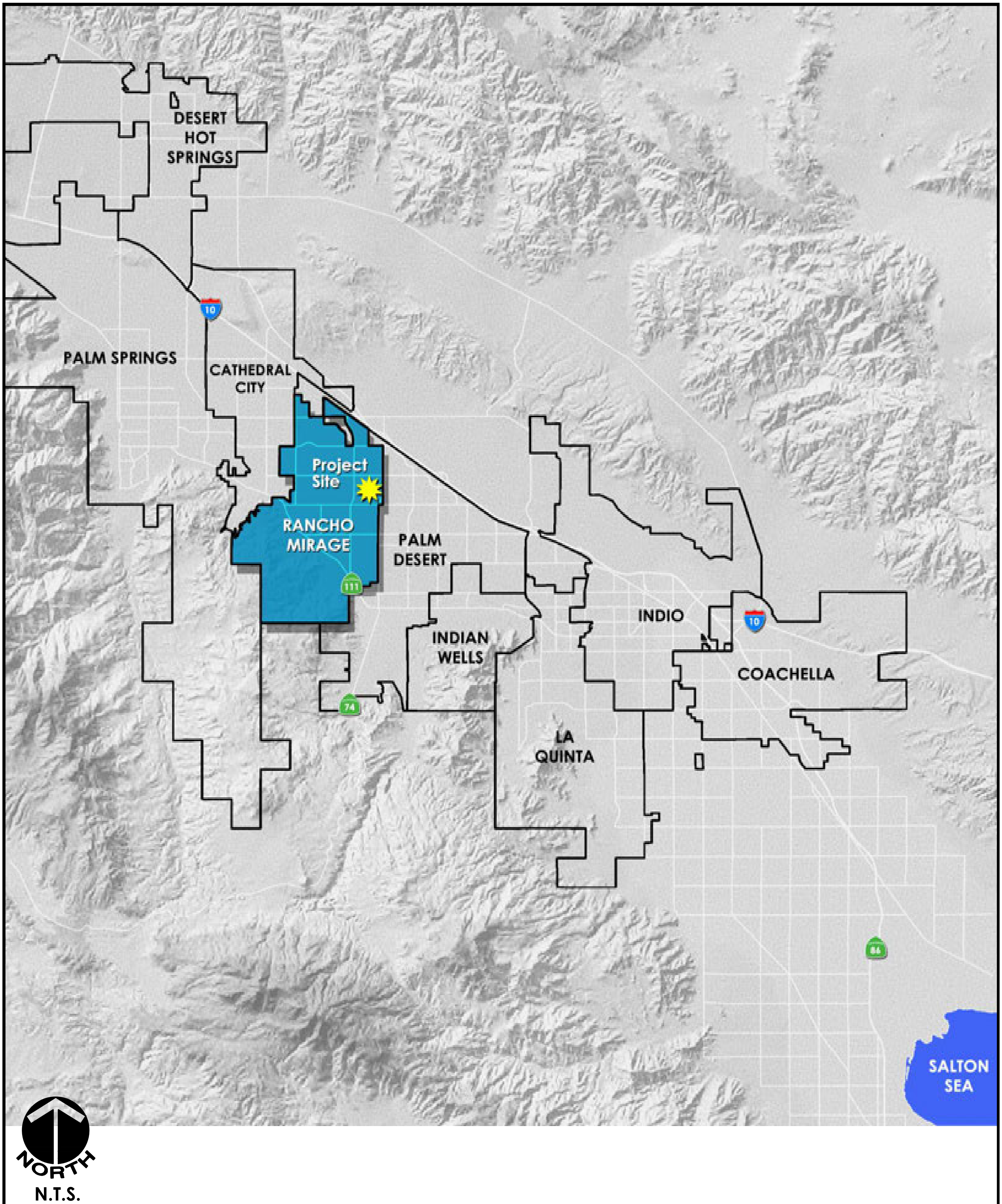
The Project is subject to the CEQA process and is a subdivision as defined by the California Government Code Section 66473.7. The City of Rancho Mirage as the Lead Agency, and CVWD as the PWS, for the Project requires a WSA to complete CEQA compliance, and that a written WSV will be required pursuant to the Subdivision Map Act.

CVWD completed its 2015 Urban Water Management Plan (UWMP) in compliance with the Urban Water Management Planning Act established in 1983 and most recently amended by Senate Bill x7-7, which requires a 20 percent reduction in per-capita water use by 2020. The CVWD also maintains a separate water management planning document, the 2010 Coachella

Valley Water Management Plan (CVWMP) Update. The two planning documents are considered the primary reference documents for this WSA/WSV. The 2010 CVWMP Update discusses the Quantification Settlement Agreement (QSA), which allocates Colorado River water resources. The QSA and related agreements were signed in 2003. A number of lawsuits have unsuccessfully challenged the QSA in state and federal courts. Both the 2015 UWMP and 2010 CVWMP Update evaluate water supplies under the QSA and prior to implementation of the QSA.

The State of California Department of Water Resources (DWR) issues its Final State Water Project Delivery Capability Report (SWPDCR) generally every two years. The 2015 SWPDCR report was utilized in the 2015 UWMP. The 2017 SWPDCR contains the most recent information and accounts for the impacts to water delivery capability through 2035 associated with climate change and recent federal litigation. Based on information from the 2017 SWPDCR, the average capability of State Water Project (SWP) Table A deliveries through 2035 has remained the same as the 2015 SWPDCR and is projected to be 62 percent of SWP Table A amounts after taking into consideration the effects of climate change. In order to anticipate future reductions in capability, the 2010 CVWMP Update and the 2015 UWMP assume an even lower long-term reliability of 50 percent.

Effective January 1, 2017, SB 1262 amends Water Code Section 10910, the WSA statute, to require that information regarding the Sustainable Groundwater Management Act (SGMA) be included in a WSA if a water supply for a proposed project includes groundwater from a basin that is not adjudicated and is designated medium or high-priority. The water supply for this project will come from the Whitewater River (Indio) Subbasin, an unadjudicated, medium priority subbasin. CVWD is a Groundwater Sustainability Agency (GSA) in the Whitewater River (Indio) Subbasin and has submitted the 2010 CVWMP Update to DWR as the Alternative to a Groundwater Sustainability Plan (Alternative Plan) for the subbasin.



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Regional Location Map

Section 31
Water Supply Assessment

1

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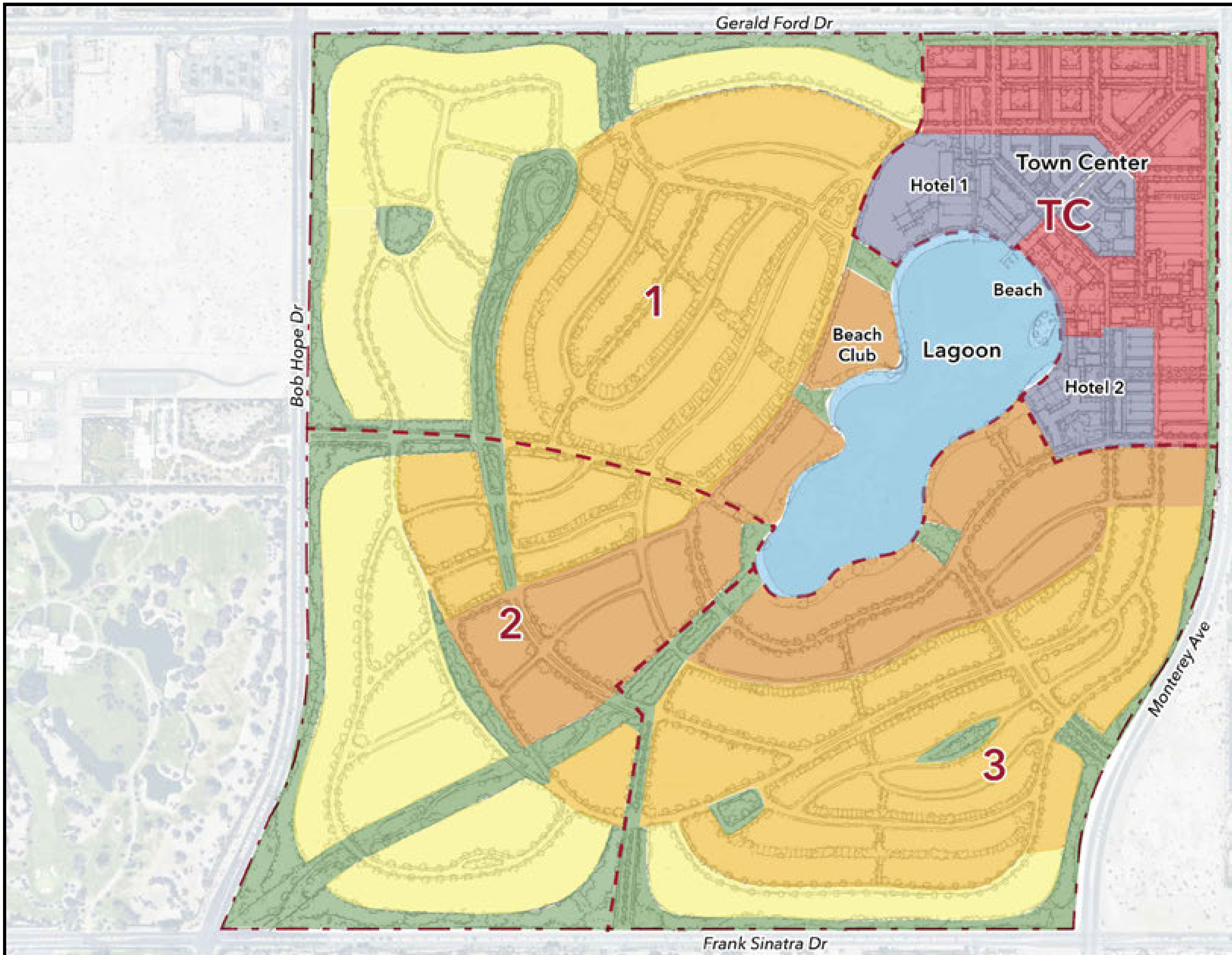
Vicinity Map

Section 31
Water Supply Assessment



LEGEND

Key	Land Use
	Lagoon
	Resort Hotel
	Mixed Use Town Center
	Residential/ Cluster
	Residential/ Conventional
	Residential/ Estate
	Open Space/ Parks
	Planning Area
	Project Boundary

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Site Plan - Hart Howerton

Section 31
Water Supply Assessment

1.3 Purpose and Validity of Document

CVWD, as a Public Water System (PWS), is required by law to provide a WSA document during the CEQA process and is required by law to provide a WSV following approval of the Tentative Map for the residential portion of the Project. This information is included in the CEQA documentation and it becomes evidence used in the approval process for the proposed development. It is noted that this WSA/WSV addresses the overall water supply available to the CVWD to meet the demands of existing customers and other future demands. The WSA/WSV does not address the water delivery system within the CVWD's system since the focus is on the overall water supply. Adequacy of the delivery system is addressed in the CVWD's Water Master Plan. The WSA/WSV makes a finding of reasonable sufficiency of water supplies that either are available or will be available to CVWD to meet future demands. The Water Code requires a determination for a 20-year period (2019-2039) from the start of Project development.

The WSA/WSV must be reviewed every five years or in the event the water planning assumptions have changed, until the Project begins construction. The Project applicant shall notify CVWD when construction has begun. The review will insure that the information included in the WSA/WSV remains accurate and no significant changes to either the Project or CVWD's water supply have occurred. If neither the Project applicant nor the lead agency contacts CVWD within five years of approval of this WSA/WSV, it will be assumed that the Project no longer exists, and the WSA/WSV provided by this document will become invalid.

1.3.1 Water Supply Assessment

Requirements for the preparation of a WSA are set forth in Senate Bill 610 (SB 610), which was enacted in 2001 and became effective January 1, 2002. SB 610 amended Section 21151.9 of the Public Resources Code. It requires cities and counties and other CEQA lead agencies to request specific information on water supplies from the PWS that would serve any project that is subject to CEQA and is defined as a "Project" in Water Code Section 10912. This information is to be incorporated into the environmental review documents prepared pursuant to CEQA.

The Water Code requires a WSA be prepared for any project that consists of one or more of the following:

- A proposed residential development of more than 500 dwelling units
- A proposed shopping center or business establishment employing more than 1,000 persons or having more than 500,000 square feet of floor space
- A proposed commercial office building employing more than 1,000 persons or having more than 250,000 square feet of floor space

- A proposed hotel or motel, or both, having more than 500 rooms
- A proposed industrial, manufacturing, or processing plant, or industrial park planned to house more than 1,000 persons, occupying more than 40 acres of land, or having more than 650,000 square feet of floor area
- A mixed-use project that includes one or more of the projects specified above
- A project that would demand an amount of water equivalent to, or greater than, the amount of water required by a 500-dwelling unit project
- For public water systems with fewer than 5,000 service connections, a project that meets the following criteria: any proposed residential, business, commercial, hotel or motel, or industrial development that would account for an increase of 10 percent or more in the number of public water system's existing service connections, or a mixed-use project that would demand an amount of water equivalent to, or greater than, the amount of water required by residential development that would represent an increase of 10 percent or more in the number of the public water system's existing service connections.

The proposed development is a "Project" as defined by Water Code Section 10912 and requires a WSA because it proposes over 500 housing units and potentially greater than 500,000 square feet of commercial space.

Effective January 1, 2017, SB 1262 amends Water Code Section 10910, the WSA statute, to require that SGMA-related information be included in a WSA if a water supply for a proposed project includes groundwater from a basin that is not adjudicated and is designated medium or high-priority. The Project will use groundwater from the Whitewater River (Indio) Subbasin, which is designated medium priority by DWR and is not adjudicated.

1.3.2 Water Supply Verification

Senate Bill 221 (SB 221) was enacted in 2001 and became effective as of January 1, 2002. SB 221 amends Section 11010 of the Business and Professional Code, and Sections 66455.3, 66473.7, and Section 65867.5 of the Government Code. SB 221 establishes the relationship between the WSA prepared for a project and the project approval under the Subdivision Map Act. Pursuant to California Government Code Section 65865.5 and 66473.7, the approval of a development agreement or tentative map that includes a subdivision for a project including more than 500 units shall be conditioned to obtain a WSV.

The purpose of the WSV is to provide the legislative body of a city, county or the designated advisory agency with written verification from the applicable public water purveyor that a sufficient water supply is available, or, in addition, a specified finding is made by the local agency that sufficient water supplies are, or will be, available prior to completion of the project.

Therefore, a WSV is required since this Project has over 500 housing units and is a "Subdivision" as defined by Government Code Section 66473.7.

1.4 WATER SYSTEM AND SUPPLY

1.4.1 Water System

The proposed potable water master plan is the “backbone” system for the Project. All of the in-tract water distribution facilities will be shown on subsequent improvement plans and will be designed and constructed in accordance with CVWD requirements.

CVWD’s existing water supply and conveyance systems include, or will include, adequate capacity for daily demands and emergency fire protection. This includes groundwater pumping, transmission pipelines, distribution storage and surface pumping within internal roadways or other rights-of-way to provide domestic service to each residential and commercial tenant within the Project.

Non-potable water facilities of CVWD do not currently extend to the Project vicinity. At this time, CVWD has plans to extend non-potable water facilities to the Project vicinity. The potable system is currently the only water delivery system for the Project from CVWD. The Project will utilize non-potable water from CVWD when it becomes available. The Project will use potable water pumped from the groundwater basin by private wells.

1.4.2 Water Supply

CVWD is the PWS that will provide water for the proposed Project following Project approval. Established in 1918 under the County Water District Act provisions of the California Water Code, CVWD provides water related services for domestic water, wastewater collection and treatment, recycled water, agricultural irrigation water, drainage management, imported water supply, groundwater replenishment, stormwater management, and flood control and water conservation.

CVWD currently has approximately 108,000 domestic water connections and provided approximately 86,303 AF of water in 2017. CVWD serves all of Rancho Mirage, Thousand Palms, Palm Desert, Indian Wells, La Quinta, and a portion of Indio and Coachella. Other areas served with domestic water by CVWD include a portion of lands near Desert Hot Springs, the Indio Hills area, and a portion of Cathedral City. CVWD also serves other rural communities, including Thermal, Mecca, Oasis, Desert Shores, Salton Sea Beach, Salton City, North Shore, Bombay Beach, and Hot Mineral Springs and other portions of unincorporated Riverside and Imperial Counties.

The CVWD service area encompasses approximately 640,000 acres, mostly within Riverside County, but also extends into northern Imperial and San Diego Counties; however, CVWD provides no urban water services to San Diego County. The Coachella Valley is bordered on the west and north by high mountains, which provide an effective barrier against coastal storms, and which greatly reduce the contribution of direct precipitation to recharge the Coachella Valley Groundwater Basin. The majority of natural recharge comes from runoff from the adjacent mountains.

1.4.3 Historical Context

The need to enhance the public water supply in the Coachella Valley has been recognized for many years. The formation of CVWD in 1918 was a direct result of the concern of local residents about a plan to export water from the Whitewater River to Imperial County. Early on, Coachella Valley residents also recognized that action was needed to stem the decline of the water table, which was occurring as a result of local pumping in the eastern Coachella Valley. As a result, CVWD entered into an agreement for the construction of the Coachella Branch of the All American Canal in order to bring Colorado River water to the Coachella Valley. Since 1949, the Coachella Branch Canal has been providing water for irrigation use in the area that generally encompasses the Cities of Indio and La Quinta southerly to the Salton Sea. Colorado River water is delivered by an underground irrigation distribution piping system from the approximately 120-mile canal to farms and a growing number of golf courses in the Coachella Valley. In recent years, CVWD has begun a program of recharging the aquifer in the eastern Coachella Valley with this source.

The need for additional water supplies was recognized due to the onset of development in the western Coachella Valley. As a result, in 1963 CVWD and the Desert Water Agency (DWA), which serves the Palm Springs area and a portion of Cathedral City and the Desert Hot Springs, entered into separate contracts with the State of California in order to ensure that SWP water would be available. Because a direct pipeline from the SWP system to the Coachella Valley does not exist, CVWD and DWA entered into an exchange agreement with the Metropolitan Water District of Southern California (MWD) to receive water from the MWD Colorado River Aqueduct (CRA), which crosses the upper portion of the Coachella Valley near Whitewater. Since 1973, in exchange for their SWP water, CVWD and DWA have been receiving Colorado River water from MWD's CRA turnout located at Whitewater Canyon to replenish groundwater in the western Coachella Valley.

In addition, CVWD has recognized the need to provide other sources of water to replenish the Coachella Valley Groundwater Basin. CVWD has been recycling reclaimed wastewater since 1967 and operates five water reclamation plants, two of which currently recycle water. Recycled water is currently used for golf course and greenbelt irrigation in the cities of Palm Desert, Indian Wells, and Indio, thereby reducing demand on groundwater in the basin.

1.5 EXISTING WATER MANAGEMENT PLANS

1.5.1 Coachella Valley Water Management Plan 2010 Update

CVWD initiated the first water management planning process in the early 1990s to address the overdraft conditions in the aquifer and to ensure that there would be adequate water supplies in the future. The plan is a 35-year blueprint for wise water management and the basis for all of CVWD's efforts to preserve the Coachella Valley's groundwater source.

The Coachella Valley Water Management Plan (CVWMP) was adopted by the CVWD Board in September 2002. The goal of the CVWMP is to reliably meet current and future water demands in a cost effective and sustainable manner. The CVWD Board recognized the need to update the CVWMP periodically to respond to changing external and internal conditions. The 2010 CVWMP Update meets that need. It defines how the goal will be met given changing conditions and new uncertainties regarding water supplies, water demands, and evolving federal and state regulations.

The 2010 CVWMP Update calls for a multifaceted approach including:

- Increased water conservation by all types of water users
- Increased imported water supply from the Coachella Canal and State Water Project
- Increased use of the imported supply and recycled water, instead of groundwater, for irrigation
- Expanded groundwater replenishment efforts, especially in the eastern Coachella Valley

The 2010 CVWMP Update identifies several water conservation measures with the goal to reduce overall water consumption by 20 percent by 2020, and the goal to maintain this level of reduction through 2045. These measures included water efficient landscaping and irrigation controls, water efficient plumbing, tiered or seasonal water pricing, public information and education programs, alternative water supplies, water restrictive municipal development policies, appointing a CVWD conservation coordinator and refining the maximum water allowance budget for landscaped and recreational areas. The 2010 CVWMP Update reduces reliance on groundwater sources by utilizing more Colorado River water, SWP water and recycled water over the long term.

The 2010 CVWMP Update emphasizes cooperation with municipalities, local water agencies, and tribes in regional planning and implementation. The following are among some of the recommended activities outlined in the 2010 CVWMP Update for the CVWD Board of Directors to consider over the next 35 years.

- Provide incentives and support to agricultural customers to conserve water, such as through converting from flood/sprinkler irrigation to more efficient micro-sprinkler/drip systems.

- Encourage existing golf courses to convert landscaping to meet the most current landscape ordinance, requiring no more than 4 acres of grass per hole and 10 acres of grass per practice area.

- Expand landscape conversion rebates for domestic customers to encourage less grass and more desert appropriate landscaping.

- Complete construction of subsequent phases of the Mid-Valley Pipeline system to provide a blend of recycled and Colorado River water for up to 50 golf courses in-lieu of groundwater.

The 2010 CVWMP Update recognizes that groundwater storage makes up the difference between demand and supply. Other than canal water for irrigation and groundwater recharge, and recycled water, all water delivered to the end users is obtained from the Coachella Valley Groundwater Basin. The Coachella Valley Groundwater Basin has a capacity of approximately 39.2 million acre-feet (AF). It is capable of meeting the water demands of the Coachella Valley for extended periods.

The 2010 CVWMP Update discusses many CVWD programs to maximize the water resources available including:

- Recharge of Colorado River and SWP supplies

- Recycled wastewater, desalinated shallow semi-perched brackish groundwater, and conversion of groundwater uses to canal water; and

- Water conservation including tiered water rates, landscaping ordinance, outreach and education.

The 2010 CVWMP Update and CVWD's Replenishment Assessment Program establishes a comprehensive and managed effort to eliminate groundwater overdraft. These programs allow CVWD to maintain the groundwater basin as its primary water supply and to recharge the groundwater basin as other supplies become available.

CVWD prepared the 2014 and 2016 CVWMP Status Reports to evaluate the effectiveness of the 2010 CVWMP Update, including progress on eliminating groundwater overdraft. Both Status Reports demonstrated that the 2010 CVWMP Update is working and that continued implementation ensures that groundwater overdraft will be eliminated within 10 years as shown in the *Status of the Overdraft – Annual Change in Storage* chart on page 16. The status of the Annual Change in Storage is updated annually in the Indio and Mission Creek Subbasin

Annual Reports by Water Year, and in CVWD's Engineer's Report on Replenishment and Assessment. Over the ten-year period preceding 2014, there was no groundwater overdraft mainly as a result of increases in urban conservation and increases in imported water deliveries to the Coachella Valley. Between 2014 and 2016, imported water deliveries were significantly reduced as a result of the statewide drought, however, groundwater pumping was also significantly reduced due to the Governor's drought restrictions.

Groundwater levels have increased in the Palm Springs area and in the eastern Coachella Valley. However, water levels are still declining in the Mid-Coachella Valley areas near Rancho Mirage, Palm Desert and Indian Wells. Groundwater levels in this area will continue to decline until full implementation of Mid-Coachella Valley programs that reduce pumping take effect. These Mid-Coachella Valley Programs include urban conservation, source substitution programs including non-potable water system expansion to golf courses and landscaping, and additional groundwater recharge. The 2014 and 2016 CVWMP Status Reports are publically available at www.cvwd.org.

1.5.2 CVWD 2015 Urban Water Management Plan, SBx7-7, and Water Shortage Contingency Ordinance

CVWD has completed its 2015 Urban Water Management Plan (UWMP) and it was approved by the State on September 29, 2016. Water Code Section 10910(c)(2) states that if demand from potential future growth is accounted for in the most recently adopted 2015 UWMP, the water supplier may incorporate the requested information from the 2015 UWMP in preparing the WSA/WSV. CVWD water demand projections contained in the 2015 UWMP take into account the increased growth throughout its service area.

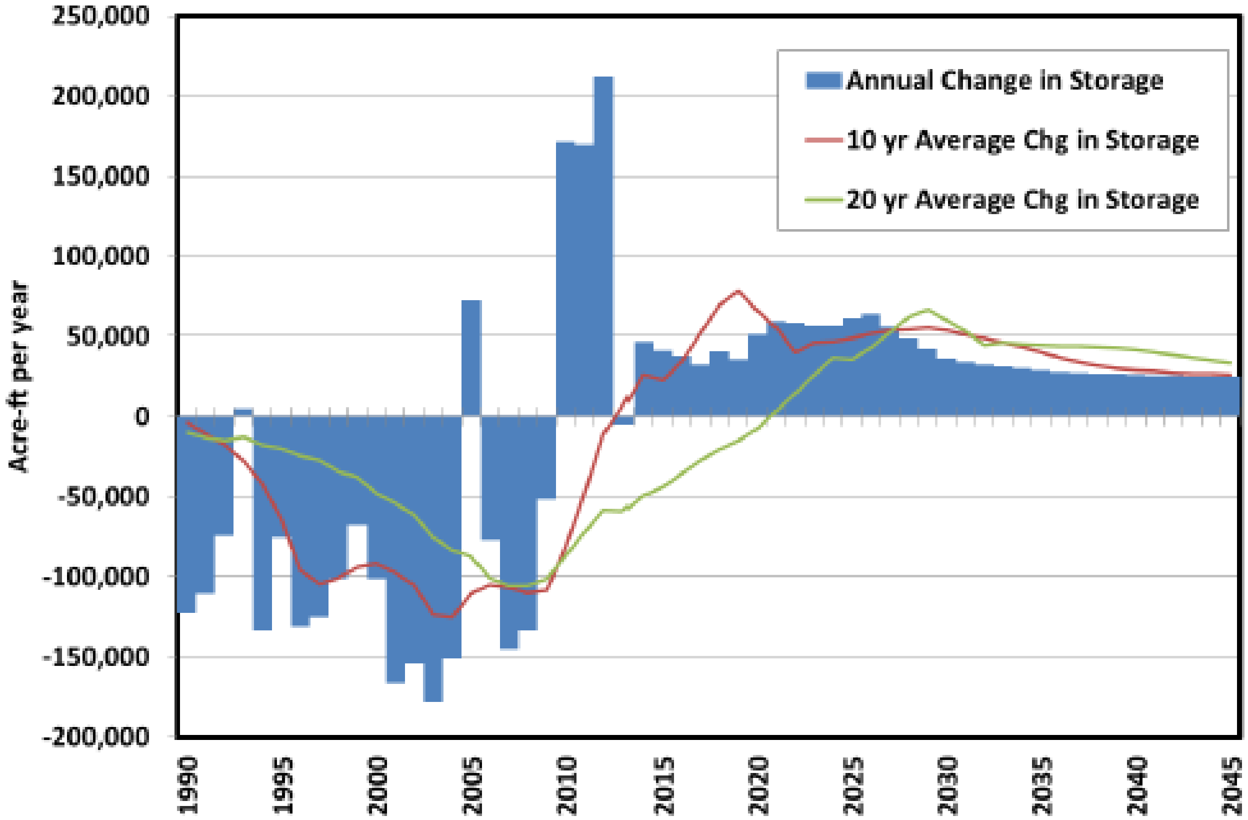
In November 2009, SB x7-7 was approved and adopted by the State. DWR provides alternative water use reduction "targets" for urban water suppliers to select, and guidance to achieve the target goal. The legislation includes requirements to improve the management of CVWD water resources by monitoring groundwater basins, developing agricultural water management plans, reducing statewide per capita water consumption by 2015 and 2020, and reporting water diversions and uses in the Sacramento-San Joaquin River Delta.

SB x7-7 creates a framework of future planning and actions by urban and agricultural water suppliers to reduce California's water use. This bill requires the development of agricultural water management plans and requires urban per capita water consumption to be reduced by 20 percent by the year 2020.

The recent drought that began in 2013 resulted in record low precipitation both statewide and in the Coachella Valley, and resulted in implementation of severe water use restrictions mandated by the State Water Resources Control Board (SWRCB).

Since the CVWMP was adopted in 2002, overdraft has averaged about 22,000 AF. Increased imported water recharge combined with reduced pumping due to water conservation and source substitution are expected to bring the basin into a long-term balance. CVWD evaluates groundwater balance using ten-year (red line) and twenty-year (green line) historical periods as shown on **Figure 4: *Historical and Projected Groundwater Balance.*** Over the past ten years, the basin has been balanced; however, over the past twenty years, about 45,000 AF of storage has been lost to overdraft. Implementation of the programs recommended in the 2010 CVWMP Update is expected to result in elimination of storage losses by about 2022, assuming average hydraulic conditions.

Figure 4
Historical and Projected Groundwater Balance



On January 17, 2014, Governor Brown proclaimed a State of Emergency due to severe drought conditions. The governor issued Executive Order B-29-15, which ordered the SWRCB to adopt emergency regulations imposing restrictions to achieve a 25 percent reduction in potable water usage across the State. Agencies assigned to Tier 9, including CVWD, having residential water use above 215 gallons per capita per day (gpcd), were required to reduce water use by 36 percent compared to 2013 water use. This reduction was reduced to 32 percent in February 2016 and became locally implemented in May 2016.

Following an above normal snowpack in Southern California, Governor Brown issued Executive Order B-37, in May 2016. This Executive Order focused on long-term water use efficiency. In response to that order, the SWRCB adopted revised emergency regulations in May 2016 that transition the mandates away from demand-based regulations. Under the new regulations, individual districts will self-certify the level of available water supplies assuming three additional dry years and the level of conservation necessary to ensure adequate supply over that time. It is anticipated that the new self-certification process will result in a reduction in the emergency mandatory reduction target imposed on CVWD by the SWRCB.

CVWD's urban water shortage contingency planning efforts are described in detail in Section 8 of CVWD's 2015 UWMP including a description of each ordinance CVWD has adopted during Governor Brown's drought emergency declaration, stages of implementation, and restrictions and prohibitions on end users.

1.5.3 Integrated Regional Water Management Plan

The Coachella Valley Integrated Regional Water Management (IRWM) Plan serves as a combined plan that addresses the requirements of the DWR. The IRWM program presents a regional approach for addressing local water management issues through a process that identifies and involves water management stakeholders, individuals, and groups; and attempts to address the issues and different perspectives of all the entities involved through mutually beneficial solutions. In 2008, the five public water agencies in the Coachella Valley formed the Coachella Valley Regional Water Management Group (CVRWMG); and in 2010, they adopted the Coachella Valley IRWM Plan. The CV IRWM Plan was updated in 2014, and a 2018 update has been completed, which includes a Stormwater Resource Plan. These efforts demonstrate the cooperative and collaborative approach that the CVRWMG has adopted to ensure that the Coachella Valley as a whole will focus on sustainable water resources. All water agencies in the Coachella Valley work together, share information, discuss concerns and viewpoints, and build consensus in supporting future projects that benefit all of the region. Since its formation, the CVRWMG has added Valley Sanitary District as member and has provided this opportunity to other planning partners.

1.5.4 Sustainable Groundwater Management Act Alternative Plan

In September 2014, Governor Brown signed three bills into law, Assembly Bill 1739 (AB 1739), SB 1319, and SB 1168, that became collectively known as the Sustainable Groundwater Management Act (SGMA), creating a framework for sustainable management of groundwater throughout California, primarily by local authorities.

The SGMA was adopted by the California Legislature in 2014 in response to the severe overdrafting of groundwater in what was then the third year of a historic drought. The final legislation created a framework that requires the most heavily used groundwater basins in the state (127 of 515 basins identified by the DWR in its Bulletin 118 Groundwater Update) to be managed sustainably by 2042 (or 2040 for the most critically overdrafted basins). SGMA was amended in 2015 by SB 13.

SGMA requires local agencies to establish a new governance structure, the Groundwater Sustainability Agency (GSA), and to develop Groundwater Sustainability Plans (GSPs) for groundwater basins or subbasins that are designated as medium or high priority. SGMA established a process for local agencies to develop an alternative in-lieu of a GSP (See Water Code Section 10733.6) for evaluation by DWR. According to the SGMA, an Alternative to a GSP (Alternative Plan) is required to be submitted to DWR for review no later than January 1, 2017, and every five years thereafter. In general, Alternative Plans must be consistent with one of the following (Water Code Section 10733.6(b))

- A plan developed pursuant to Part 2.75 (commencing with Section 10750) or other law authorizing groundwater management;

- Management pursuant to an adjudication; or

- An analysis of basin conditions that demonstrates that the basin has operated within its sustainable yield over a period of at least 10 years.

The Whitewater River (Indio), Mission Creek, and San Gorgonio Pass Subbasins of the Coachella Valley Groundwater Basin have been designated by DWR as medium priority subbasins. Pursuant to California Water Code section 10723.8 of the SGMA, CVWD filed a notice on November 6, 2015 of its election to serve as a GSA for the portions of the Whitewater River (Indio) Subbasin (DWR Sub-Basin No. 7-21.01) underlying the CVWD boundary. CVWD did not elect to be the GSA for those portions of the subbasin within the water service boundaries of DWA, Indio Water Authority (IWA), and Coachella Water Authority (CWA).

DWA, CWA, and IWA separately filed a notice of election to serve as the GSA for the portions of the Whitewater River (Indio) Subbasin underlying their service boundaries.

CVWD, DWA, CWA, and IWA jointly submitted the 2010 CVWMP Update with a supporting Bridge Document to DWR as the Alternative Plan for the Whitewater River (Indio) Subbasin on December 29, 2016. On February 1, 2018, DWR notified all GSAs who submitted Alternative Plans that they would be required to submit annual reports pursuant to SGMA by April 1, 2018, and every year thereafter. CVWD, CWA, DWA, and IWA have collaboratively prepared and jointly submitted the Indio Subbasin Annual Report for Water Years 2016-2017, and 2017-2018.

2.0 WATER DEMANDS

2.1 Project Specific Water Demand Estimate

The unit water usage for this Water Supply Assessment/Water Supply Verification (WSA/WSV) are based on indoor water use performance standards as provided in the California Water Code for residential water demand Water Code Section 10910 approved November 10, 2009, codified in California Water Code section 10608.20 (b)(2)(A), the American Water Works Association Research Foundation's (AWWARF's) Commercial and Institutional End Uses of Water, and the Coachella Valley Water District's (CVWD's) Landscape Ordinance No. 1302.4 (AB 1881, Laird) which meets the water conservation goals of the California Department of Water Resources (DWR) Model Water Efficient Landscape Ordinance (MWELO).

The overall goal of CVWD's Landscape Ordinance 1302.4 is to reduce landscape water use, reduce or eliminate runoff in streets, and limit turf. Specific landscape design for the Section 31 Specific Plan (Project) is unknown at this time. CVWD's Maximum Applied Water Allowance (MAWA), as outlined in Appendix D of CVWD's Landscape Ordinance No. 1302.4 is used to estimate outdoor irrigation usage. The MAWA complies with Division 2, Title 23, California Code or Regulation, Chapter 7, Section 702.

CVWD recycles more than 2 billion gallons of wastewater each year. The wastewater is subject to an advanced multi-step process that filters out solids, organic materials, chemicals and germs. Recycled/non-potable water is a safe alternative when the guidelines are followed and is used for its intended purpose. CVWD's non-potable water facilities do not currently extend to the Project vicinity. However, CVWD is in the design phase for non-potable water facilities to the Project site. This extension would result in 1000 gpm for 12 hours and provide a maximum of 806.56 AFY on non-potable when it becomes available. This could provide a source substitution of non-potable water. The Project will utilize non-potable water from this extension when it becomes available.

The Project planning area includes a total of approximately 618 acres and the estimated water demand is 1,531.84 acre-feet per year (AFY). To provide an accurate estimate of the Project's water demand, a site-specific analysis was completed. Potable water demand was calculated for all indoor uses based on Project specific estimates.

The following factors are pertinent to the Project:

- Indoor Residential (Multi-family) = 55 gallons per day (gpd) per person
- City of Rancho Mirage density per home is 2.03 people per home (CA Dept. of Finance) = 111.65 gpd per home
- Outdoor irrigation based on CVWD's Maximum Applied Water Allowance (MAWA)
- Indoor non-residential (retail, grocery, office, restaurant) based on AWWARF
- Common Area Landscape (parks/catchment/medians) based on MAWA.

Residential Demand

Project water demand is distinguished between indoor and outdoor usage. **Table 2.01 Residential Water Demands** summarized below outlines the water demand of the residential portion of the Project.

Table 2.0-1 Residential Water Demands

Land Use	Units	*gpd/Unit	Demand (gpd)	Indoor Residential Annual Consumption (AFY)
Residential 4				
Branded Residential	230	111.65	25,679.50	28.76
Mixed-Use Residential	501	111.65	55,936.65	62.66
Residential - Stacked View Units	231	111.65	25,791.15	28.89
Residential 5				
Residential - Small Lot SFD (Cluster)	242	111.65	27,019.30	30.27
Residential 6				
Residential - Conventional SFD	320	111.65	35,728.00	40.02
Residential 7				
Residential - Large Lot SFT	225	111.65	25,121.25	28.14
Residential 8				
Residential - Estate Lot SFD	132	111.65	14,737.80	16.51
Residential 9				
Residential - Custom Lot SFD	51	111.65	5,694.15	6.38
Grand Total	**1932**	**111.65**	**215,707.80**	**241.62**

(*55 gpd/person x 2.03 persons/unit = 111.65 gpd/unit
2.03 persons/unit derived from 2018 CA Dept of Finance Population Estimate for the City of Rancho Mirage)

Non-Residential Demand

For the purposes of this WSA/WSV, the AWWARF's Commercial and Institutional End Uses of Water (2000) was used to estimate indoor non-residential water use. In the absence of documented local indoor non-residential usage factors that would accurately represent water use trends, the AWWARF document provides water use data applicable to mixed use commercial development projects of desert areas within southern California and Arizona and sets water efficiency benchmarks for specific commercial uses. Based on these benchmarks, usage factors for the distinct uses of Hotel, Office Building, Restaurant, and Supermarkets were developed for the Project. **Table 2.0-2 Non-Residential Water Demand** summarizes non-residential indoor demands.

A total of approximately 94.60 acres of open space in addition to the 34-acre lagoon will be distributed throughout the Specific Plan with integrated publicly accessible plazas/greenspaces, private neighborhood parks, paseo corridors, and joint use retention/recreation facilities.

Table 2.0-2 Non-Residential Water Demand

Row Labels	Units	Building Area	gpd/Unit	Demand (gpd)	Indoor Non-Residential Annual Demand (AFY)
Hotel					
Hotel - Rooms	400		115	46,000.00	51.53
Office Building					
Hotel - Commercial use		175,000	35	16,780.82	18.80
Residential - Beach Club		15,000	35	1,438.36	1.61
Restaurant					
Restaurants		50,000	331	45,342.47	50.79
Supermarkets					
Mixed-Use		50,000	64	8,767.12	9.82
Neighborhood Commercial		75,000	64	13,150.68	14.73
Grand Total	**400**	**365,000**		**131,479.45**	**147.28**

Landscape Irrigation Demand

The Coachella Valley receives an annual rainfall of less than 6 inches, and experiences extremely high temperatures with a wide daily temperature range. Several maximum monthly average temperatures exceed 100 degrees Fahrenheit. **Table 2.0-3 Outdoor Water Demand** summarizes outdoor demands.

The total potential evapotranspiration (ETo) is well above the total rainfall and is due to the high temperatures and abundant sunlight. The Coachella Valley rarely experiences a water surplus condition with respect to precipitation versus ETo. Prime ETo sites in the Coachella Valley are well watered lawns, lakes, decorative water fountains, and golf courses.

Landscape water demand for the Project is based on the estimated landscape irrigation area and water usage equations of the CVWD’s Landscape Ordinance No. 1302.4. Although the landscape design is unknown, this method ensures that a sufficient budget is provided to have a sustainable landscape that meets the criteria established in CVWD’s Landscape Ordinance. Therefore, the MAWA equation for the project was used to project irrigation demand. The equation uses a reference ETo rate of 83.34 inches per year (CVWD Zone 5) and an ETo adjustment factor (ETAF) of 0.45.

The water demand for Project landscaping is based on CVWD's Landscape Ordinance 1302.4: Maximum Applied Water Allowance (MAWA) for ETo Zone 5. Adherence to the MAWA requirements as outlined in the CVWD Landscape Ordinance assures compliance with CVWD water conservation goals and requirements.

The demand factors were applied to the estimated landscaped area calculated from the Project design standards.

The MAWA is based on the Project area's ETo rate, the amount of the Project's landscaped area in square feet, a plant factor to irrigation ratio of 0.45, otherwise known as an Evapotranspiration Adjustment Factor (ETAF), and a Conversion Factor (KC), when combined, the following formula is used to calculate MAWA. MAWA is calculated into hundred cubic feet.

Table 2.0-3 Outdoor Water Demand

Land Use	Total Outdoor Acreage (AC)	Outdoor Landscaped Area	Outdoor Landscaped Area -Adjusted (sf)	Total Outdoor Annual Consumption (AFY)
Hotel				
Hotel - Rooms	16.00	60%	418,176.00	29.73
Office Building				
Hotel - Commercial use	16.00	60%	418,176.00	29.73
Residential - Beach Club	3.50	60%	91,476.00	6.50
Open Space				
Beach + Edge	6.24	30%	81,544.32	5.80
Multi-Use Lake	33.96	100%	1,484,977.42	105.57
Streets / ROW	131.44	30%	1,717,657.92	122.11
Open Space - Parks/Paseos/Perimeter	94.60	90%	3,719,828.35	264.45
Residential 4				
Branded Residential	28.00	45%	548,856.00	39.17
Mixed-Use Residential	28.00	45%	548,856.00	39.17
Residential - Stacked View Units	12.80	65%	362,419.20	25.86
Residential 5				
Residential - Small Lot SFD (Cluster)	16.67	65%	471,994.38	33.68
Residential 6				
Residential - Conventional SFD	36.85	65%	1,043,370.90	74.46
Residential 7				
Residential - Large Lot SFT	49.59	65%	1,404,091.26	100.20
Residential 8				
Residential - Estate Lot SFD	60.61	65%	1,716,111.54	122.47
Residential 9				
Residential - Custom Lot SFD	40.98	65%	1,160,307.72	82.80
Restaurant				
Restaurants	12.33	60%	322,256.88	22.91
Supermarkets				
Mixed-Use	12.33	40%	215,636.11	15.33
Neighborhood Commercial	18.50	40%	323,524.49	23.00
Grand Total	**618.40**		**16,049,260.49**	**1142.94 ac-ft/y**

*Lake - Crystal Lagoons applies a proprietary additive to reduce evaporation by as much as 30%. Evaporation reduction products used on Lake Mead have demonstrated up to a 50% reduction in evaporation; see appendix.
**<u>Residential Rate 4</u>: Stacked View Units, 2000 sf lot, 35% lot coverage, 65% Landscaped
Branded Residential Units, 2000 sf lot, 55% lot coverage, 45% Landscaped
Mixed-Use Residential Units, 2000 sf lot, 55% lot coverage, 45% Landscaped
**<u>Residential Rate 5</u>: Small lot SFD (Cluster wide and shallow SFD, 3000 sf lot, 35% lot coverage, 65% outdoor water
**<u>Residential Rate 6:</u> Conventional SFD - 5000 sf lot, 35% lot coverage, 65% outdoor water use 206.27 gpd/unit
**<u>Residential Rate 7</u>: Estate 1/4 ac Conventional Large SFD, 10,000 sf lot, 35% lot coverage, 65% outdoor water use
**<u>Residential Rate 8</u>: Estate Lot SFD- 20,000 sf lot, 35% lot coverage, 65% outdoor water use
**<u>Residential Rate 9:</u> Estate Lot SFD, 35,000 sf lot, 35% lot coverage, 65% outdoor water use

The following language is an excerpt of standards included in the Project's Specific Plan and shall be implemented throughout the Project.

"General Guidelines: Landscape design in Section 31 SP should be sensitive to its natural setting. New development should be integrated into the natural environment by respecting the existing native habitat and unique natural systems. This is achieved by preserving a network of open

natural areas and creating recreation spaces, urban streetscapes, parks and plazas that are designed and planted with an ecologically appropriate palette of materials".

1. *Selected landscape materials shall be drought-tolerant and low maintenance.*

2. *Plant materials listed in the Specific Plans project plant material palette (Table 12-1) shall be used, as well as approved plants listed in the Coachella Valley Water District's (CVWD's) Lush and Efficient Landscape Gardening book and in the Coachella Valley Multispecies Habitat Conservation Plan (CVMSHCP) are also appropriate.*

3. *Vegetative turf shall only be used in parks and recreation areas or as an accent material in limited quantities. Artificial turf may also be used as an accent material.*

4. *Plants with similar soil, water and sun exposure needs should be grouped to conserve water and encourage optimal growth.*

5. *Landscape shall be designed to encourage the use of drip irrigation and other low-flow irrigation methods, with no water overflow onto pavement, and such that wind does not blow irrigation water onto people, cars and pavement.*

Table 2.0-4, Estimated Project Water Service Demands for Residential, Commercial and Other Uses, provides a summary of the water demand that would need to be provided to the Project.

Land Use	AFY
Residential Indoor Demand	241.62
Non-Residential Indoor Demand	147.28
Outdoor Demand	1,142.94
Total Project Demand	**1,531.84**

The Project would need approximately 1531.84 AFY, or 2.48 AF per acre, using the project specific demand factors. This estimation includes indoor and outdoor use for the Residential and Non-Residential areas. This quantity is approximately 0.78-percent of the total project water supplied by the CVWD in 2035 (194,000 AFY).

Adherence to the MAWA requirements as outlined in CVWD's Model Landscape Ordinance No. 1302.4 ensures compliance with CVWD's water conservation goals and requirements. To meet the ETAF of 0.45, a landscape design must use highly water efficient plant materials and efficient irrigation technology, to include drip emitters and smart controllers.

Summary

The Project would have a total water demand of 1,531.84 AFY, or 2.48 AF per acre. The residential water demand is 241.62 AFY, the non-residential indoor demand is 147.28 AFY, and outdoor water demand is estimated to be 1142.94 AFY. Additionally, the Project may have

806.56 AFY of non-potable water which would provide a source substitution of non-potable water for potable water, that could help offset the total potable water demand.

2.2 Water Conservation Measures

CVWD has made significant effort to provide private and public consumers of local water resources with information to help conserve these resources through the use of drought tolerant desert plants and efficient irrigation systems. In addition, the City of Rancho Mirage (City) has adopted the CVWD Landscape Ordinance 1302.4 and requires that development within the City be water efficient.

The 2010 CVWMP Update identifies several conservation measures with the goal of reducing urban water demand by 20 percent by 2020. The 2010 CVWMP Update includes water efficient landscaping and irrigation, water efficient plumbing and appliances, tiered or budget-based water pricing, public information and education programs, alternative water supplies, water restrictive municipal development policies and maximum water allowance for landscaped and recreational areas. CVWD employs a full-time conservation coordinator with sufficient staffing to review all new landscape plans for compliance with CVWDs Landscape Ordinance.

2.2.1 Desert Landscaping/Native and Drought Tolerant Plants

The need for progressive water conservation and control of landscape maintenance costs has also prompted the greater use of native and non-native drought-tolerant planting materials within the Project. The Coachella Valley and CVWD have been a leader in the promotion of these desert landscape materials and design themes, most notably in Landscape Ordinance 1302.4. As a result, thoughtful and conservative management and use of water resources have guided development of this Project landscape plan.

2.2.2 Project Specific Water Conservation Measures

An Environmental Impact Report (EIR) is being prepared for the Project, and a broad range of design components and mitigation measures have been included in the EIR to address the Project's potential impacts on water resources.

Project developers shall be required to implement the following measures in order to assure the most efficient use of water resources and to meet and maintain the 2010 CVWMP Update goals throughout the life of the Project:

1. To the greatest extent practicable, native plant materials and other drought-tolerant plants shall be used in all non-turf areas of Project landscaping. Large expanses of lawn and other water-intensive landscaped areas shall be kept to the minimum necessary and consistent with the functional and aesthetic needs of the Project, while providing soil stability to resist erosion.

2. In the event recycled water becomes available to the Project, the potential use of tertiary treated water will be reviewed to determine feasibility of its use for on-site landscaped areas to reduce the use of groundwater for irrigation.

3. The installation and maintenance of efficient on-site irrigation systems will minimize runoff and evaporation and maximize effective watering of plant roots. Drip irrigation and moisture detectors will be used to the greatest extent practicable to increase irrigation efficiency.

4. The use of low-flush toilets and water-conserving showerheads and faucets shall be required in conformance with Section 17921.3 of the Health and Safety Code, Title 20, California Code of Regulations Section 1601(b), and applicable sections of Title 24 of the State Code.

5. Project developers will pay any required CVWD groundwater replenishment fees for the purpose of buying additional supplies of water for importation into the basin.

3.0 WATER SUPPLY ASSESSMENT

3.1 General

Having established that the 2010 Coachella Valley Water Management Plan (CVWMP) Update and 2015 Urban Water Management Plan (UWMP) are applicable to this Section 31 Specific Plan (Project), the next requirement of a Water Supply Assessment (WSA) is to identify and describe the water supply sources of the Public Water System (PWS) that will serve the Project. State Water Code Section 10910(d) requires a WSA to identify and describe the existing water supply sources available to the Coachella Valley Water District (CVWD) that will serve the Project. State Water Code Section 10910(d) requires a WSA to include identification of any existing water supply State Water Project (SWP) Table A amounts, water rights, or water service contracts relevant to the identified water supply for the proposed Project. The WSA shall include a description of the quantities of water received in prior years by the PWS. According to the 2015 UWMP, the aquifer and other sources of supply are adequate for an average year, single dry year and also multiple dry years, for a 20-year period (UWMP, Section 5.)

3.2 IDENTIFICATION OF WATER SOURCES

3.2.1 Primary Water Sources

The primary source of water supply in the Coachella Valley, and for this Project is the Coachella Valley Groundwater Basin. The groundwater basin is recharged by other sources of water, such as Colorado River water, recycled water, SWP supplies, and potentially desalinated shallow semi-perched brackish groundwater. Colorado River water is also available for potential domestic use if treated. Colorado River water via the Coachella Branch of the All American Canal supplies water for irrigation of the eastern Coachella Valley. The proposed Project is located in the western portion of the Coachella Valley which does not currently have access to this water. The Mid-Valley Pipeline Project, when completed, will deliver recycled water and Colorado River water via the Coachella Canal in the Whitewater River (Indio) Subbasin.

3.2.2 Additional Water Sources

In addition to Colorado River water and groundwater, CVWD and the Coachella Valley have additional sources of water that include imported SWP water, recycled water, and a limited amount of surface water. These sources are described in the following analysis of the Water Supply section. In the future, shallow, semi-perched brackish groundwater in the eastern Coachella Valley could be treated and used to meet non-potable uses as described in the 2010 CVWMP Update. The area within the Project is planned for access to recycled water when it becomes available for source substitution.

3.3 ANALYSIS OF WATER SUPPLY

3.3.1 Groundwater

Since the early part of the 20th century, the Coachella Valley has been dependent primarily on groundwater as a source of domestic water supply. Groundwater is also used to supply water for crop irrigation, fish farms, duck clubs, golf courses, greenhouses, and industrial uses in the Coachella Valley.

California Water Code Section 10910 requires that cities and counties conduct a WSA for projects that are subject to CEQA. If the water supply for the proposed Project includes groundwater, the WSA is required to include additional information such as a description of the groundwater basin, the rights of the PWS to use the groundwater basin, the overdraft status of the groundwater basin, any past or planned overdraft mitigation efforts, historical use of the groundwater basin by the PWS, projected use of the groundwater basin by the Project, and a sufficiency analysis of the groundwater basin.

3.3.2 ANNUAL RECHARGE DELIVERIES

The annual amounts of water delivered for recharge in the West Whitewater River Subbasin Area of Benefit are shown in **Table 3.0-1 Whitewater River Groundwater Replenishment Facility Annual Recharge Deliveries** on the following page.

Table 3.0-1
Whitewater River Groundwater Replenishment Facility Annual Recharge Deliveries

Year	Recharge Delivery (AF)
1973	7,475
1974	15,396
1975	20,126
1976	13,206
1977	0
1978	0
1979	25,192
1980	26,341
1981	35,251
1982	27,020
1983	53,732
1984	83,708
1985	251,994
1986	298,201
1987	104,334
1988	1,096
1989	12,478
1990	31,721
1991	14
1992	40,870
1993	60,153
1994	36,763
1995	61,318
1996	138,266
1997	113,677
1998	132,455
1999	90,601
2000	72,450
2001	707
2002	33,435
2003	902
2004	13,244
2005	165,554
2006	98,959
2007	16,009
2008	8,008
2009	57,024
2010	228,330
2011	232,214
2012	257,267
2013	26,620
2014	3,533
2015	865
2016	35,699
2017	385,994
2018	129,725
Total	**3,447,907**

3.3.3 Description of the Aquifer

Groundwater is the principal source of municipal water supply in the Coachella Valley. CVWD serves domestic water to most of the developed portions of the Coachella Valley and along both sides of the Salton Sea in the Imperial Valley. CVWD obtains water from both the Whitewater River (Indio) Subbasin and the Mission Creek Subbasin of the Coachella Valley Groundwater Basin. A common groundwater source, the Whitewater River (Indio) Subbasin, is shared by CVWD, Desert Water Agency (DWA), Indio Water Authority (IWA), Coachella Water Authority (CWA), Myoma Dunes Water Company, and numerous private groundwater users.

The Coachella Valley Groundwater Basin, as described by the California Department of Water Resources (DWR) in Bulletin 118 is bound on the north and east by non-water bearing crystalline rocks of the San Bernardino and Little San Bernardino Mountains, and on the south and west by the crystalline rocks of the Santa Rosa and San Jacinto Mountains. At the west end of the San Gorgonio Pass, between the Cities of Beaumont and Banning, the basin boundary is defined by a surface drainage divide separating the Coachella Valley Groundwater Basin from the Beaumont Groundwater Basin of the Upper Santa Ana drainage area.

The subbasins present in the Coachella Valley Groundwater Basin are the Mission Creek, Desert Hot Springs, San Gorgonio Pass, and Whitewater River (also known as Indio). The Whitewater River (Indio) Subbasin in the Coachella Valley Groundwater Basin can be described as a giant tilted bathtub full of sand, with the high end at the northwest edge of the Coachella Valley near the community of Whitewater and the low end at the Salton Sea. The aquifer underlies the Cities of Palm Springs, Cathedral City, Rancho Mirage, Palm Desert, Indian Wells, La Quinta, Indio, and Coachella, and the unincorporated communities of Thousand Palms, Thermal, Bermuda Dunes, Oasis, and Mecca. The Whitewater River (Indio) Subbasin includes five subareas: Palm Springs, Garnet Hill, Thermal, Thousand Palms and Oasis. The Palm Springs Subarea is in the forebay or main area of recharge to the subbasin, and the Thermal Subarea comprises the pressure or confined area within the subbasin. The other three subareas are peripheral areas having unconfined groundwater conditions. The subbasins with their groundwater storage reservoirs are defined without regard to water quantity or quality. They delineate areas underlain by formations, which readily yield the stored groundwater through water wells and offer natural reservoirs for the regulation of water supplies.

The Whitewater River (Indio) Subbasin comprises the major portion of the floor of the Coachella Valley and encompasses approximately 400 square miles. The historical fluctuations of water levels within the Whitewater River (Indio) Subbasin indicate a steady decline in the levels throughout the subbasin prior to 1949. After 1949, levels in the eastern Thermal Subarea (south of Point Happy) where imported Colorado River water is used for irrigation rose sharply, although water levels continued to decline elsewhere in the subbasin. With the use of Colorado River water from the Coachella Canal, the demand on the groundwater subbasin declined in the eastern Coachella Valley (generally east and south of Washington Street below Point Happy). Water levels in the deeper aquifers rose from 1950 to 1980. However, water levels in this area declined due to increasing urbanization and groundwater usage from 1980-2010. Recharge in the eastern Coachella Valley has resulted in water levels rising in the past few years.

The Whitewater River (Indio) Subbasin is located northwest of the Salton Sea and receives low precipitation, averaging about 6 inches per year, and a wide range of temperatures. The Banning fault bounds the subbasin on the north and the semi-permeable rocks of the Indio Hills mark the northeast boundary. Impermeable rocks of the San Jacinto and Santa Rosa Mountains bound the subbasin on the south. A bedrock constriction separates the Whitewater River (Indio) Subbasin from the San Gorgonio Pass Subbasin on the northwest. The Salton Sea is the eastern boundary and the subbasin's primary discharge area. A low drainage divide forms a short boundary with the West Salton Sea Groundwater Basin in the southeast.

In the western part of the Whitewater River (Indio) Subbasin, groundwater is unconfined, whereas to the south and southeast groundwater is mostly confined except on the edges of the subbasin where unconfined conditions are found. Depth to groundwater varies widely in the southeast part of the subbasin and some wells historically delivered artesian flow.

From a management perspective, the Whitewater River (Indio) Subbasin is commonly divided into west and east Areas of Benefit (AOBs), with the dividing line extending from Point Happy in La Quinta to the northeast and terminating at the San Andreas Fault and the Indio Hills at Jefferson Street. The West Whitewater River Subbasin AOB is defined generally as that portion of the Thermal Subarea west of this line and includes the Palm Springs and Thousand Palms Subareas.

The Whitewater River (Indio) Subbasin is recharged naturally with runoff from the San Jacinto, Santa Rosa, and San Bernardino Mountains. Since the 1950s, groundwater extractions in the Whitewater River (Indio) Subbasin have exceeded the long-term natural recharge, placing the subbasin in a state of overdraft and resulting in declining groundwater levels.

Groundwater Storage

As shown in **Table 3.0-2 Groundwater Storage Capacity of the Coachella Valley Groundwater Basin**, the DWR estimated in 1964 that the Coachella Valley Groundwater Basin contained a total of approximately 39.2 million acre-feet (AF) of water in the first 1,000 feet below the ground surface, much of which originated from runoff from adjacent mountains. However, the amount of water in the aquifer has decreased over the years due to the groundwater pumping to serve urban, rural, and agricultural development in the Coachella Valley, which has withdrawn water from the aquifer at a rate faster than its natural rate of recharge. DWR has calculated the storage capacity of the Whitewater River (Indio) Subbasin to be 29.8 million AF.

Table 3.0-2 Groundwater Storage Capacity of the Coachella Valley Groundwater Basin

Area	Storage (AF) [1]
Whitewater River (Indio) Subbasin	
Palm Springs Subarea	4,600,000
Thousand Palms Subarea	1,800,000
Oasis Subarea	3,000,000
Garnet Hill Subarea	1,000,000
Thermal Subarea	19,400,000
Subtotal Whitewater River (Indio) Subbasin	29,800,000
San Gorgonio Pass Subbasin	2,700,000
Mission Creek Subbasin	2,600,000
Desert Hot Springs Subbasin	4,100,000
Total Coachella Valley Groundwater Basin:	**39,200,000**

1. First 1,000 feet below ground surface. DWR estimate (DWR, 1964).

Groundwater Levels

The rate of groundwater level decline has increased since the early 1980s due to increased urbanization and increased groundwater use by domestic water purveyors, farmers, golf courses and public parks.

Although water levels have been declining throughout most of the subbasins since 1945, water levels in the southeastern portion of the Coachella Valley had risen until the early 1980s because of the use of imported water from the Coachella Branch of the All American Canal and the resulting decreased pumping in that area. The rate of groundwater level decline increased from the early 1980s until about 2010 due to increased urbanization and increased use by domestic water purveyors, local farmers, golf courses, and fish farms. Since 2010, groundwater levels in the southeastern portion of the Coachella Valley have risen as a result of reduced pumping in the eastern Coachella Valley combined with recharge of Colorado River water at the Thomas E. Levy Groundwater Replenishment Facility (TEL GRF).

The historic declining water table in the eastern portion of the Whitewater River (Indio) Subbasin led to the determination that a management program is required to stabilize water levels and prevent other adverse effects such as water quality degradation and land subsidence. CVWD's Groundwater Replenishment Program is reducing declining water levels in this subbasin. Groundwater recharge in the eastern Whitewater River (Indio) Subbasin began in 1997, and the benefits of recharge can be seen in recent groundwater level measurements.

Direct replenishment with imported water from the Colorado River Aqueduct began in 1973 at the Whitewater River Groundwater Replenishment Facility. A total of approximately 3.5 million AF of imported water from the Colorado River Aqueduct has been delivered to the Whitewater River GRF for replenishment of the Management Area. During the last 10 years, groundwater levels have increased up to about 180 ft around the Whitewater River GRF. Groundwater levels observed at monitoring wells throughout the West Whitewater River AOB have demonstrated the benefit and effectiveness of the Ground Water Replenishment Program (GRP) in sustaining the groundwater supplies.

Water surface elevations in the western area of the Coachella Valley are highest at the northwest end of the subbasin, illustrating the regional groundwater flow is from the northwest to the southeast in the Coachella Valley.

Groundwater Production

CVWD's total groundwater production in the West Whitewater River Subbasin Management Area, as shown in **Table 3.0-3 Groundwater Production and Surface-Water Diversions within the West Whitewater River Subbasin Management Area**, total groundwater production within the West Whitewater River Subbasin Management Area was estimated to be 154,755 AF in 2018. Annual water production within the West Whitewater River Subbasin Management Area (groundwater extractions plus surface water diversions) for all producers, has averaged 160,496 AFY for the past 6 years (2013-2018), down from the 191,638 AFY average from the previous 5-year period (2008-2012). Based on production records, approximately 22 to 25 percent of annual water production within the West Whitewater River Subbasin Management Area is allocable to DWA, and the remaining 75 to 78 percent is allocable to CVWD.

As presented in the 2010 CVWMP Update, groundwater production within the West Whitewater River Subbasin Area of Benefit was estimated to be 208,439 AF during 1999. The reported production for 2017 was 155,543 AF, and for 2018 was 154,755 AF. Groundwater production within the East Whitewater River Subbasin Area of Benefit was estimated to be 168,300 AF during 1999. The reported production for 2017 was 177,444 AF and 120,935 AF for 2018.

Table 3.0-3 Groundwater Production and Surface-Water Diversions within the West Whitewater River Subbasin Management Area

Calendar Year	Production within CVWD AOB[1] (AF)	Production within DWA AOB[2,3] (AF)	Surface-Water Diversions[4] (AF)	Total Production (AF)
1977	67,696	18,661	7,000	93,357
1978	61,172	28,100	8,530	97,802
1979	72,733	29,393	7,801	109,927
1980	84,142	32,092	7,303	123,537
1981	86,973	33,660	7,822	128,455
1982	83,050	33,382	6,512	122,944
1983	84,770	33,279	6,467	124,516
1984	104,477	38,121	7,603	150,201
1985	111,635	39,732	7,143	158,510
1986	115,185	40,965	6,704	162,854
1987	125,229	44,800	5,644	175,673
1988	125,122	47,593	5,246	177,961
1989	129,957	47,125	5,936	183,018
1990	136,869	45,396	5,213	187,478
1991	126,360	42,729	4,917	174,006
1992	128,390	42,493	4,712	175,595
1993	131,314	41,188	6,363	178,865
1994	134,223	42,115	5,831	182,169
1995	134,583	41,728	5,809	182,120
1996	137,410	45,342	5,865	188,617
1997	137,406	43,658	5,626	186,690
1998	142,620	41,385	7,545	191,550
1999	157,148	44,350	6,941	208,439
2000	161,834	44,458	6,297	212,589
2001	125,122	47,593	4,928	208,807
2002	129,957	47,125	4,221	213,410
2003	156,185	43,463	4,627	204,275
2004	159,849	48,093	4,758	212,700
2005	153,462	46,080	4,799	204,341
2006	160,239	48,967	4,644	213,850
2007	157,487	50,037	3,490	211,014
2008	161,695	45,405	3,593	210,693
2009	155,793	41,913	1,443	199,149
2010	141,481	39,352	1,582	182,415
2011	141,028	40,071	1,724	182,823
2012	141,379	39,507	2,222	183,108
2013	143,108	37,730	1,802	182,640
2014	136,027	36,372	1,787	174,186
2015	115,588	30,332	1,539	147,459
2016	115,659	30,705	2,031	148,395
2017	120,383	33,164	1,996	155,543
2018	119,250	33,873	1,632	154,755

Notes:
1 – Excludes production by minimal pumpers who extract 25 AFY or less and other users exempt from the RAC.

2 – Excludes production by minimal pumpers who extract 10 AFY or less and other users exempt from the RAC.
3 – Production within DWA AOB includes production within DWA's Garnet Hill Subbasin AOB (starting 2016).
4 – Whitewater Mutual Water Company, Chino Creek, Snow Creek, and Falls Creek (DWA AOB).

Groundwater Inflows and Outflows

CVWD divides the Whitewater River (Indio) Subbasin within its service area into Management Areas. Total inflows and outflows to the West Whitewater River Subbasin Management Area for the year 2017 are summarized in **Table 3.0-4 Annual Water Balance in the West Whitewater River Subbasin Management Area for Calendar Year 2017**. The natural inflow of 52,058 AF includes natural recharge and flow across subbasin boundaries. The non-consumptive return of applied water is estimated at 51,220 AF, which is 10.5 percent of the reported inflow of 489,272 AF. The total inflow includes the natural inflow, the non-consumptive return, and the 385,994 AF of actual water replenished at the Whitewater River Groundwater Replenishment Facility (Whitewater River GRF). Total outflow is the reported 156,123 AF of groundwater production estimates, the 7,935 AF of evaporative losses, and the 22,622 AF of natural outflow. The annual balance is the total inflow less the total outflow, for a net increase of approximately 302,680 AF of water in storage to the management area.

In 2017, the change in groundwater in storage in the West Whitewater River Subbasin Management Area was positive, and imported water may offset annual changes in the groundwater in storage in a particular year. However, on a long-term basis, water requirements are likely to continue to place demands on groundwater storage. Without artificial replenishment, the annual reduction in stored groundwater within the West Whitewater River Subbasin Management Area in 2017 would have resulted in a net loss of approximately 83,402 AF, compared to the annual balance of approximately 305,592 AF.

Table 3.0-4 Annual Water Balance in the West Whitewater River Subbasin Management Area for Calendar Year 2017

Item	Annual Calculation (AF)
Inflows	
Infiltration of Natural Runoff[1]	40,823
Surface Water Diverted	1,996
Subsurface Inflows from Adjacent Basins[1]	11,235
Infiltration of Applied Irrigation Water[2]	38,481
Wastewater Percolation	7,169
Septic Tank Percolation[2]	3,574
Artificial Replenishment[3]	385,994
Total Inflows	**489,272**
Outflows	
Metered Groundwater Pumping and Surface Water Diversions[4]	155,623
Assumed Approximate Production by Unmetered Minimal Pumpers	500
Evaporative Losses[5]	7,935
Subsurface Outflow to Adjacent Basins[1][6]	22,622
Total Outflows	**186,680**
Change in Storage[7]	**302,592**

(1) MWH 2011
(2) See Appendix B
(3) Water delivered to the Whitewater River Groundwater Replenishment Facility
(4) Total surface water diversions, assessable groundwater production, and metered groundwater production from minimal pumpers.
(5) Estimated losses from spreading basins and percolation ponds.
(6) To the East Whitewater Subbasin Area of Benefit
(7) This was an increase in stored groundwater equal to 1.02% of the Whitewater River Subbasin's storage capacity of 29,800,000 AF in 2017.

Surface runoff, surface inflow, and artificial replenishment are significant sources of recharge to the Whitewater River (Indio) Subbasin. Annual deliveries of Colorado River water through the Coachella Canal of approximately 300,000 AFY are a significant component of southeastern Coachella Valley hydrology. Direct groundwater replenishment within the West Whitewater River Subbasin AOB, which began in 1973, has so far replenished the western portion of the Whitewater River (Indio) Subbasin with a cumulative total of approximately 3,447,907 AF of imported water. Imported water in the amount of 385,994 AF and 129,725 AF was delivered to the Whitewater River GRF during 2017 and 2018, respectively.

Aquifer Adjudication

The Whitewater River (Indio) Subbasin has not been adjudicated. From a management perspective, CVWD divides the portion of the Whitewater River (Indio) Subbasin within its service area into two AOBs designated as the West Whitewater River Subbasin AOB and the East Whitewater River Subbasin AOB. The dividing line between these two areas is an irregular line trending northeast to southwest between the Indio Hills north of the City of Indio and Point Happy in La Quinta. The West Whitewater River Subbasin Management Area is jointly managed by CVWD and DWA under the terms of the 2014 Whitewater Management Agreement. The East Whitewater River Subbasin AOB is managed by CVWD.

Overdraft Status of the Aquifer

Groundwater overdraft is manifested not only as a prolonged decline in groundwater storage but also through secondary adverse effects, including decreased well yields, increased energy costs, water quality degradation, and land subsidence. Continued groundwater replenishment will be necessary to eliminate or reduce overdraft in the future.

The Coachella Valley Groundwater Basin (and its subbasins) has been historically in a state of overdraft condition. With maximum SWP Table A allocations, recharge in the Whitewater River (Indio) Subbasin would offset the current annual overdraft, although overdraft in future years is virtually unpredictable, due to the difficulty of projecting long-term growth and the reliability of SWP supplies.

Direct groundwater replenishment within the West Whitewater River Subbasin AOB began in 1973 and has so far replenished the western portion of the Whitewater River (Indio) Subbasin with a cumulative total of 3,447,907 AF of imported water. Imported water in the amount of 129,725 AF was delivered to the Whitewater River GRF during 2018.

CVWD and DWA request their full amount of SWP Table A amounts each year, for a combined total of 194,100 AF, and continue to exchange their SWP for Colorado River water with the Metropolitan Water District of Southern California (MWD). Given that water demand and groundwater extractions are expected to increase in the future, the current Groundwater Replenishment Program will need to be continued and increased in the future to eliminate overdraft. Cumulative replenishment water deliveries between the Mission Creek GRF and Whitewater River GRF will be balanced as determined by CVWD, DWA, and MSWD, but no later than 20 years from December 7, 2004.

Over the past 10 years, the Whitewater River (Indio) Subbasin has been balanced; however, during the past 20 years, about 45,000 AFY of storage has been lost to overdraft. Projected water requirements through 2040 for the Whitewater River (Indio) Subbasin are based on the water balance model utilized in the 2010 CVWMP Update and the 2016 Status Report for the 2010 CVWMP Update. The Project requirements are largely offset by potable supplies; however, on a long-term basis, water requirements are likely to continue to place demands on groundwater storage. Implementation of the programs recommended in the 2010 CVWMP Update is expected to result in elimination of storage losses by about 2022, assuming average hydrologic conditions.

Overdraft Mitigation Efforts

Coachella Valley Water Management Plan Update

In addition to the requirements for the 2015 UWMP, CVWD maintains water management policies within its 2010 CVWMP Update to comprehensively protect and augment the groundwater supply. As defined in the 2010 CVWMP Update, CVWD is reducing reliance on groundwater sources by utilizing more Colorado River water, SWP water, and recycled water. Per this plan, CVWD also implements source substitution and conservation measures to reduce demands on the aquifer. The goal is to reduce the overall water demand by 20 percent by 2020 pursuant to SB x7-7. The CVWD anticipates this water use reduction level will be maintained through the remainder of the planning period.

CVWD Landscape Ordinance

CVWD Landscape Ordinance 1302.4 required a series of reduction methods, including requirements that new developments install weather-based irrigation controllers that automatically adjust water allocation. Additional requirements included setbacks of spray emitters from impervious surfaces, as well as use of porous rock and gravel buffers between grass and curbs to eliminate run-off onto streets. With the exception of turf, all landscaping, including groundcover and shrubbery, must be irrigated with a drip system. Also, the maximum water allowance for landscaped areas through the CVWD service area has been reduced. This new reduction goal requires that developers maximize the use of native and other drought-tolerant landscape materials and minimize use of more water-intensive landscape features, including turf and fountains.

Source Substitution

Source substitution is the delivery of an alternate source of water to users currently pumping groundwater. The substitution of an alternate water source reduces groundwater extraction and allows the groundwater to remain in storage, thus reducing overdraft. Alternative sources of water include municipal recycled water from Water Reclamation Plant (WRP)-7, WRP 10, and the City of Palm Springs Wastewater Treatment Plant, Colorado River water, and in the future, desalinated shallow semi-perched brackish groundwater and re-use of aquaculture water. Source substitution projects include:

- Conversion of existing and future golf courses in the eastern Coachella Valley from groundwater to Colorado River water
- Conversion of existing and future golf courses in the western Coachella Valley from groundwater to recycled water and/or Colorado River water via SWP Exchange water
- Conversion of existing and future golf courses in the eastern Coachella Valley from groundwater to Colorado River water via the Mid-Valley Pipeline
- Conversion of agricultural irrigation from groundwater to Colorado River water, in both the Oasis and Mecca area
- Conversion of some municipal use from groundwater to treated Colorado River water

Examples of effective alternative source substitute efforts include the following:

- CVWD has a non-potable water system that treats recycled water from two water reclamation plants, blends in with canal water and delivers to golf courses, schools, and open spaces for irrigation. Approximately 39,194 AF of recycled water was delivered in 2017.

- CVWD has completed construction of a 54-inch diameter pipeline to deliver Colorado River water to the Mid-Coachella Valley area for use with CVWD's recycled water for golf course and open space irrigation. This will reduce pumping from the groundwater basin for these uses.

- CVWD has secured rights to the Colorado River and participated in the construction of the All-American Canal and the Coachella Branch of the All-American Canal. Beginning in the late 1940's, CVWD worked with the U.S. Bureau of Reclamation (USBR) and constructed a distribution system to deliver Colorado River water to the farms in the eastern Coachella Valley. This system delivered 333,160 AF of Colorado River water in 2017.

- CVWD has recharged the eastern Coachella Valley with up to 40,000 AFY of Colorado River at the TEL GRF and has completed the construction of Phase I of the Palm Desert GRF that will expand the recharge program with an additional 15,000 AFY of recharge. The largest recharge program is operated at the Whitewater River GRF.

- CVWD has secured rights to SWP water and negotiated exchange and advanced delivery agreements with the Metropolitan Water District of Southern California (MWD) to exchange CVWD's SWP water for MWD's Colorado River water source. The SWP exchange water is used to recharge the aquifer in the western Coachella Valley. This recharge program was started in 1973 and has replenished the aquifer with over two million AF of water.

- CVWD plans to utilize treated shallow semi-perched brackish groundwater for irrigation purposes. A desalination pilot study was completed in 2007.

- CVWD has worked with an aquaculture farm and developed water efficiency programs that include water treatment and reuse.

- CVWD intends to implement expansion of the Oasis area irrigation system. This project will reduce groundwater pumping by extending Colorado River water delivery to the Oasis Slope. The Oasis system would deliver Canal water and desalinated shallow semi-perched brackish groundwater to serve urban non-potable water uses such as irrigation.

Conservation Programs

CVWD continues to work with the cities in its service area to limit the amount of water that is used for outdoor landscaping. As a result of the adoption of statewide indoor water conservation measures requiring low flush toilets, shower and faucet flow restrictors and other devices, the amount of water used inside homes has been significantly reduced. With the large number of new homes constructed, these conservation programs have reduced impacts of new development on the aquifer. Also, in 2016 CVWD adopted Water Budget based tiered rates to discourage excessive water use.

The Project will be required to implement the CVWD conservation measures in order to assure that the most efficient use of water resources and to meet and maintain the 2020 water conservation goals throughout the life of the Project. In addition, the Project will strictly adhere to CVWD's Landscape Ordinance 1302.4.

Historical Groundwater Use

CVWD's annual Engineer's Report on Water Supply and Replenishment Assessment 2019-2020, reviews the historical use of groundwater in the Coachella Valley. In 1936, groundwater use totaled 92,400 AF and increased steadily to about 376,000 AF in 1999 and 398,510 AF in 2007. Total groundwater use, including private pumping, has dropped off slightly since 2007, due to a combination of water conservation efforts, source substitution projects and the effects of the ongoing economic recession. In 2014, as a continued result of conservation and source substitution programs, total groundwater use dropped even further to approximately 297,652 AF. In 2015, mostly due to mandatory drought reductions, total groundwater use dropped even further to 261,165 AF. These reductions represent 25 and 34 percent reductions in reported Coachella Valley groundwater pumping, respectively, since 2007.

Groundwater Sufficiency Analysis

The 2015 UWMP reports CVWD's actual service area urban water demand at 92,974 AF in 2015. Projected urban water demand in the 2015 UWMP for the year 2040 is anticipated to be 194,300 AF.

Total buildout water demand of the Project is estimated to be approximately 1531.84 AFY, or 2.48 AF per acre, which represents approximately 0.78 percent of the total anticipated urban demand of 194,300 AF in CVWD's urban water system projected for 2040.

With almost 30 million AF of combined storage followed by groundwater management planning adopted in the 2015 UWMP and 2010 CVWMP Update, the aquifer has sufficient available water to supply the Project and other present and anticipated needs for normal year, as well as one or more multiple dry years, over the next 20 years.

3.3.4 ADDITIONAL WATER SOURCES

As stated previously, groundwater provides the water supply for the Project. This WSA focuses on the adequacy of groundwater to meet the water demands of this Project. Additional water sources are considered as a supplement to groundwater in that they are used to recharge the aquifer, serve as a source substitution for groundwater, or are used for irrigation in other locations in the subbasin.

If it becomes available to the Project site, the Project will utilize recycled water on site to meet non-potable water demands.

Colorado River Water

The Coachella Canal is a branch of the All-American Canal, which brings Colorado River water into the Imperial and Coachella Valleys. The service area for Colorado River water delivery under CVWD contract with the USBR is defined as Improvement District No. 1 (ID-1). Under the 1931 California Seven Party Agreement, CVWD has high priority water rights to Colorado River water as part of the first 3.85 million AF of the 4.4 million AF allocated to California.

California's Colorado River supply is protected by the 1968 Colorado River Basin Project Act, which provides that the Colorado River supplies to Arizona and Nevada projects constructed after 1968 shall be reduced to zero before California will be reduced below 4.4 million AF in any year. This provision assures full supplies to the Coachella Valley except in periods of extreme drought.

Historically, CVWD has received approximately 330,000 AFY of Priority 3A Colorado River water delivered via the Coachella Canal. The 2003 Quantification Settlement Agreement (QSA) among some of the California Colorado River contactors provides contractual obligation for the supply to CVWD. A number of lawsuits have unsuccessfully challenged the QSA agreements and transfers in state and federal court.

Table 3.0-5 Annual CVWD Colorado River Diversions at Imperial Dam – 1964 to 2018

Year	Diversion Volume (ac-ft)	Year	Diversion Volume (ac-ft)	Year	Diversion Volume (ac-ft)	Year	Diversion Volume (ac-ft)
1964	526,417	1979	530,733	1993	318,990	2008	299,064
1965	524,686	1980	531,791	1994	326,102	2009	322,730
1966	489,429	1981	452,260	1995	326,697	2010	251,249
1967	465,053	1982	424,868	1996	331,473	2011	265,270
1968	478,583	1983	362,266	1997	338,466	2012	329,576
1969	495,082	1984	355,789	1998	337,466	2013	331,137
1970	449,263	1985	337,002	1999	333,810	2014	349,372
1971	470,683	1986	339,702	2000	342,871	2015	342,074
1972	511,476	1987	322,625	2001	325,097	2016	356,358
1973	522,356	1988	331,821	2002	331,107	2017	335,321
1974	558,864	1989	359,419	2003	296,808	2018	335,035
1975	570,987	1990	369,685	2004	318,616		
1976	524,800	1991	317,563	2005	304,769		
1977	508,635	1992	309,367	2006	329,322		
1978	509,491	1992	318,990	2007	311,971		

Source: U.S. Department of the Interior, Bureau of Reclamation Lower Colorado Region, Colorado River Accounting and Water Use Reports for Arizona, California, and Nevada for years 1964 through 2018.

The QSA was entered into and between CVWD, Imperial Irrigation District (IID), MWD, and the San Diego County Water Authority (SDCWA). The QSA quantifies distribution allotments of Colorado River water rights in California, including CVWD's Colorado River Rights, for the next 75 years. The agreements provide for additional transfer of Colorado River allocations to CVWD from the IID and MWD. As of 2015, CVWD receives 378,000 AFY of Colorado River Water. CVWD's allocation of Colorado River Water will increase to 419,000 AFY in 2018, and 459,000 AFY in 2026, then reduce to 456,000 AFY in 2048 and remain at the level for the remaining 75-year term of the QSA.

Table 3.0-6 CVWD Deliveries
Under the Quantification Settlement Agreement

Component	2015 Amount (AFY)	2026-2047 Amount (AFY)	2048-2077 Amount (AFY)
Base Entitlement	330,000	330,000	330,000
Less Coachella Canal Lining (to SDCWA)	-26,000	-26,000	-26,000
Less Miscellaneous/Indian PPRs	-3,000	-3,000	-3,000
1988 MWD/IID Approval Agreement	20,000	20,000	20,000
First IID/CVWD Transfer	36,000	50,000	50,000
Second IID/CVWD Transfer	0	53,000	0
MWD/CVWD Replacement Water[1]	0	0	50,000
MWD/CVWD SWP Transfer[2]	35,000	35,000	35,000
Total Allocation	**392,000**	**459,000**	**456,000**
Less Conveyance Losses and Regulatory Water[3]	-14,000	-14,000	-14,000
Total Deliveries to CVWD	**378,000**	**445,000**	**442,000**

NOTES:
1 MWD assumes the obligation to provide 50,000 AFY of replacement water after 2048.
2 The 35,000 AFY may be delivered at either Imperial Dam or Whitewater River and is not subject to SWP or Colorado River reliability.
3 Conveyance losses and regulatory water based on 2009-2014 averages.

Water from the Coachella Canal provides a significant supply source for the eastern Coachella Valley. In 1999, the Coachella Canal supplied over 60 percent of the water used in the eastern Coachella Valley, but provided less than one percent of the water supply to the western Coachella Valley. Most of the canal water was used for crop irrigation in the eastern Coachella Valley.

In 1995, CVWD began operating the Dike No. 4 pilot recharge facility in La Quinta. As discussed previously in Source Substitution, this facility has successfully demonstrated the adequacy of this site to recharge the aquifer. This facility was expanded in 1998. This site is known as the TEL GRF as the Dike No. 4 site was expanded in 2009 and put into full operation.

Future development and associated increases in water demand, as well as quality concerns, are expected to increase use of Colorado River water for domestic purposes. Determining the best way to treat this water in order to substitute for and decrease the area's dependency on groundwater is an important objective of the 2010 CVWMP Update and 2015 UWMP. The 2010

CVWMP Update calls for the treatment and distribution of as much as 62,000 AF of Colorado River water for domestic use annually.

3.3.5 State Water Project Water

CVWD and DWA are SWP contractors for the Whitewater River (Indio) Subbasin. The SWP includes 660 miles of aqueduct and conveyance facilities extending from Lake Oroville in the north to Lake Perris in the south. The SWP has contracts to deliver 4.1 million AFY to 29 contracting agencies. CVWD's original SWP water right (Table A amount) was 23,100 AFY and DWA's original SWP Table A amount was 38,100 AFY for a combined Table A amount of 61,200 AFY.

In 2004, CVWD purchased an additional 9,900 AFY of SWP water from the Tulare Lake Basin Water Storage District, which brought CVWD's SWP allotment to 33,000 AFY.

In addition, CVWD and DWA have also negotiated an exchange agreement with MWD for 100,000 AFY of SWP Table A amount. MWD has permanently transferred 88,100 AFY and 11,900 AFY of its SWP Table A amounts to CVWD and DWA, respectively. This exchange agreement increases the total SWP Table A amount for CVWD and DWA to 178,100 AFY, with CVWD's portion equal to 126,350 AFY. This agreement provides that CVWD and DWA generally receive this water from the SWP during wet years, which allows the two agencies to recharge the groundwater basin and operate a conjunctive use program, storing water in wet years and pumping the groundwater basin in dry years.

In 2007, CVWD and DWA made a second purchase of SWP water from the Tulare Lake Basin Water Storage District. CVWD purchased 5,250 AFY and DWA purchased 1,750 AFY. In 2007, CVWD and DWA completed the transfer of 12,000 AFY and 4,000 AFY, respectively, from the Berrenda Mesa Water District for a total Table A amount of 16,000 AFY. Therefore, the total SWP Table A amount for CVWD and DWA is 194,100 AFY, with CVWD's portion equal to 138,350 AFY. **Table 3.0-7, State Water Project Water Sources**, summarizes CVWD and DWA total allocations of Table A SWP water to be delivered when available.

Table 3.0-7 State Water Project Water Sources (AFY)

Agency	Original SWP Table A	Tulare Lake Basin Transfer #1	Tulare Lake Basin Transfer #2	MWD Transfer	Berrenda Mesa Transfer	Total
	AFY					
CVWD	23,100	9,900	5,250	88,100	12,000	138,350
DWA	38,100	0	1,750	11,900	4,000	55,750
Total	**61,200**	**9,900**	**7,000**	**100,000**	**16,000**	**194,100**

SWP contractors make annual requests to the DWR for water allocations and DWR makes an initial SWP Table A allocation for planning purposes, typically in the last month before the next water delivery year. Throughout the year, as additional information regarding water availability becomes available to DWR, its allocation/delivery estimates are updated.

Table 3.0-8, Department of Water Resources Table A Water Allocations, outlines the historic reliability of SWP deliveries, including their initial and final allocations.

Table 3.0-8, Department of Water Resources Table A Water Allocations

Year	Water Year Type 1	Initial Allocation	Final Allocation
1988	Critical	100%	100%
1989	Dry	100%	100%
1990	Critical	100%	100%
1991	Critical	85%	30%
1992	Critical	20%	45%
1993	Above Normal	10%	100%
1994	Critical	50%	50%
1995	Wet	40%	100%
1996	Wet	40%	100%
1997	Wet	70%	100%
1998	Wet	40%	100%
1999	Wet	55%	100%
2000	Above Normal	50%	90%
2001	Dry	40%	39%
2002	Dry	20%	70%
2003	Above Normal	20%	90%
2004	Below Normal	35%	65%
2005	Above Normal	40%	90%
2006	Wet	55%	100%
2007	Dry	60%	60%
2008	Critical	25%	35%
2009	Dry	15%	40%
2010	Below Normal	5%	50%
2011	Wet	25%	80%
2012	Below Normal	60%	65%
2013	Dry	30%	35%
2014	Critical	5%	5%
2015	Critical	10%	20%
2016	Below Normal	45%	60%
2017	Wet	60%	85%
2018	Dry	20%	35%

Source: DWR, Water Contract Branch within the State Water Project Analysis Office, Notices to State Water Contractors, 1988-2018.

1 Water year designation based on Sacramento Valley Water Year Hydraulic Classification which is based on the sum of the unimpaired runoff in the water year as published in the DWR Bulletin 120 for the Sacramento River at Bed Bridge, Feather River Inflow to Oroville, Yuba River to Smartville and American River to Folsom reservoir.

As noted previously, CVWD and DWA do not directly receive SWP water. Rather, CVWD and DWA have entered into an exchange agreement with MWD that allows MWD to take delivery of CVWD and DWA SWP Table A water. In exchange, MWD provides an equal amount of Colorado River water that MWD transports through its Colorado River Aqueduct, which crosses the Coachella Valley near Whitewater. The exchange agreement allows for advanced delivery and storage of water, thereby providing better and more efficient water management. Water is only recharged when SWP and exchange waters are available. The large storage capacity of the Coachella Valley Groundwater Basin and the large volume of water in storage allows CVWD and DWA to pump from the aquifer for a number of years without recharging. Large amounts of water can be recharged into the aquifer when the water is available.

Factors Potentially Impacting SWP Delivery Reliability

DWR issues the State Water Project Delivery Reliability Report every two years. The Final State Water Project Availability Report, 2017 (Final 2017 SWP Report), accounts for impacts to water delivery reliability associated with climate change and recent federal litigation. This allocation percentage is based on computer modeling of the state's watersheds, and past hydrology adjusted for factors that affect reliability. In considering future water supply needs in the 2010 CVWMP Update, CVWD considered an even lower SWP delivery reliability to allow for the uncertainty of future court decisions, State Water Resources Control Board actions, Endangered Species Act (ESA) and other restrictions, modeling error, levee failure and relaxation in the biological opinions (BO) as the result of better science.

There are three significant factors contributing to uncertainty in the delivery reliability of the SWP: 1) possible effect from climate change and sea level rise; 2) the vulnerability of the Sacramento-San Joaquin River Delta levees to failure, and 3) greater operation restrictions imposed by the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) in response to decreasing population of endangered fish species.

CVWD considers purchases of additional Table A Amounts from SWP contractors as they become available.

3.3.6 Surface Water

CVWD does not currently use or intend to use any local surface water (non-imported surface water) as part of its urban water supply. Local runoff is captured and used for groundwater recharge.

Surface water supplies come from several local rivers and streams including the Whitewater River, Snow Creek, Falls Creek and Chino Creek, as well as a number of smaller creeks and washes. In 1999, surface water supplied approximately three percent of the total water supply to the western Coachella Valley to meet municipal demand, and none to the eastern Coachella Valley. Because surface water supplies are affected by variations in annual precipitation, the annual supply is highly variable.

3.3.7 Stormwater

The Coachella Valley drainage area is approximately 65 percent mountainous and 35 percent typical desert valley with alluvial fan topography buffering the valley floor from the steep mountain slopes. The mean annual precipitation ranges from 44 inches in the San Bernardino Mountains to less than 3 inches at the Salton Sea. Three types of storms produce precipitation in the drainage area: general winter storms, general thunder storms and local thunderstorms. Longer duration, lower intensity rainfall events tend to have higher recharge rates, but runoff and flash flooding can result from all three types of storms. Otherwise, there is little to no flow in most of the streams in the drainage area.

Significant amounts of local runoff are currently captured at the Whitewater River GRF and in the debris basins and unlined channels of the western Coachella Valley. Additional stormwater will be captured when the Thousand Palms Flood Control Project is completed and when the flood control is constructed in the Oasis area. However, limited data exists to estimate the amount of additional stormwater that could be captured by new facilities in the Coachella Valley. Consequently, large scale stormwater capture is not expected to yield sufficient water to be worth the investment as a single purpose project. Small scale stormwater retention systems located in areas of suitable geology to allow percolation could capture small intensity storms as well as street runoff. The potential yield of these systems is not known at this time, and stormwater capture should be considered in conjunction with projects that construct stormwater and flood control facilities (CVWD, 2012).

3.3.8 Wastewater and Recycled Water

Wastewater that has been highly treated and disinfected can be reused for landscape irrigation and other purposes; however, treated wastewater is not suitable for direct potable use. Recycled wastewater has historically been used for irrigation of golf courses and municipal landscaping in the Coachella Valley since the 1960s. As growth occurs in the eastern Coachella Valley, the supply of recycled water is expected to increase, creating an additional opportunity to maximize local water supply.

CVWD operates five water reclamation plants (WRPs), two of them (WRP-7 and WRP-10) generate recycled water for irrigation of golf courses and large landscaped areas. WRP-4 became operational in 1986 and serves the communities from La Quinta to Mecca. WRP-4 effluent is not currently recycled; however, it will be in the future when the demand for recycled water develops and tertiary treatment is constructed. The other two WRPs serve isolated communities near the Salton Sea. A sixth WRP (WRP-9) was decommissioned in July 2015.

Table 3.0-9 Current and Projected Recycled Water Direct Beneficial Uses within CVWD's Service Area

Beneficial Use Type	General Description of Uses	Level of Treatment	2015	2020	2025	2030	2035	2040 (opt)
Agricultural irrigation	Served by WRP-4	Tertiary	0	0	12,700	15,100	17,500	19,200
Landscape irrigation (excludes golf courses)	HOAs and one high school served by WRP-10	Tertiary	387	400	400	400	400	400
Golf course irrigation	Served by WRP-7 and WRP-10	Tertiary	8,282	13,900	14,600	15,300	16,000	16,700
Golf course irrigation	Served by WRP-9	Secondary, Disinfected - 23	80	0	0	0	0	0
		Total	**8,749**	**14,300**	**27,700**	**30,800**	**33,900**	**36,300**
NOTES: WRP-9 was taken offline on July 15, 2015 and has been decommissioned.								

3.3.9 Desalinated Shallow Semi-Perched Brackish Groundwater

The CVWD 2015 UWMP identifies CVWD's plan to use treated shallow semi-perched brackish groundwater for irrigation purposes. It is planned that shallow semi-perched brackish groundwater will be desalinated to a quality equivalent to Canal water for irrigation use. The amount of shallow semi-perched brackish groundwater that would be treated and recycled depends on supply availability, the overall supply mix (the amount of additional water needed), and the cost of treatment and brine disposal. According to the 2010 CVWMP Update the amount of water recovered through desalination of shallow semi-perched brackish groundwater will range from 55,000 AFY to 85,000 AFY by 2045.

Product water would be delivered to the Canal distribution system for non-potable use. This supply would offset groundwater pumping in the subbasin.

Treated shallow semi-perched brackish groundwater could be delivered to the Canal water distribution system and used as a non- potable supply for agricultural, golf course and landscape irrigation and potentially for potable water supply. Since the desalinated shallow semi-perched brackish groundwater is local water, it could be used anywhere within the CVWD service area.

A brackish groundwater treatment pilot study and feasibility study was completed in 2008 (Malcolm-Pirnie, 2008a and 2008b). The 2008 study recommended a combined source water strategy involving wells and direct connection to the open drain outfalls. Such a combined approach will provide additional flexibility and reliability to this new water supply. This study concluded that shallow semi-perched brackish groundwater can effectively be treated for reuse as non-potable water and potentially as new potable water.

3.3.10 Purchases, Exchanges or Transfers

To further help meet its long-term supply needs, CVWD purchases SWP Table A Amounts from SWP contractors as they have become available and meet CVWD's needs. Additional purchases from the SWP and from other agencies with water rights, mainly in the Central Valley of California, will be evaluated as they become available to determine whether they meet CVWD's needs. If they do, CVWD may purchase additional SWP water rights.

3.3.11 Summary of Primary and Additional Water Sources

Table 3.0-10 Existing CVWD Water Supply SWP Table A Amounts shows CVWD's existing and water supply entitlements, rights and service contracts

Table 3.0-10 Existing CVWD Water Supply SWP Table A Amounts

Supply		Existing Supplies AFY	Entitlement	Right	Contract	Other	Ever Utilized
Groundwater	Whitewater River (Indio) Subbasin	Unspecified [1]				X	Yes
Coachella Canal Colorado River Water	Coachella Canal 2003 QSA	459,000 [2]			X		Yes
SWP Exchange Water [3]	SWP Contracts and MWD Exchange Agreement	138,350 [4]	X	X			Yes
Recycled Water	CVWD and DWA	14,188 [5]				X	Yes

[1] CVWD shares a common groundwater source that has not been adjudicated.
[2] As quantified in the Qualification Settlement Agreement between IID, MWD, and CVWD, October 2003.
[3] Imported SWP Exchange Water is not used as direct water supply source, but rather is used to recharge groundwater in the Coachella Valley.
[4] Includes Original Table A Amount, Tulare Agreement and MWD Agreement.
[5] Indio Subbasin Annual Report for Water Year 2017-2018.

3.4 Analysis of Water Supply and Demand

The analysis of supplies and demands for the Project WSA/WSV is based on the 2015 UWMP and the 2010 CVWMP Update. In accordance with SB x7-7, CVWD's 2015 UWMP sets interim and final urban water use targets for complying with California's 2020 conservation program based on DWRs defined Target Method No. 1 which provides for an agency goal of 80 percent of baseline demands. The 2015 UWMP relies on and summarizes the water supplies and water supply program details in the 2010 CVWMP Update.

The 2010 CVWMP Update is a 35-year plan to reliably meet current and future water demands in a cost effective and sustainable manner. The planning areas for the 2010 CVWMP Update is the Whitewater River (Indio) Subbasin including Salton City and areas north of the Banning Fault that are within the service areas in the Cities of Indio and Coachella. The 2010 CVWMP Update evaluates all of the water demand and supplies in the planning area through 2045, for all water users including urban, agricultural and golf and provides a preferred alternative water supply plan for meeting demands. The 2010 CVWMP Update evaluates long-term risks to water supplies such as reduced SWP reliability and reduced Colorado River supplies and provides contingencies for addressing these risks. The elements of the preferred alternative are imported water supplies, recharge, source substitution and conservation. The preferred alternative identifies projects and programs that implement these plan elements.

The 2010 CVWMP Update relies on the Riverside County Population Projections 2006 (RCP-2006). The 2014 Status Report updated the Population Projections based on the Riverside County Population Projections 2010 (RCP-2010) which are lower. The updated projections are relied upon in the 2015 UWMP.

In 2005, Riverside County was experiencing rapid growth. Recognizing the need for more accurate growth forecasts the Riverside County Center for Demographic Research (RCCDR) was established under the joint efforts of the County of Riverside, the Western Riverside Council Governments, the Coachella Valley Association of Governments and the University of California Riverside for the development of demographic data and related support products to serve all of Riverside County. The RCCDR was tasked with developing the RCP-2006 growth forecast to provide agencies with a consistent and standard set of population, housing, and employment forecasts. The RCP-2006 was adopted by the Southern California Association of Governments for use in their regional growth forecasts.

Although the growth forecast indicated significant future growth for the Coachella Valley, these forecasts were based on potential development that had not yet been approved by the cities and county. Prior to 2008, there was substantial development pressure to transition from agricultural to urban land uses. As agricultural land converts to urban uses, the characteristic of its water demands and infrastructure will change. The 2010 CVWMP Update reflects these changes in its water demand projections and the ways that water is used in this area. As urban development occurs, land that currently is irrigated with untreated Coachella Canal water could begin using groundwater replenished with the canal water or use treated canal water for indoor use and untreated canal water for outdoor use.

Tribal land in the Coachella Valley makes up over 49,000 acres. While much tribal land in the western Coachella Valley has been developed to varying degrees, a substantial amount of tribal land in the eastern Coachella Valley is undeveloped. An understanding of the timing and degree of development on tribal lands is important. All of the Coachella Valley tribes have developed one or more major casinos, which have provided them important economic opportunities. As development continues in the Coachella Valley, it is expected that additional growth will occur on the remaining tribal lands.

In other portions of the Coachella Valley, development of tribal land is closely coordinated with the Coachella Valley cities where they are located. RCP-2006 growth forecasts are assumed to include development of these lands.

As shown in **Table 3.0-11, Projected Average Urban Water Supply (AFY)**, the 2015 UWMP projects that the percentage of water from each of the current water supply sources will change significantly by 2040, relative to 2015 conditions.

Table 3.0-11, Projected Average Urban Water Supply (AFY)

Water Supply	Additional Detail on Water Supply	Projected Water Supply (AF)				
		2020	2025	2030	2035	2040 (opt)
Groundwater	Potable urban use	113,400	102,100	112,700	106,600	101,000
Purchased or Imported Water	Treated Canal water for potable urban use in East Valley [1]	0	18,000	18,000	31,000	40,000
	Urban Potable Subtotal	**113,400**	**120,100**	**130,700**	**137,600**	**141,000**
Purchased or Imported Water	Untreated Canal water for non-potable urban use in East Valley [1]	1,200	11,000	17,000	26,300	33,300
Desalinated Water	Desalinated drain water for non-potable urban use	0	5,000	10,000	15,000	20,000
	Urban Non-potable Subtotal	**1,200**	**16,000**	**27,000**	**41,300**	**53,300**
Recycled Water	WRP-7 [2]	3,400	3,700	4,000	4,300	4,600
Recycled Water	WRP-10 [2]	10,900	11,300	11,700	12,100	12,500
Recycled Water	WRP-4 [2,3]	0	12,700	15,100	17,500	19,200
	Recycled Water Subtotal	**14,300**	**27,700**	**30,800**	**33,900**	**36,300**
	Total Retail Supply	**128,900**	**163,800**	**188,500**	**212,800**	**230,600**
Purchased or Imported Water	Sale of Canal water to IWA for potable use	5,000	10,000	20,000	20,000	20,000
	Total Wholesale Supply	**5,000**	**10,000**	**20,000**	**20,000**	**20,000**

NOTES:
[1] Total Colorado River allotment will increase from 397,000 AF in 2016 to 459,000 AF in 2026. Colorado River water supply does not sum to total right because of nonurban supply not shown on this table and projected wholesale to other agencies.
[2] Recycled water safe yield is based on total projected flows at each WWTP; surface discharge and percolated wastewater effluent is not included in the reasonably available supply estimates.
[3] Assumes tertiary treatment is not available until after 2020 at WRP-4.

Effects of the 2008-2011 Recession

Riverside County was hit particularly hard by the economic downturn that started in 2008. The recession resulted in a lower than projected growth rate for the Coachella Valley and, because the planning period for the 2010 CVWMP Update is through 2045, the effects of the recession on growth in the Coachella Valley have begun and will continue to attenuate over the long term. The 2010 CVWMP Update incorporates these factors as it is assumed that development within the Coachella Valley will continue and that the Riverside County Planning growth forecast is applicable in the long term.

In CVWD's 2014 CVWMP Status Report, the RCP-2010 population projections were considered and future water demands were re-evaluated. Using RCP-2010 results in an estimated 22 percent lower urban water demand in 2035 and a 13 percent higher agricultural water demand. Overall demand would be about 14 percent lower in 2045. It is important to note that this is not an elimination of demand but a deferral of demand to later years. Growth will continue but at a slightly slower rate.

Water conservation is a major component of future water management. CVWD is committed to reducing its urban water use by 20 percent by 2020. Therefore, CVWD has been conservative in the calculation of 2015 and 2020 urban conservation targets. 2010 U.S. Census Data was not available to be used in the preparation of the 2015 UWMP. CVWD used 2000 census data. Water Code Section 10608.2 allowed urban water suppliers to update 2020 urban targets in the 2015 UWMP based on the availability of 2010 Census Data. Because CVWD's recalculated urban conservation targets were higher than those committed to in the 2010 UWMP, CVWD retained its 2010 per capita targets of 540 gallons per capita per day (gpcd) by 2015 and 473 gpcd by 2020 which will result in greater water savings. CVWD's actual 2015 water use was 383 gpcd. Drought restrictions played a significant role in achieving this reduction.

The golf industry represents a significant water demand sector in the Coachella Valley and is expected to remain so in the future. CVWD, working in cooperation with the Southern California Golf Association and the local golf community, has established a Golf and Water Task Force to reduce overall golf course water use by ten percent.

The 2010 CVWMP Update assumes that the fish farm and duck club growth will be much lower than projected in the 2002 CVWMP. Some of the large fish farms have moved from the traditional fish farming business. The replacement use at these farms is suspected to significantly reduce the water demand. Based on the available information at this time, future fish farm demand of 8,500 AFY and duck club demand of 2,000 AFY was assumed.

It was also assumed that the growth occurring on tribal land will be similar to other areas in the Coachella Valley, and land uses will be proportional to the growth that occurs on non-tribal land in the eastern Coachella Valley. Corresponding water demands are calculated based on this growth assumption.

The 2010 CVWMP Update increases the water conservation requirement during the next 35 years. A 14 percent reduction in agricultural water use is targeted by 2020. Urban water use, CVWD's Landscape Ordinance 1302.4, updated in 2019 will govern the irrigation demands of new golf courses as well as reduce the demands of existing golf courses by 10 percent.

The 2010 CVWMP Update water demand projections for the Whitewater River (Indio) Subbasin for the period 2010 to 2030 in five-year intervals increases from 678,000 AF in 2010 to 783,300 AF in 2030, or 15 percent. During this same period, using RCP-2006, the population in the Coachella Valley is estimated to increase by over 100 percent, or about four percent per year. In the 2014 Status Report, RCP-2010 projections were used and the Whitewater River (Indio) Subbasin water demand was revised to 691,500 AF in 2030, a 12 percent reduction.

Groundwater and Groundwater Storage

As supply and demand changes, the amount of groundwater in storage changes to make up the difference between the demand and the supply. Other than Canal water and recycled wastewater, all water delivered to the end users is obtained from the groundwater subbasin. The Whitewater River (Indio) Subbasin has the capacity of approximately 29.8 million AF. It acts as a very large reservoir and is capable of meeting the water demands of the Coachella Valley for extended periods.

As discussed in the 2010 CVWMP Update, CVWD has many programs to maximize the water resources available to it including recharge of its Colorado River and SWP supplies, recycled wastewater, desalinated shallow semi-perched brackish groundwater, conversion of groundwater uses to Canal water and conservation including tiered water rates, a landscaping ordinance, and outreach and education. The 2010 CVWMP Update and CVWD replenishment assessment programs establish a comprehensive and managed effort to eliminate overdraft.

The 2014 CVWMP Status Report evaluated progress to date on eliminating overdraft. The report illustrates the effectiveness of the CVWMP programs and shows that overdraft did not occur in the ten years from 2003 and 2013. The report also shows that with continued implementation of CVWMP programs, overdraft will be eliminated in 2021. The effectiveness of the CVWMP's programs is clear and shows that there will be a steady increase in water in storage with limited disruption to this pattern through 2045.

Coachella Canal Water

Colorado River supplies available to CVWD under the 1931 Seven Party Water Priority 43 Agreement and QSA agreement are considered in the 2015 UWMP and 2010 CVWMP Update. CVWD has maximized delivery of these supplies by participating in canal lining projects, which reduces loss from water transport. In 2008, the Coachella canal was fully lined. The annual reporting of CVWD Colorado Diversions at Imperial Dam for the period 1964 to 2008 were prepared as required by the U.S. Supreme Court decree. CVWD average annual diversion for this 45-year period was 402,702 AFY. CVWD's average annual diversion for the period 1983 to 2008 (26 years of decree records) was 328,698 AFY. The difference of 74,004 AFY is the result of the water conserved by the lining of the first 49 miles of the Coachella Branch of the All-American Canal by the US Bureau of Reclamation (USBR) under repayment contract with CVWD. In the most recent 6-year period (2008 to 2013), the annual average diversion was 313,971 AFY. The QSA assures that CVWD receives a quantified allotment of Colorado River water. The QSA has been unsuccessfully challenged in state and federal courts and remains in effect.

Additional SWP Table A Amounts

DWA and CVWD have increased their SWP contract supplies from a total of 61,200 AFY in 2002 to a current (2018) total of 194,100 AFY.

State Water Project Reliability

The 2015 State Water Project Delivery Capability Report (SWPDCR) projections are the result of computer modeling by DWR that reflect the results of adjusting 82 years of hydrology data to incorporate the results of climate change models. The 2015 SWPDCR projections also take into consideration the existing physical facilities and the regulatory restrictions, which include the restriction on the SWP and Central Valley Project (CVP) operations in accordance with the Biological Opinions of the USFWS and NMFS as issued on December 15, 2008 and June 4, 2009, respectively.

The 2015 SWPDCR has also been adjusted to allow for the uncertainty of future court decisions, SWRCB actions, state and federal ESAs and other restrictions, modeling error, levee failure, and relaxation of biological opinions as the result of improved scientific research.

Although in recent years, uncertainty has resulted in reduced capability, SWP capability has been 100 percent as recently as 2006 and dropped to 5 percent in 2014 with the onset of the California Drought. SWP capability increased to 20 percent in 2015, 60 percent in 2016, 85 percent in 2017, and was at 35 percent in 2018 for a 20-year average of 62 percent. CVWD plans for a long-term average capability of 50 percent in the 2010 CVWMP Update and 2015 UWMP.

Metropolitan Water District of Southern California Callback

In 1984, MWD, DWA, and CVWD entered into an advanced delivery agreement, which allowed MWD to store water from its Colorado River Aqueduct in the Coachella Valley. Prior to this agreement, DWA and CVWD were exchanging their annual SWP Table A amount with MWD for the same amount of water from MWD's Colorado River Aqueduct. This exchange is necessary because the SWP conveyance system does not extend into the Coachella Valley. The 1984 agreement allows MWD to deliver more water into the Coachella Valley during wet periods or periods when it has excess water, and to build a credit that it can use to provide the water in exchange for DWA’s and CVWD's Table A amounts during dry periods. This ability for advanced delivery and exchange creates a conjunctive use program among the three agencies.

In 2003, MWD, DWA, and CVWD entered into an exchange agreement whereby MWD transferred title to 100,000 AF of its SWP Maximum Table A amount to DWA and CVWD. Under the agreement, MWD obtained the right to callback the SWP water for its use for a maximum number of times in a given period of years. The 100,000 AF was divided into two 50,000 AF blocks. The 2015 UWMP and 2010 CVWMP Update assume that MWD will periodically exercise its option to callback the 100,000 AF. The actual callback would depend on availability of MWD's supplies to meet their demands. Since 2003, MWD exercised its callback option one time, in 2005.

Long-Term Average SWP Deliveries

The amount of SWP supply that is available to CVWD for its own use was considered as the long-term average SWP supply. The published capability of the SWP water has decreased over time. The factors that could affect the SWP capability are considered in the 2015 UWMP and the 2010 CVWMP update are:

- Uncertainty in modeling restrictions associated with biological opinions,
- Risk of levee failure in the Sacramento-San Joaquin River Delta,
- Additional pumping restrictions resulting from biological opinions on new species or revisions to existing biological opinions,
- Impacts associated with litigations such as the California ESA lawsuit, and
- Climate change impacts.

Due to these factors and the need to plan for higher contingency, the planning assumption in the 2010 CVWMP Update and the 2015 UWMP is that the long-term future annual average SWP capability will be at 50 percent until successful completion of the Bay-Delta Conservation Plan and Delta conveyance facilities.

Groundwater basin recharge through direct and in-lieu (indirect) recharge is a major element of CVWD's water management activities. CVWD has recharged at the Whitewater River GRF since 1973. They have spent over $43.5 million on the construction of the TEL GRF in the eastern Coachella Valley and over $42 million on the construction of the Mid-Valley Pipeline to move canal water into the northern Coachella Valley for source substitution of groundwater. Phase I of the Palm Desert GRF was completed in 2018. The protection of the aquifer storage will be addressed through additional water supply purchases, water conservation, and source substitution similar to the ones described in the 2010 CVWMP Update.

The available supplies and water demands for CVWD's service area were analyzed in the water supply conditions of the 2015 UWMP to assess the region's ability to satisfy current and future urban water demands, including those of the Project, under three scenarios: a normal water year, a single dry year, and multiple dry years. According to the 2015 UWMP, the urban water demands in the CVWD service area (retail supply totals) are estimated to grow from 114,600 AF in 2020 to 194,300 AF in 2040. Therefore, the estimated Project demands (1531.84 AFY) represent approximately 1.3 percent of the total water supply number (114,600 AF) for 2020 and would represent 0.78 percent of the total water supply number (194,300 AF) for 2035.

The following tables provide CVWD's projected water supplies and demands in a normal year, single dry year, and multiple dry years. These tables combine retail and wholesale numbers to simplify the presentation. It should be noted that the retail supplies and demands presented in the tables below include recycled water delivered to CVWD's non-urban customers based on DWR's standardized tables and the 2015 UWMP Guidebook. However, as discussed in Sections 4 and 6 of the CVWD's 2015 UWMP, recycled water is not considered an urban water supply and is not delivered to CVWD's urban water customers. Instead, recycled water is used to offset the groundwater pumping of private well owners (mainly golf courses) to eliminate overdraft. The wholesale demand and supply listed is the anticipated sale of raw Colorado River water to the Indio Water Authority. These tables indicate that CVWD will be able to meet current and future urban water demand needs through groundwater pumping, recharge with Colorado River water, and distribution of treated Colorado River water during normal, single dry, and multiple dry years over at least the next 20 years.

DWR, requires the supply reliability tables to include both potable and recycled water; this is summarized below in **Table 3.0-12: Normal Year Supply and Demand Comparison** (adapted from DWR Table 7-2 R and DWR Table 7-2 W), for the average year.

Table 3.0-12 Supply and Demand Comparison – Normal Year (AFY)

		2020	2025	2030	2035	2040 *(Opt)*
Retail	Supply totals (AF)	128,900	163,800	188,500	212,800	230,600
	Demand totals (AF)	128,900	163,800	188,500	212,800	230,600
	Difference (AF)	0	0	0	0	0
Wholesale	Supply totals (AF)	5,000	10,000	20,000	20,000	20,000
	Demand totals (AF)	5,000	10,000	20,000	20,000	20,000
	Difference (AF)	0	0	0	0	0

CVWD does not use recycled water in its urban water supply; therefore, a version of this table without recycled water is presented in **Table 3.0-13: Normal Year Supply and Demand Comparison – Urban Supply Only**, which more accurately represents CVWD's urban water supply reliability.

Table 3.0-13 Normal Year Supply and Demand Comparison Urban Supply Only

		2020	2025	2030	2035	2040 *(Opt)*
Retail	Supply totals (AF)	114,600	136,100	157,700	178,900	194,300
	Demand totals (AF)	114,600	136,100	157,700	178,900	194,300
	Difference (AF)	0	0	0	0	0
Wholesale	Supply totals (AF)	5,000	10,000	20,000	20,000	20,000
	Demand totals (AF)	5,000	10,000	20,000	20,000	20,000
	Difference (AF)	0	0	0	0	0

Urban water supplies during the single dry year are 100% reliable. Thus, the supply and demand comparison for the single dry year, shown in **Table 3.0-14 Single Dry Year Supply and Demand Comparison** (adapted from DWR Table 7-3 R and DWR Table 7-3 W) is the same as the average year.

Table 3.0-14 Supply and Demand Comparison – Single Dry Year (AFY)

		2020	2025	2030	2035	2040 *(Opt)*
Retail	Supply totals (AF)	128,900	163,800	188,500	212,800	230,600
	Demand totals (AF)	128,900	163,800	188,500	212,800	230,600
	Difference (AF)	0	0	0	0	0
Wholesale	Supply totals (AF)	5,000	10,000	20,000	20,000	20,000
	Demand totals (AF)	5,000	10,000	20,000	20,000	20,000
	Difference (AF)	0	0	0	0	0

Table 3.0-15 Single Dry Year Supply and Demand Comparison – Urban Only, presents the urban supply and demand comparison without recycled water.

Table 3.0-15 Supply and Demand Comparison Urban Use Only – Single Dry Year (AFY)

		2020	2025	2030	2035	2040 *(Opt)*
Retail	Supply totals (AF)	114,600	136,100	157,700	178,900	194,300
	Demand totals (AF)	114,600	136,100	157,700	178,900	194,300
	Difference (AF)	0	0	0	0	0
Wholesale	Supply totals (AF)	5,000	10,000	20,000	20,000	20,000
	Demand totals (AF)	5,000	10,000	20,000	20,000	20,000
	Difference (AF)	0	0	0	0	0

Similar to the single dry year, the multiple dry year urban water supply reliability is 100 percent. **Table 3.0-16 Multiple Dry Years Supply and Demand Comparison** (adapted from DWR Table 7-4 R and DWR Table 7-4 W), summarizes the multiple dry year supply and demand comparison.

Table 3.0-16 Supply and Demand Comparison - Multiple Dry Years (AFY)

			2020	2025	2030	2035	2040 (Opt)
Retail	First year	Supply totals (AF)	128,900	163,800	188,500	212,800	230,600
		Demand totals (AF)	128,900	163,800	188,500	212,800	230,600
		Difference (AF)	0	0	0	0	0
	Second year	Supply totals (AF)	128,900	163,800	188,500	212,800	230,600
		Demand totals (AF)	128,900	163,800	188,500	212,800	230,600
		Difference (AF)	0	0	0	0	0
	Third year	Supply totals (AF)	128,900	163,800	188,500	212,800	230,600
		Demand totals (AF)	128,900	163,800	188,500	212,800	230,600
		Difference (AF)	0	0	0	0	0
Wholesale	First year	Supply totals (AF)	5,000	10,000	20,000	20,000	20,000
		Demand totals (AF)	5,000	10,000	20,000	20,000	20,000
		Difference (AF)	0	0	0	0	0
	Second year	Supply totals (AF)	5,000	10,000	20,000	20,000	20,000
		Demand totals (AF)	5,000	10,000	20,000	20,000	20,000
		Difference (AF)	0	0	0	0	0
	Third year	Supply totals (AF)	5,000	10,000	20,000	20,000	20,000
		Demand totals (AF)	5,000	10,000	20,000	20,000	20,000
		Difference (AF)	0	0	0	0	0

Table 3.0-17: Multiple Dry Years Supply and Demand Comparison – Urban Only, presents the urban supply and demand comparison without recycled water.

Table 3.0-17 Supply and Demand Comparison - Multiple Dry Years (AFY)

			2020	2025	2030	2035	2040 (Opt)
Retail	First year	Supply totals (AF)	114,600	136,100	157,700	178,900	194,300
		Demand totals (AF)	114,600	136,100	157,700	178,900	194,300
		Difference (AF)	0	0	0	0	0
	Second year	Supply totals (AF)	114,600	136,100	157,700	178,900	194,300
		Demand totals (AF)	114,600	136,100	157,700	178,900	194,300
		Difference (AF)	0	0	0	0	0
	Third year	Supply totals (AF)	114,600	136,100	157,700	178,900	194,300
		Demand totals (AF)	114,600	136,100	157,700	178,900	194,300
		Difference (AF)	0	0	0	0	0
Wholesale	First year	Supply totals (AF)	5,000	10,000	20,000	20,000	20,000
		Demand totals (AF)	5,000	10,000	20,000	20,000	20,000
		Difference (AF)	0	0	0	0	0
	Second year	Supply totals (AF)	5,000	10,000	20,000	20,000	20,000
		Demand totals (AF)	5,000	10,000	20,000	20,000	20,000
		Difference (AF)	0	0	0	0	0
	Third year	Supply totals (AF)	5,000	10,000	20,000	20,000	20,000
		Demand totals (AF)	5,000	10,000	20,000	20,000	20,000
		Difference (AF)	0	0	0	0	0

Summary

As summarized below **in Table 3.0-18 Impact of Project Demand on Groundwater Supply**, projected water demand associated with the Project represents 0.78 percent of CVWD's total projected urban water demand in 2040.

Per the 2015 UWMP and the 2010 CVWMP Update, CVWD included water demand from new development that it assumed would occur within its service area. The projected demand for the Project will therefore account for only a small fraction of the projected demands.

Table 3.0-18 Impact of Project Demand on Groundwater Supply

Section 31 Specific Plan	2035
Total CVWD Supply	**194,000 AF**
Total Project Demand	**1,531.84 AF**
Percent of CVWD Supply	**0.78**
Source: Total supply extrapolated from 2015 UWMP, Table 7-4. Project demand extrapolated from data Table 7 of this WSA, based on a 20-year build-out. Note: 2039 is the projected final buildout year for the Section 31 Specific Plan and completion of the Project	

3.5 Conclusions

Based on the information, analysis, and findings documented in this WSA for the Project, there is substantial evidence to support a determination that there will be sufficient water supplies to meet the demands of the Project, as well as for future demands of the Project plus all forecasted demands in the next 20 years. This is based on the volume of water available in the aquifer, CVWD's Colorado River contract supply, SWP Table A amounts, water rights and water supply contracts, and CVWD's commitment to eliminate overdraft and reduce per capita water use in CVWD's service area. CVWD has committed sufficient resources to further implement the primary elements of the 2010 CVWMP Update and 2015 UWMP, which includes the full utilization of imported water supplies, purchase of additional water supplies, water conservation, and source substitution.

The domestic water supply (potable) for the Project will be from the Whitewater River (Indio) Subbasin in the Coachella Valley Groundwater Basin. Groundwater storage will be used in dry years to make up the difference between the demand and the supply. The groundwater subbasin has a storage capacity of approximately 29.8 million AF within the first 1,000 feet below ground surface, simulating the benefit of a very large reservoir, and is capable of meeting the water demands of the Coachella Valley for normal and extended drought periods.

As discussed in the 2010 CVWMP Update, the 2015 UWMP, and this WSA, CVWD has many programs to maximize the water resources available to the CVWD including recharge of the subbasin using its Colorado River and SWP supplies, recycled wastewater, desalinated shallow semi-perched brackish groundwater, conversion of groundwater uses to canal water and water conservation including tiered water rates, landscaping ordinance, and outreach and education.

CVWD's groundwater replenishment programs establish a comprehensive and managed effort to eliminate overdraft. These programs allow CVWD to maintain the groundwater subbasin as its primary water supply and to recharge the groundwater subbasin as its other supplies are available. CVWD has purchased 115,250 AF of additional annual SWP Table A amount since 2002.

Project Water Requirements

As shown in this WSA analysis, the projected demand for the Project will be 1,531.84 AFY, or 2.48 AF per acre, and accounts for approximately 0.78 percent of the total projected growth in water demands presented in the 2015 UWMP for 2040.

It is anticipated that the Project will incorporate elements of CVWD's water conservation plan as required by SB X7-7. These include conservation elements for indoor and outdoor use for residential units, the mixed-use town center, and open space uses. This may further reduce the ultimate Project demands.

4.0 WATER SUPPLY VERIFICATION

4.1 General

As discussed previously, the Section 31 Specific Plan (Project) is subject to a Water Supply Verification (WSV) subject to the requirements of Senate Bill 221 (SB 221) pursuant to the Subdivision Map Act because more than 500 residential dwelling units are proposed.

4.2 Water Source

Project domestic water supplies and associated landscape irrigation supplies will be provided from groundwater. The WSV addresses: (1) Information included in the Coachella Valley Water District's (CVWD's) 2010 Coachella Valley Water Management Plan (CVWMP) Update and CVWD's 2015 Urban Water Management Plan (UWMP); (2) issues related to groundwater recharge of non-groundwater sources, namely Colorado River water and State Water Project (SWP) water; and (3) consideration of historical litigation regarding the 2003 Quantification Settlement Agreement (QSA).

4.3 Supporting Documentation

This WSV relies on CVWD's 2010 CVWMP Update. Supporting information is also used from CVWD's 2015 UWMP, as permitted by Government Code Section 66473.7 (c).

4.4 Factors of Reliability

4.4.1 General

Government Code Section 66473.7(a) requires that all of the following factors be considered: (1) The availability of the water supply over 20 years; (2) the applicability of CVWD's Water Shortage Contingency Analysis found in the 2015 UWMP; (3) the reduction of water supply to a specific user by ordinance or resolution; and (4) the reasonable amount of groundwater supply that can be relied upon, considering its natural sources as well as the supporting recharge sources of SWP water and Colorado River water.

4.4.2 Historical Availability of Supply

As discussed previously in the Water Supply Assessment (WSA), the Coachella Valley has been primarily dependent on groundwater as a source of domestic water supply since the early part of the 20th century. The 2010 CVWMP Update and the CVWD 2015 UWMP review the historical use of water in the Coachella Valley. In 1936, groundwater use was 92,400 acre-feet (AF), and usage increased steadily to about 376,000 AF in 1999. The groundwater use in 2009 dropped to 358,700 AF due to a combination of water conservation efforts, source substitution projects, and effects of the ongoing economic recession.

Groundwater use in the Whitewater River (Indio) Subbasin is currently 288,308 AF as shown in the Indio Subbasin Annual Report for Water Year 2017-2018. Deliveries of Colorado River water and Metropolitan Water District of Southern California (MWD) SWP Exchange water help offset groundwater use. The Colorado River water deliveries have averaged approximately 285,000 acre-feet per year (AFY) over the past five years.

4.4.3 Coachella Valley Water Shortage Contingency

The CVWD developed its Water Shortage Contingency Plan during the 1986-1992 drought pursuant to the requirements of the Government Code 10632. The key element of CVWD's Water Shortage Contingency Plan is an ordinance with phased water use restrictions and a drought penalty rate structure.

- Ordinance 1414 – Stage 2 – 10% Mandatory Reduction;
- Ordinance 1419 – Stage 3 – 36% Mandatory Reduction;
- Ordinance 1422– Stage 3 – Adopt Additional Watering Restrictions; 36% Mandatory Reduction
- Ordinance 1426 – Stage 3 – Replace Previous Ordinance, 32% Reduction

After the State Water Resources Control Board's (SWRCB's) adoption of revised regulations in May 2016, CVWD repealed these ordinances and adopted Ordinance 1422.5, which established Stage 2 restrictions that remain in effect until the SWRCB rescinds its emergency regulations. The key element of CVWD's Water Shortage Contingency Plan is an ordinance with phased water use restrictions and drought-related rate structure, as summarized in **Table 4.0-1 Water Shortage Contingency Plan**.

Table 4.0-1 Water Shortage Contingency Plan

Stage	Percent Supply Reduction	Water Supply Condition
1 - Voluntary	10%	Normal Water Supplies
2 – Mandatory	20%	10% reduction in total groundwater and imported supplies relative to a long-term average condition
3 – Mandatory	25%	25% reduction in total groundwater and imported supplies relative to long-term average conditions.
4 – Mandatory	50%	50% reduction in total groundwater and imported supplies relative to long-term average conditions.

The trigger levels (to move from one stage to the next) depend on the local water situation. Based on voluntary response during Stage 1, CVWD's General Manager can determine that it is necessary to implement Stage 2 to protect the public welfare and safety. Prior to the implementation of each mandatory phase, CVWD will hold a public hearing for the purpose of determining whether a shortage exists, and which measures should be implemented. The public will be informed of the public hearing at least ten days prior to the hearing and CVWD will notify the public of its determination by public proclamations.

4.4.4 Reduction of Water Supply

No reduction of water supply is expected to any user due to this Project's use of water resources, or due to CVWD's ongoing management of water resources and planning for growth within their service area and throughout the Coachella Valley.

4.4.5 SWP and Colorado River Water

CVWD's Colorado River water rights and SWP Table A allotments will provide supplemental water for direct use and groundwater recharge to the Coachella Valley. CVWD proposes to develop direct treatment of Colorado River water for potable uses in the future. The Coachella Valley Groundwater Basin has the capacity to meet future demands. Based on the information provided in the 2011 State Water Reliability Report (June, 2012), CVWD's Colorado River rights, recycled water, desalinated water, and CVWD's conservation program, water supplies will be sufficient to meet the Project's needs and CVWD's existing and future demands in the event that additional conservation and/or supply limitations are necessary. The Project will adhere to any and all limitations associated with their potential reduction in supply.

In addition, the United State Bureau of Reclamation (USBR) has developed interim surplus and shortage guidelines for management of the Colorado River water supplies. The USBR preferred alternative provides flexibility for the potential storage of additional conserved Colorado River or Non-Colorado River water in Lake Mead. The guidelines that were adopted by USBR have been updated and extended through 2026. The revised guidelines address the operation of Lake Mead at relatively full elevations and determine when "surplus" water supplies would be available to water users in Southern California, including the eastern Coachella Valley. As currently drafted, the guidelines indicate water shortages will not negatively impact the Colorado River water supply for the Coachella Valley. CVWD benefits from California's agricultural entitlement for Colorado River water, which is protected by an overall entitlement of two million AF of Lower Basin Colorado River water with lower priority.

4.5 Impacts on Other Projects

This Project is within the goals of the 2010 CVWMP Update, and should not have a significant impact on agricultural, potable, or industrial users. In addition, this Project should not affect the water supply for future low-income housing projects.

The Project will comply with CVWD Landscape Ordinance 1302.4. The Project may be responsible for funding the purchase of additional imported water supplies to support its projected demands on the public water system (PWS). Based on the findings of the WSV, it is expected that the impacts to the groundwater subbasin are fully mitigated.

4.6 Rights to Groundwater

CVWD has the legal authority to manage the groundwater basins within its service area under the County Water District Law (California Water Code, Division 12). The Coachella Valley Groundwater Basin is not adjudicated. CVWD has the right to extract the groundwater as needed to supply this Project. In 2015, CVWD filed a Notice of Election with the California Department of Water Resources (DWR) to become a Groundwater Sustainability Agency (GSA) for the Whitewater River (Indio) Subbasin in accordance with the Sustainable Groundwater Management Act (SGMA). CVWD has submitted the 2010 CVWMP Update to DWR as the Alternative to a Groundwater Sustainability Plan (Alternative Plan) for the Whitewater River (Indio) Subbasin.

4.7 Verification

This document provides verification that adequate water supply for this Project is available, as required by California Government Code Section 66473.7.

5.0 LIST OF ACRONYMS

AB	Assembly Bill
AF	Acre-feet
AFY	Acre-Feet per Year
AOB	Area of Benefit
CEQA	California Environmental Quality Act
CFS	Cubic Feet per Second
CVSC	Coachella Valley Stormwater Channel
CVWD	Coachella Valley Water District
CVRWMG	Coachella Valley Regional Water Management Group
CVWMP	Coachella Valley Water Management Plan
CWA	Coachella Water Authority
DWA	Desert Water Agency
DWR	California Department of Water Resources
EIR	Environmental Impact Report
ESA	Endangered Species Act
ETAF	Evapotranspiration Adjustment Factor
gpcd	gallons per capita per day
gpd	gallons per day
GRF	Groundwater Replenishment Facility
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan

ID-1	CVWD's Improvement District No. 1
IID	Imperial Irrigation District
IRWMP	Integrated Regional Water Management Plan
IWA	Indio Water Authority
KC	Conversion Factor
MAWA	Maximum Applied Water Allowance
MGD	million gallons per day
MSWD	Mission Springs Water District
MWD	Metropolitan Water District of Southern California
QSA	Quantification Settlement Agreement
RCP	Riverside County Projections
SB	Senate Bill
SDCWA	San Diego County Water Authority
SGMA	Sustainable Groundwater Management Act
SWSC	Supplemental Water Supply Charge
SWP	State Water Project
SWRCB	State Water Resources Control Board
USFWS	U.S. Fish and Wildlife Service
UWMP	Urban Water Management Plan
WRP	Water Reclamation Plant
WSA	Water Supply Assessment
WSV	Water Supply Verification

6.0 REFERENCES

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Appendix A – 2010 CVWD Water Management Plan Executive Summary

PREPARED FOR
COACHELLA VALLEY WATER DISTRICT

Coachella Valley Water Management Plan Update

FINAL REPORT

January 2012

MWH

BUILDING A BETTER WORLD

Water Consult
Engineering and Planning Consultants

COACHELLA VALLEY WATER MANAGEMENT PLAN 2010 UPDATE

Final Report

January 2012

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Table of Contents

Section Name **Page Number**

Appendices

LIST OF TABLES

Table Name **Page Number**

LIST OF FIGURES

Figure Name **Page Number**

Executive Summary

Executive Summary

The Coachella Valley Water Management Plan was adopted by the Board of Directors, Coachella Valley Water District (CVWD) in September 2002. The goal of the Water Management Plan is to reliably meet current and future water demands in a cost-effective and sustainable manner. The Board recognized the need to update the Plan periodically to respond to changing external and internal conditions. This 2010 Water Management Plan Update (2010 WMP Update) meets that need. It defines how the goal will be met given changing conditions and new uncertainties regarding water supplies, water demands, and evolving federal and state laws and regulations.

ES-1 THE COACHELLA VALLEY

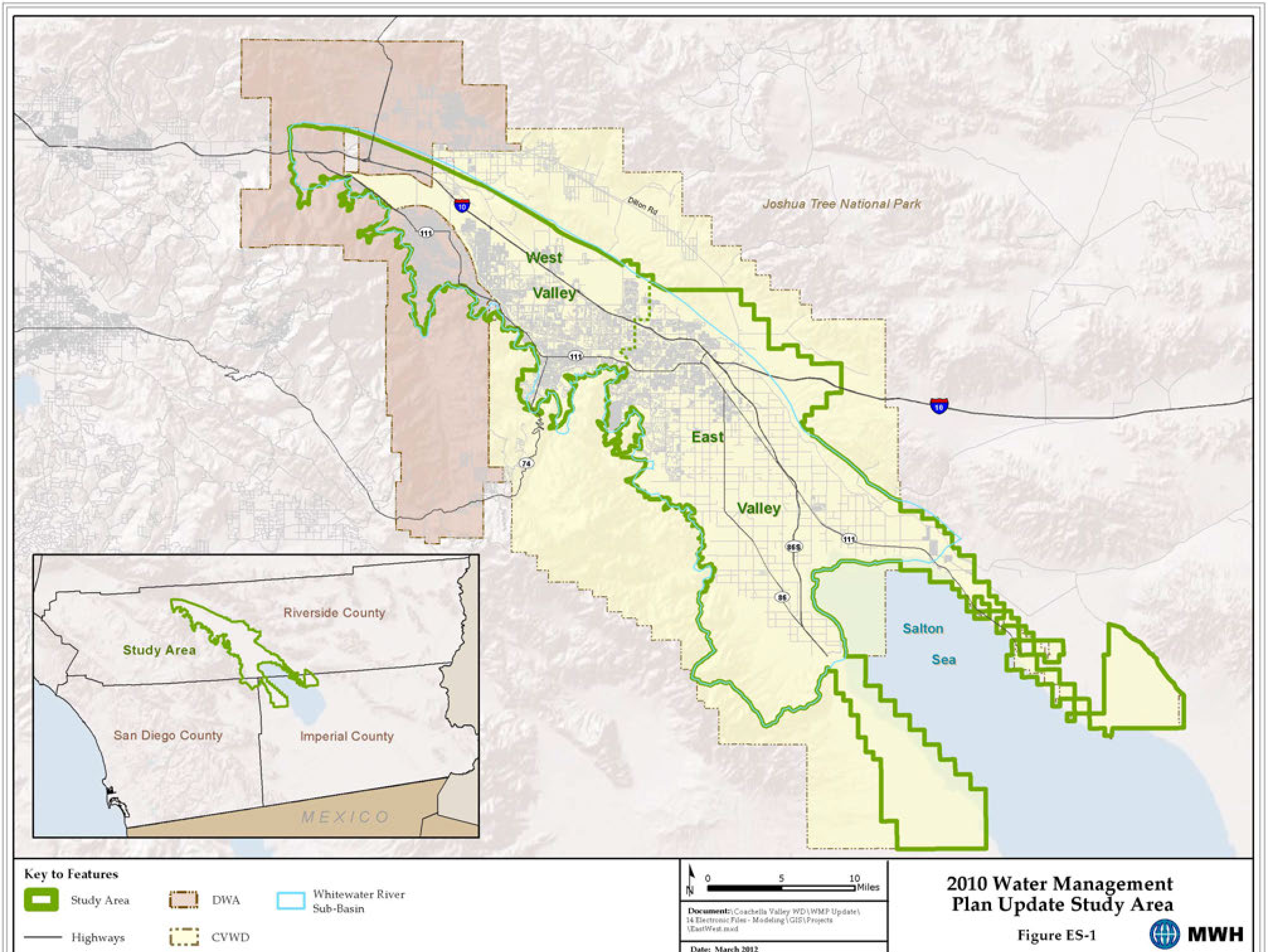
The Coachella Valley is located in the central portion of Riverside County. For purposes of this Water Management Plan, the Coachella Valley is divided into the West Valley and the East Valley. Geographically, the East Valley is southeast of a line extending from Washington Street and Point Happy northeast to the Indio Hills near Jefferson Street, and the West Valley is northwest of this line (**Figure ES-1**).

The West Valley includes the cities of Palm Springs, Cathedral City, Rancho Mirage, Indian Wells, and Palm Desert, a portion of the city of Indio, and the unincorporated communities of Sun City and Thousand Palms. The West Valley has a predominately resort/recreation-based economy. Water demand in the West Valley is supplied by several sources: groundwater, surface water from local streams, and recycled water. The East Valley includes the cities of Coachella, Indio, and La Quinta, and the unincorporated communities of Bermuda Dunes, Mecca, Oasis, Thermal, and Vista Santa Rosa. Historically, the East Valley has had an agricultural-based economy. Urban growth is occurring in the East Valley and is projected to continue in the future. East Valley water sources consist primarily of Coachella Canal water and groundwater, with a small amount of recycled fish farm effluent for agricultural uses.

The Coachella Valley's principal groundwater basin, the Whitewater River (Indio[1]) Subbasin, extends from Whitewater in the northwest to the Salton Sea in southeast. The basin has an estimated storage capacity of approximately 30 million acre-feet[2] (AF) (DWR, 1964). Water placed on the ground surface in the West Valley will percolate through the sands and gravels directly into the groundwater aquifer. In the East Valley, however, several impervious clay layers lie between the ground surface and the main groundwater aquifer. Water applied to the surface in the East Valley does not readily reach the lower groundwater aquifers due to these impervious clay layers. The only outlets for groundwater in the Coachella Valley are through subsurface outflow under the Salton Sea or through collection in drains and transport to the Salton Sea via the Coachella Valley Storm Channel (CVSC).

1 The California Department of Water Resources (DWR) assigned the name "Indio Subbasin" in its Bulletin 108. CVWD and Desert Water Agency use the designation "Whitewater River Subbasin."

2 One acre-foot (AF) is the amount of water that would cover one acre of land (approximately the size of a football field), one foot deep or about 326,000 gallons.



2010 Water Management Plan Update Study Area

Figure ES-1

Source: DWR, ESRI, County of Riverside

ES-2 WATER MANAGEMENT IN THE COACHELLA VALLEY

Water management in the Valley began as early as 1915. With groundwater levels falling, the need for a supplemental water source was recognized for the Valley to continue to flourish.

The Coachella Valley Stormwater District was formed in 1915 followed by formation of CVWD in January 1918. CVWD's first directors quickly filed paperwork to secure rights to all unclaimed Whitewater River water, an important source for aquifer recharge. In 1918, a contract was awarded for construction of water spreading and recharge facilities in the Whitewater River northwest of Palm Springs.

CVWD next focused on obtaining imported Colorado River water. In 1934, negotiations with the federal government were completed, and plans were put in place for the construction of the Coachella Branch of the All American Canal. Construction of the Canal began in 1938, but was interrupted by World War II. The first deliveries of imported Colorado River water to East Valley growers began in 1949. The service area for Canal water delivery under the CVWD's contract with the U.S. Bureau of Reclamation (Reclamation) is defined as Improvement District No. 1 (ID-1). The impact of imported water on the Valley was almost immediate. By the early 1960s, water levels in the East Valley had returned to their historical high levels.

Although groundwater levels in the East Valley had stabilized, water levels in the West Valley continued to decline as growth occurred. Desert Water Agency (DWA) was formed in 1961 to import State Water Project (SWP) water into the Palm Springs and Desert Hot Springs areas. In 1962 and 1963 respectively, DWA and CVWD entered into contracts with the State of California for 61,200 acre-feet per year (AFY) of SWP water. To avoid the then estimated $150 million cost of constructing an aqueduct to bring SWP water directly to the Valley, CVWD and DWA entered into an agreement with the Metropolitan Water District of Southern California (Metropolitan) to exchange SWP water for Colorado River water.

Starting in 1973, the CVWD and DWA began exchanging their annual SWP allocation with Metropolitan for Colorado River water to recharge West Valley groundwater at the Whitewater River Recharge Facility. CVWD, DWA, and Metropolitan also signed an advance delivery agreement in 1984 that allows Metropolitan to store additional water in the Valley. Since 1973, the spreading facility had percolated in excess of 2.6 million AF of Colorado River water exchanged for SWP water.

By the 1980s, groundwater demand in the East Valley had again exceeded supplies, resulting in significant groundwater level decreases in some parts of the East Valley. Because relatively impervious clay layers in the Valley floor impede groundwater recharge in the East Valley, CVWD began looking for sites sufficiently far away from the main clay layer to allow groundwater recharge. In 1995, the CVWD began operating the Dike No. 4 pilot recharge facility located on the west side of the East Valley in La Quinta. The pilot successfully demonstrated the feasibility of East Valley groundwater recharge. The facility was expanded in 1998 to determine the ultimate recharge capacity at this location. In October 2009, the Thomas E. Levy Groundwater Replenishment Facility (Levy facility, formerly Dike 4) was dedicated. It has a current recharge capacity of 32,000 AFY, upgradable to 40,000 AFY.

Recycled water has been a priority water supply in the Valley since 1965. Currently, CVWD and DWA provide more than 14,000 AFY of recycled water for golf course and greenbelt irrigation purposes from four wastewater treatment facilities. While recycled water is available in the East Valley, it is not currently treated to sufficient levels for unrestricted reuse. Water conservation is also a key element of managing water demands.

ES-3 CURRENT CONDITION OF COACHELLA VALLEY GROUNDWATER BASIN

The demand for groundwater has annually exceeded the limited natural recharge of the groundwater basin. The condition of a groundwater basin in which the outflows (demands) exceed the inflows (supplies) to the groundwater basin over the long term is called *"overdraft."* Overdraft has caused groundwater levels to decrease in significant portions of the East Valley. Groundwater levels in the West Valley have also decreased substantially, except in the areas near the Whitewater Recharge Facility where artificial recharge has successfully raised water levels.

Overdraft has serious consequences. The immediate and direct effect is increased groundwater pumping costs for all water users. With continued overdraft, wells will have to be deepened, pumps that are more powerful will have to be installed, and energy costs will increase as the pump lifts increase. The need for deeper wells and more powerful pumps will increase the cost of water for agriculture, municipalities, resorts, homes, and businesses. Continued decline of groundwater levels could result in a substantial and possibly irreversible degradation of water quality in the groundwater basin due to the intrusion of lower quality, high TDS water applied at the surface for irrigation and reduced drain flows carrying the salts out of the basin. Continued overdraft also increases the possibility of land subsidence. As groundwater is removed, the dewatered soil begins to compress from the weight of the ground above, causing subsidence. Subsidence can cause ground fissures and damage to buildings, homes, sidewalks, streets, and buried pipelines – all of the structures that make the Valley livable. Subsidence also reduces storage capacity in the aquifer. Continued overdraft would eventually stifle growth in the Valley, as it would not be possible to demonstrate that adequate water supplies exist to support growth.

The 2010 WMP Update uses a calculation of change in storage based on long-term local hydrology and imported water deliveries to estimate long-term overdraft. Since the local hydrology varies significantly from year to year, a long term average provides a better method for estimating the local inflows, which are dampened by the large storage volume of the basin. Because imported water recharge deliveries in the West Valley also vary widely from year to year, recharge is based on estimated long-term average SWP Exchange reliability rather than year-to-year values. Other inflows and outflows are estimated using the groundwater model. This approach dampens the variations in the annual change in storage and gives a more accurate indication of long-term overdraft. Based on these adjustments, the average annual overdraft for 2000 through 2009 is estimated to be 70,000 AFY. When the 2010 WMP Update was adopted in January 2012, CVWD and DWA experienced two years of very high recharge with nearly 461,000 AF recharged at Whitewater (including advanced deliveries).

ES-4 THE 2002 WATER MANAGEMENT PLAN

Continued decline of groundwater levels and ongoing overdraft is unacceptable. CVWD and DWA are charged with providing a reliable, safe water supply now and in the future. In order to fulfill obligations to Valley residents, these agencies must take action to prevent continuing decline of groundwater levels and degradation of water quality on a long-term basis. To meet responsibilities for ensuring adequate water supplies in the future, the CVWD and DWA initiated planning in the early 1990s. The comprehensive Water Management Plan developed in 2002 guides CVWD and DWA in efforts to eliminate overdraft, prevent groundwater level decline, protect water quality, and prevent land subsidence.

The 2002 Water Management Plan clearly identified the significant groundwater overdraft that had occurred over decades and, equally important, the threat of continued overdraft to the economy and quality of life in the Valley. It was based on then current projections of growth and corresponding water demand. The Plan identified the actions needed to eliminate overdraft while maintaining the quality of life and avoiding adverse impacts to the environment. The Plan area originally included the Whitewater River and Garnet Hill Subbasins. Portions of Desert Hot Springs Subbasin east of Indio and Coachella were added to the planning area for this Update, as shown in **Figure ES-1**.

ES-4.1 Goals and Objectives

The goal of the 2002 Water Management Plan is to reliably meet current and future water demands in a cost effective and sustainable manner. To meet this goal, four objectives were identified for the 2002 WMP:

1. Eliminate groundwater overdraft and its associated adverse impacts, including:
    - groundwater storage reductions
    - declining groundwater levels
    - land subsidence, and
    - water quality degradation,
2. Maximize conjunctive use opportunities,
3. Minimize adverse economic impacts to Coachella Valley water users, and
4. Minimize environmental impacts.

The 2002 WMP included five major elements:

- water conservation (urban, golf course, and agricultural),
- substitution of surface water supplies (Colorado River water, SWP water, recycled water) for urban, agricultural, and golf course uses in lieu of pumping groundwater,
- continued groundwater recharge at the Whitewater Recharge Facility and development of two new groundwater recharge facilities in the East Valley,

- increasing surface water supplies, and
- monitoring of groundwater production, levels, water quality and land subsidence.

Within each element, the 2002 WMP identified specific actions to aid in eliminating overdraft. Many of the elements of the 2002 WMP have been accomplished as described in **Section ES-4.2**.

ES-4.2 Accomplishments Since 2002

The actions to eliminate overdraft pursuant to the 2002 WMP taken by CVWD, DWA, other water agencies, municipalities, and tribes are summarized below.

ES-4.2.1 Water Conservation

A broad range of water conservation actions was included in the 2002 WMP. Most of those actions have been achieved, some ahead of schedule.

Urban Conservation

CVWD first passed a Landscape Ordinance in 2003. The ordinance was updated in 2007, and changes were made in 2009 for consistency with the State's updated model landscape ordinance. The ordinance has been adopted by nearly all Valley cities. The ordinance sets a maximum applied water allowance for new developments, requires efficient irrigation systems, specifies the use of climate appropriate plant materials, reduces applied water runoff and overflow, reduces non-recreational turf at golf courses, and mandates smart irrigation controllers on all new landscapes. The ordinance, in combination with other water conservation measures, results in a significant reduction in existing and new water use.

CVWD established an urban water conservation program in 1988. A water conservation coordinator was appointed in 2007, and the program now has a full-time staff of twelve employees. In 2009, CVWD established tiered domestic water pricing for customers based on individual water budgets. A turf buy-out partnership was established with the cities of Cathedral City, La Quinta, and Palm Desert. CVWD also provides weather-based irrigation controllers to eligible customers in participating cities. CVWD maintains water efficient demonstration gardens at the CVWD offices in Coachella and Palm Desert. CVWD sponsors well-attended semi-annual landscape workshops and tours, and creates displays for special events. CVWD produces the popular book, "*Lush & Efficient: Landscape Gardening in the Coachella Valley*," and various other publications. Analysis of water use for CVWD's 2011 Urban Water Management Plan shows water usage has declined by 18 percent compared to average usage from 1996 through 2005.

DWA offers large water users (condominiums, public parks, and businesses) comprehensive irrigation system water audits at no charge and assists in implementing recommended improvements. In partnership with CVWD and Cathedral City, DWA furnishes irrigation controllers at cost to customers. Free controllers are provided with new water meter installation. In addition, DWA recently installed artificial turf and recycled water drip-irrigation for xeriscaping at its operations center (DWA website, 2010). The City of Palm Springs also promotes water efficiency programs including landscape water training programs and rebates for water efficient toilets (City of Palm Springs website, 2010). Analysis of per capita water use for DWA's 2011 Urban Water Management Plan indicates a comparable 18 percent reduction in water use. Indio and Coachella have also implemented water conservation programs that are described in their respective Urban Water Management Plans. Their plans show 14 percent and 20 percent per capita demand reductions compared to their respective demand baselines.

Agricultural Conservation

The 2002 WMP established a goal of seven (7) percent agricultural water use reduction through conservation. Based on a comparison of the average water use per acre in the 2000 through 2002 period, agricultural water use has generally declined about 9.9 percent through 2008. While this estimate may be due in part to variations in weather conditions, crop water needs, and crop patterns, it represents a significant decrease in agricultural water use over the period. Agricultural water conservation measures included irrigation scheduling, salinity management, and irrigation uniformity evaluation programs for irrigators.

Golf Course Conservation

The 2002 WMP goal was to reduce water demand at existing courses by at least five percent by 2010 and for new courses by up to 25 percent compared to historical use by existing courses. Actual use per irrigated acre in the West Valley, where data are available, indicates a reduction of about 14 percent compared to the 2000 to 2002 average. Adoption of the 2009 Landscape Ordinance throughout the Valley is expected to reduce water use by new courses through turf limitations by about 22 percent compared to existing courses. CVWD initiated a program of monitoring golf course water use to ensure that maximum water allowances are not exceeded. A symposium for golf course operators to promote golf course water conservation is held each year.

Stakeholder Review and Input

In 2006, CVWD completed, with extensive stakeholder involvement, a Water Management Plan Implementation Program. This effort included review, evaluation, and prioritization of water conservation programs and other elements of the 2002 WMP by stakeholders with recommendations to the CVWD Board (Water Consult, 2006). The Board uses the recommendations in the Implementation Program to guide development of annual budgets.

ES-4.2.2 Additional Water Supplies

The 2002 WMP identified the need for CVWD and DWA to acquire additional water supplies to manage current and future groundwater overdraft. Supplies identified included the Colorado River, State Water Project, other transfers, recycled water, and desalinated drain water.

Quantification Settlement Agreement

In 2003, CVWD, IID, and Metropolitan, along with the State of California and Reclamation, successfully completed negotiation of the Quantification Settlement Agreement (QSA). The QSA quantifies the Colorado River water allocations of California's agricultural water contractors for 75 years and provides for the transfer of water between agencies. Under the QSA, CVWD has a base allocation of 330,000 AFY. In accordance with the QSA, CVWD has entered into water transfer agreements with Metropolitan and IID that increase CVWD supplies by an additional 159,000 AFY as shown in **Table ES-1**.

As of 2010, CVWD received 368,000 AFY of Colorado River water deliveries under the QSA. This includes the base allocation of 330,000 AFY, the Metropolitan/IID transfer of 20,000 AFY, 12,000 AFY of the IID/CVWD First transfer, and 35,000 AFY of Metropolitan/SWP transfer. CVWD's allocation will increase to 459,000 AFY of Colorado River water by 2026. After deducting conveyance and distribution losses, approximately 428,000 AFY will be available for CVWD use.

Table ES-1
CVWD Deliveries under the Quantification Settlement Agreement

Component	2010 Amount (AFY)	2045 Amount (AFY)
Base Allocation	330,000	330,000
1988 Metropolitan/IID Approval Agreement	20,000	20,000
Coachella Canal Lining (to SDCWA)	-26,000	-26,000
To Miscellaneous/Indian PPRs	-3,000	-3,000
IID/CVWD First Transfer	12,000	50,000
IID/CVWD Second Transfer	0	53,000
Metropolitan/SWP Transfer	35,000	35,000
Total Diversion at Imperial Dam	**368,000**	**459,000**
Less Conveyance Losses [1]	-31,000	-31,000
Total Deliveries to CVWD	**337,000**	**428,000**

Note:
1 Assumed total losses after completion of All-American and Coachella Canal lining projects

State Water Project

CVWD and DWA have made significant progress toward meeting the 2002 WMP goal of 140,000 AFY average delivery target (103,000 AFY to Whitewater Recharge Facility; 37,000 AFY via Mid-Valley Pipeline (MVP)) of SWP Exchange water in the Whitewater River Subbasin. CVWD's and DWA's SWP Table A Amounts[3] are used to replenish both the Upper Whitewater River and the Mission Creek subbasins. Per an interagency agreement, water for

[3] Each SWP contract contains a "Table A" exhibit that defines the maximum annual amount of water each contractor can receive excluding certain interruptible deliveries. Table A Amounts are used by DWR to allocate available SWP supplies and some of the SWP project costs among the contractors.

recharge is allocated in proportion to pumping in each subbasin. CVWD's and DWA's Table A water is exchanged with Metropolitan for a like amount of Colorado River water from Metropolitan's Colorado River Aqueduct (CRA).

Under the 2003 Exchange Agreement, CVWD and DWA acquired 100,000 AFY (88,100 AFY and 11,900 AFY, respectively) of Metropolitan's SWP Table A water as a permanent transfer. In any given year, the agreement allows Metropolitan to call-back the 100,000 AFY and assume the entire cost of delivery if it needs the water. This transfer became effective in January 2005.

In 2004, CVWD purchased an additional 9,900 AFY of SWP Table A water from the Tulare Lake Basin Water Storage District (Tulare Lake) in Kings County, CA. In 2007, CVWD and DWA made a second purchase of 7,000 AFY of SWP Table A water from Tulare Lake: 5,250 AFY for CVWD and 1,750 AFY for DWA. In 2007, CVWD and DWA completed the transfer of 16,000 AFY of SWP Table A water (12,000 AFY and 4,000 AFY, respectively) from the Berrenda Mesa Water District (Berrenda Mesa), effective in January 2010. With these transfers, the combined SWP Table A Amounts for CVWD and DWA total 194,100 AFY, with CVWD's portion equal to 138,350 AFY and DWA's portion equal to 55,750 AFY. **Table ES-2** summarizes CVWD and DWA total allocations of SWP Table A water.

Table ES-2
State Water Project Sources

	Original SWP Table A (AFY)	Tulare Lake Basin 2004 Transfer (AFY)	Metropolitan 2003 Transfer[1] (AFY)	Tulare Lake Basin 2007 Transfer[2] (AFY)	Berrenda Mesa 2007 Transfer[2] (AFY)	Total (AFY)
CVWD	23,100	9,900	88,100	5,250	12,000	138,350
DWA	38,100	—	11,900	1,750	4,000	55,750
Total	61,200	9,900	100,000	7,000	16,000	194,100

Notes:
1 Transfer became effective on January 1, 2005.
2 Transfer became effective on January 1, 2010.

SWP supplies vary annually due to weather and runoff variations and regulatory limitations on exports from the Delta. When the 2002 WMP was prepared, average SWP supply reliability was estimated to be about 82 percent. Under current conditions, DWR estimates the SWP can only provide about 60 percent of the Table A Amounts indicated in CVWD's and DWA's contracts based on an 82-year hydrologic average (DWR, 2011). The current availability of SWP Table A Amounts is presented in **Table ES-3.** In the absence of state and federal actions in the Bay Delta to improve supply reliability and to protect and enhance the Delta ecosystem, it is anticipated that long-term average SWP reliability (deliveries) could decrease to 50 percent of the Table A Amounts over the next twenty years. Additionally, growth and associated groundwater production increases in the Mission Creek Subbasin will result in more SWP Exchange water being delivered to that subbasin reducing supplies for the Whitewater River.

Other Water Transfers

In March 2008, CVWD and DWA entered into separate agreements with DWR for the purchase and conveyance of supplemental SWP water under the Yuba River Accord Dry Year Water Purchase Program. This program provides dry year supplies. The amount of water available for purchase in a given year varies and is based on DWR's determination of the Water Year Classification. The available water is allocated among participating SWP contractors based on their Table A Amounts. CVWD and DWA may be able to purchase up to 5,600 AFY, and 1,820 AFY, respectively. These agreements provide for the exchange of these supplies with Metropolitan for Colorado River water in accordance with the existing exchange agreements. CVWD and DWA received a total of 5,300 AF of water from this source in 2008 and 2009.

Table ES-3
Current (2010) SWP Supply Availability (60% Reliability)

SWP Components	AFY [1]
Table A Amount (Base)	194,100
Average Deliveries with Current SWP Reliability (60%) [2]	116,500
Less Average Metropolitan Callback [3]	(32,900)
Net Average SWP Supply [4]	83,600
Whitewater River Subbasin Recharge (93% of net) [5]	77,800
Mission Creek Subbasin Recharge (7% of net)	5,800

Notes:
1 Values shown are rounded to nearest 100 AFY.
2 Current reliability is based on California DWR's 2009 SWP Reliability Report.
3 Average supply conservatively assumes Metropolitan calls back its 100,000 AFY transfer in four wet years during a 10-year period.
4 Net supply is calculated by deducting the Metropolitan callback from the Table A Amount with current SWP Reliability.
5 Allocation of SWP water to Upper Whitewater River and Mission Creek subbasins is based on production in each basin.

In 2008, CVWD also executed an agreement with Rosedale-Rio Bravo Water Storage District (Rosedale) in Kern County for a one-time transfer of 10,000 AF of banked Kern River flood water that is exportable to CVWD. Deliveries to CVWD began in 2008 and will be completed by December 31, 2012.

Desalinated Drain Water

The 2002 WMP recommended that a drain water desalination facility commence operation between 2010 and 2015 with a 4,000 AFY facility to treat agricultural drainage water for irrigation purposes. The facility would be expanded to 11,000 AFY by 2025. Product water would be delivered to the Coachella Canal distribution system for non-potable use.

A brackish groundwater treatment pilot study and feasibility study was completed in 2008 (Malcolm-Pirnie, 2008a and 2008b). Reverse osmosis (RO) was recommended to meet water quality goals and provide additional flexibility in the level of water quality produced should the facility's objectives change in the future. The recommended approach to brine management was to convey the RO concentrate via pipeline to constructed wetlands located at the north shore of the Salton Sea. This study concluded that agricultural drainage water can be treated for reuse as non-potable water and potentially as new potable water.

Recycling of Municipal Effluent

CVWD and DWA currently deliver approximately 14,000 AFY of recycled water in the West Valley for golf course and other large irrigation uses. Wastewater generated in the West Valley that is not reused for irrigation is percolated into the groundwater basin. Current recycled water usage in the East Valley is approximately 700 AFY for agricultural irrigation. East Valley wastewater that is not reused is discharged to the CVSC.

ES-4.2.3 Source Substitution

Source substitution involves the delivery of alternative water supplies, such as Coachella Canal water or recycled water, to replace of groundwater pumping. Significant efforts have been made to implement source substitution projects in the Valley.

Mid-Valley Pipeline (MVP)

In the West Valley, the demand for non-potable water typically exceeds the available recycled water supply, especially in the summer months. Golf courses using recycled water currently must supplement that supply with local groundwater to meet their demands. This limits the amount of overdraft reduction that is possible to the available recycled water supply. Groundwater modeling shows a local pumping deficit (overdraft condition) that cannot be remedied by recharge at Whitewater. The MVP is a pipeline distribution system to deliver Colorado River water to the Mid-Valley area for use with CVWD’s recycled water for golf course and open space irrigation. This source substitution project will reduce groundwater pumping for these uses. Construction of the first phase of the MVP from the Coachella Canal in Indio to CVWD’s Water Reclamation Plant No. 10 (WRP-10) (6.6 miles in length) was completed in 2009.

At WRP-10, Canal water supplements recycled water for delivery to large irrigators. There are eight golf courses and five other users in the West Valley currently connected to the WRP-10 recycled water system that can receive both recycled water and Canal water via the MVP. If these courses meet at least 90 percent of their irrigation needs with non-potable water, 2,700 AFY of additional groundwater pumping will be eliminated. There are four golf courses adjacent to the MVP that can be connected to the system with minimal construction, thus making them ideal candidates to receive Canal water through the MVP. Construction of Phase 1 of the MVP included outlets along the pipeline to serve these courses. However, pipeline connections to deliver Canal water from the MVP to each course have yet to be constructed. When these four courses are connected, about 4,500 AFY of additional pumping could be eliminated. At least ten additional courses can be connected to the MVP downstream of WRP-10 with relatively simple pipeline connections, reducing pumping by another 11,200 AFY. When fully implemented, the MVP system will be capable of eliminating about 50,000 AFY of groundwater pumping.

Pilot Study of Canal Water Treatment for Urban Use

As projected growth occurs in the East Valley and farms are converted to urban land uses, agricultural demand for Canal water will decrease. To avoid increased urban groundwater pumping and to use the Valley's Colorado River water supply fully, there will be a need to treat Canal water for urban use. The 2002 WMP anticipated this need and proposed that treatment be provided beginning in the late 2020s with about 32,000 AFY being treated by 2035. Present projected domestic water demand coupled with reduced agricultural demand is expected to increase this amount substantially. Potable use will require Canal water treatment to meet drinking water standards. In anticipation of constructing potable water treatment facilities, CVWD completed a pilot treatability study for Canal water in 2008 (Malcolm-Pirnie, 2008c). This study investigated alternative approaches to treatment of Colorado River water delivered for urban use. The study recommended that blending treated Colorado River water with local groundwater be further evaluated to ensure customer satisfaction.

ES-4.2.4 Groundwater Recharge

Groundwater recharge is a critical component of basin management that involves putting water directly into the groundwater basin through surface percolation ponds. The 2002 WMP included continuing recharge at the existing Whitewater Recharge Facility in the West Valley, proposed recharge in the East Valley using Colorado River water at Dike 4, now the Thomas E. Levy Groundwater Replenishment Facility (Levy facility), and recommended another major recharge facility at Martinez Canyon.

Whitewater Recharge Facility – West Valley

The 2002 WMP established a future average annual recharge target at this facility of about 100,000 AFY. The Whitewater River Recharge Facility has a recharge capacity in excess of 300,000 AFY. Because this capacity is enough to capture the full SWP Table A amount with additional capacity for supplemental recharge, no recharge capacity expansion is required. The available capacity is valuable for conjunctive use operations by CVWD and DWA as well as Metropolitan or other interested parties. Currently, the SWP Exchange supply is expected to provide about 78,000 AFY for the Whitewater facility on average. Under future conditions, it is possible that average recharge at Whitewater could be limited to the available future supply of about 61,400 AFY of SWP Exchange, unless it is augmented with other supplies. To reach the 100,000 AFY recharge goal for the Whitewater facility, CVWD and DWA would need to acquire additional SWP Table A Amounts or other imported water sources.

Thomas E. Levy Groundwater Replenishment Facility - East Valley

Construction of the full-scale Levy facility was completed in mid-2009. Located on the west side of the Valley in La Quinta, this facility has an estimated average recharge capacity of 40,000 AFY. The current capacity may be limited by hydraulic, water delivery, and maintenance constraints within the Canal water distribution system to an average of about 32,000 AFY. Construction of an additional pipeline to the Levy facility and pumping station from Lake Cahuilla may be required in the future to reach the 40,000 AFY capacity on a consistent basis.

Martinez Canyon Pilot Recharge Facility Feasibility Assessment – East Valley

The Martinez Canyon pilot recharge facility began operation in 2005 and currently recharges about 3,000 AFY. When this project is expanded to full scale, it is expected to recharge up to 40,000 AFY.

ES-4.2.5 Groundwater/Subsidence Monitoring

CVWD maintains an extensive ongoing groundwater production, level, and water quality monitoring program throughout the Valley. The program includes monitoring of potential saltwater intrusion from the Salton Sea. The data are periodically reviewed to determine impacts of management actions on overdraft and water quality. The data are also applied to re-calibrate the groundwater model that assesses the impact of proposed management actions.

The United States Geological Survey (USGS), working with CVWD, completed subsidence monitoring reports for the Coachella Valley in 2001 and 2007. The reports indicated that subsidence was taking place in varying degrees throughout the Valley.

These studies to date have not confirmed the relationship between land subsidence and declining water levels. The USGS Scientific Investigation Report 2007-5251 states, “Although the localized character of the subsidence signals is typical of the type of subsidence characteristically caused by localized ground-water pumping, the subsidence may also be related to tectonic activity in the valley.” This report also concludes additional monitoring is needed to permit meaningful interpretations of the aquifer-system response to water level changes. CVWD’s Board of Directors has approved additional funding to continue these cooperative subsidence studies with the USGS. Future studies include additional monitoring designed to evaluate the potential relationship between declining water levels and land subsidence. Potential land subsidence caused by declining water levels was addressed by mitigation measures described in the 2002 Coachella Valley Water Management Plan Programmatic Environmental Impact Report (CVWMP PEIR).

ES-5 2010 WMP UPDATE

Significant actions have been taken since 2002 to alleviate overdraft in the long term. Changes in internal and external factors mandate new activities and increased levels of current activities to eliminate overdraft and assure reliable long term water supplies to the Valley. These new activities are identified in the 2010 WMP Update.

ES-5.1 Population and Water Demand

Since 2002, significant changes have occurred in projections of population and future water demands, including:

- Significantly increased population growth, mainly in the East Valley (**Figure ES-2**);
- Changes in land use from agricultural to urban land use and water demand in terms of both quantity and quality;

- Development on tribal lands and related water demands;
- Potential development located northeast of the San Andreas fault in the spheres of influence (SOI) of the cities of Indio and Coachella;
- Projected urban development outside the 2002 WMP study area and corresponding increases in water demands;
- Uncertainty in the timing of growth and water demands.

Figure ES-2 shows the difference in population projections used in the 2002 WMP and projections used in the 2010 WMP Update. The 2010 WMP Update provides water for approximately 500,000 more people in 2045 than the 2002 WMP.

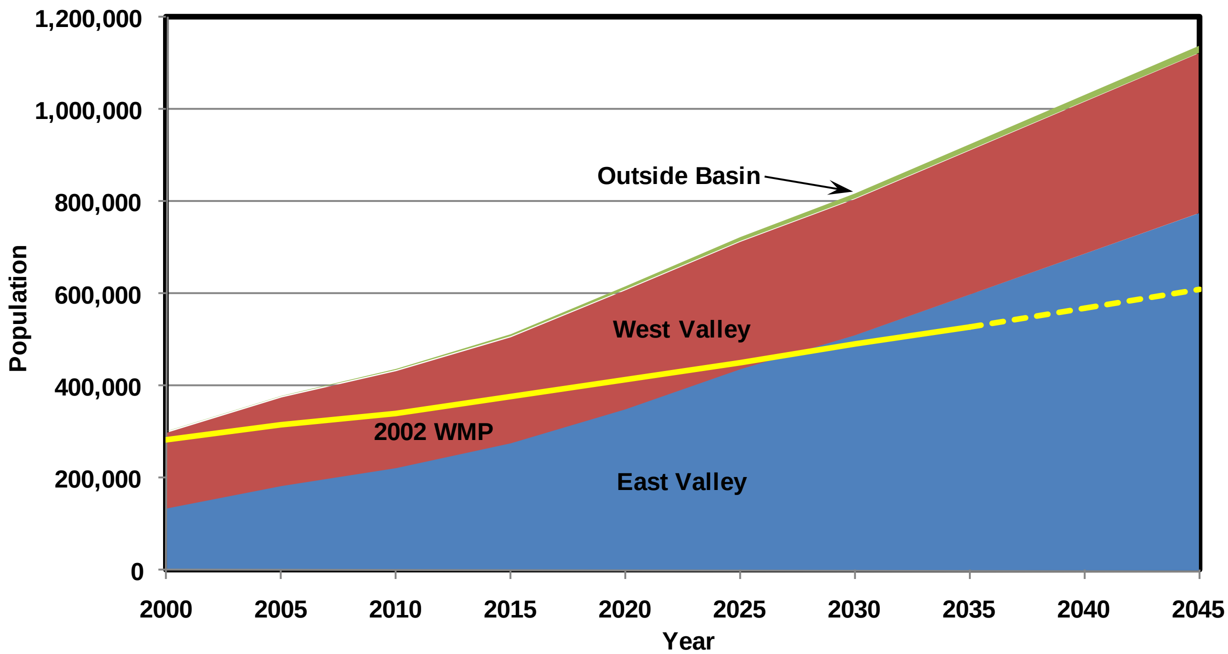


Figure ES-2
Comparison of Population Projections for the Coachella Valley

ES-5.1.1 Future Water Demands

Projected water demands for 2045 resulting from projected population growth and associated assumptions regarding land uses and water demands for land uses are shown by economic sector in **Table ES-4**. Water use by new development is expected to be more efficient due to plumbing code requirements and the Landscape Ordinance. Consequently, water demands are expected to be less than projected in the 2002 WMP. Factoring potential variations in future land use and growth forecasts into these demand projections, water demands in 2045 could range from 793,600 AFY to 971,500 AFY with a mid-range planning value of 885,400 AFY as shown on **Figure ES-3**. If the growth projection in the 2002 WMP, with assumed water conservation measures, were projected to 2045, the projected demand would be approximately 950,000 AFY.

The reduction in projected demand results primarily from the conversion of agricultural lands to urban use and increased water conservation factored into the 2010 WMP Update.

Table ES-4
2045 Baseline Water Demand Projection for the Coachella Valley

Component	2045
Agricultural	
Crop Irrigation	166,300
Total Agricultural Demand	**166,300**
Urban	
Municipal	537,000
Industrial	2,300
Total Urban Demand	**539,300**
Golf Course Demand	**169,500**
Fish Farms and Duck Clubs	
Fish Farms	8,500
Duck Clubs	2,000
Total Fish Farms and Duck Clubs	**10,500**
TOTAL DEMAND	**885,400**

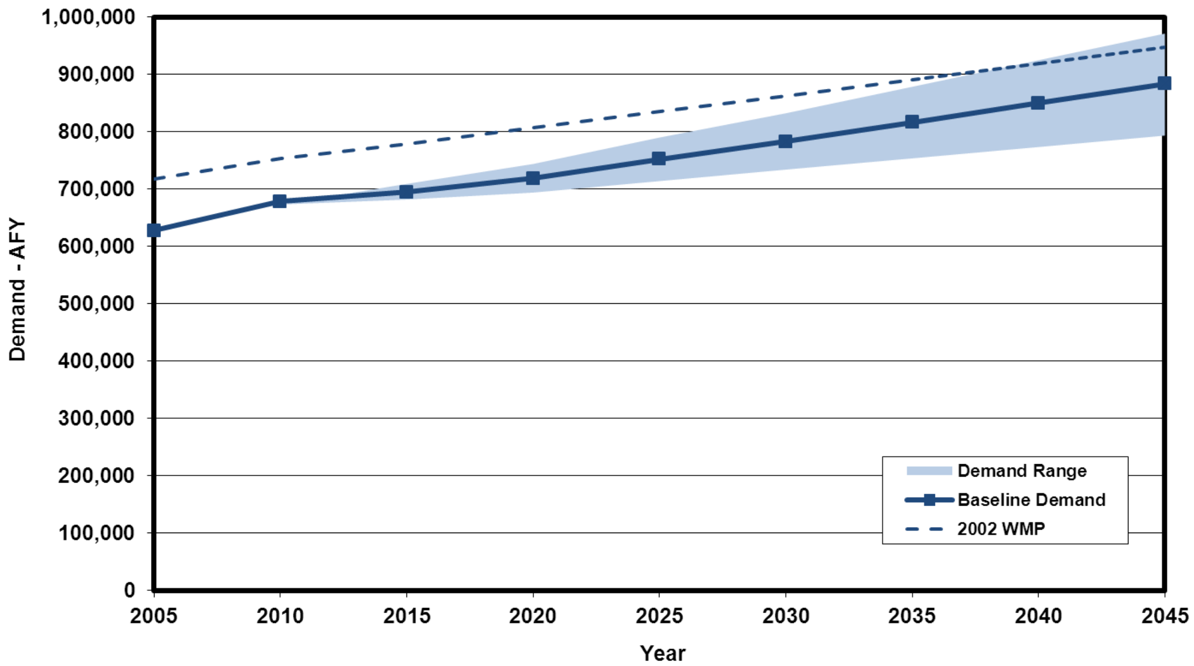


Figure ES-3
Projected Water Demands in the Study Area

ES-5.1.2 Demand Uncertainty

Future water demands are based on the latest approved population growth projections (2006) by Riverside County and assumptions regarding impacts of population growth on land uses, impacts of water conservation on water uses, and resulting water demand associated with each type of land use. There are a number of uncertainties inherent in the demand projections, including:

- Growth forecasts or rates of growth may be too high or too low
- Impacts of economic booms and busts
- Reductions in fish farm operations
- Rates of development on Tribal lands
- Rate of agricultural/vacant land conversion to urban use
- Future water demand factors for various land uses
- Growth outside the Whitewater River subbasin
- Number of future golf courses developed in the East Valley
- Acceptance and effects of water conservation measures

Figure ES-3 shows the range in potential future water demands for the study area.

ES-5.2 Future Water Supply Needs

In addition to changing water demands, changing external factors could affect Valley water supplies:

- SWP allocations fluctuate annually due to snowpack and runoff variations, and the environmental needs in the Bay-Delta.
- Recent environmental rulings have restricted the State's ability to move water through the Delta to the SWP, potentially decreasing supply reliability and deliveries. The degree to which the long-term supply of the SWP will be affected is uncertain.
- The outcome of efforts underway to prepare the Bay-Delta Conservation Plan (BDCP), which is intended to restore the Delta's ecosystem and improve water supply reliability, is uncertain.
- The QSA has been upheld in the appeals court but, as of plan adoption, environmental litigation is still pending, creating uncertainty in future Colorado River supplies.
- Climate change could affect the long term supplies of both the SWP and Colorado River and water demands within the Valley.

These changing conditions and uncertainties reinforce the need for a flexible long term Plan and for updating the Plan periodically.

Additional water supplies needed by 2045 are evaluated for four water supply scenarios that incorporate the uncertainties associated with current supply sources, with the exception of climate change. A 10 percent supply buffer addresses potential climate change impacts and other currently unforeseeable factors affecting future water supplies. **Table ES-5** shows the future water supply needs range from 300,000 to 461,000 AFY. The 2010 WMP Update identifies how this future need will be met through a combination of water conservation measures and new supply development. **Figure ES-4** presents the future water supply plan assuming Scenario 2 without the supply buffer.

Table ES-5
Water Supply Needs – 2045

Scenario	QSA Validated	Delta Conveyance Improvements	Demand (AFY)	Demand with 10% Buffer (AFY)	Available Supply (AFY) [1]	Additional Supply Required (AFY)
1	Yes	Yes	885,400	974,000	674,300	299,700
2	Yes	No	885,400	974,000	640,900	333,700
3	No	Yes	885,400	974,000	546,300	427,700
4	No	No	885,400	974,000	512,900	461,100

Note:
1 Available supplies consist of local runoff and streamflow, recycled water, returns from use, Canal water and SWP Exchange water minus anticipated drain flows and subsurface outflows from the basin as explained in Section 7.2.

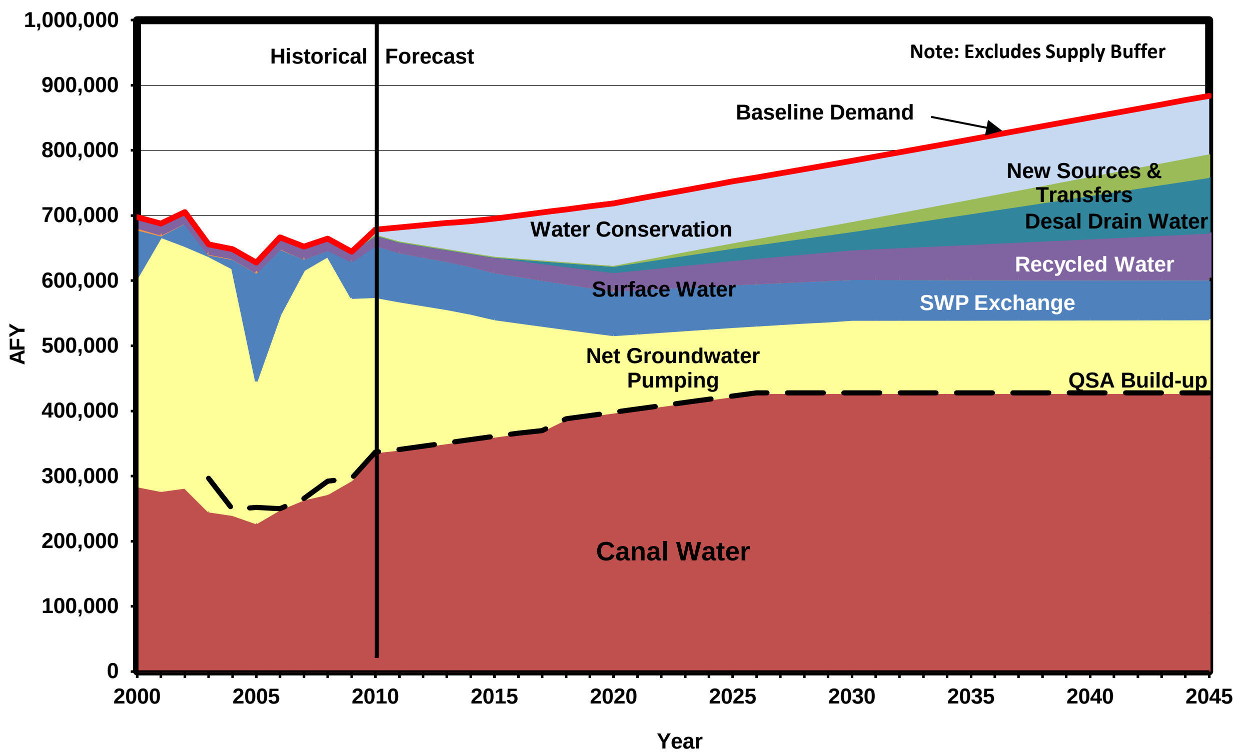


Figure ES-4
Water Supply Mix for 2010 WMP Update

ES-5.3 What is New in the 2010 WMP Update?

The 2010 WMP Update identifies proposed ways and means of meeting future water needs in light of changing conditions and uncertainties. To meet future needs, the 2010 WMP Update includes many new features in the areas of water conservation, source substitution, new supplies, and groundwater recharge. The 2010 WMP Update emphasizes enhanced cooperation in Plan implementation. The 2010 WMP Update incorporates a "bookends" approach to define target ranges for each major supply group and incremental "building blocks" of projects to deal with uncertainties in future demands and supplies.

Revised Goals: The basic goal of the WMP remains the same but has been modified to reflect a more holistic planning approach: "to reliably meet current and future water demands in a cost-effective and sustainable manner." The underlying objectives of the WMP have been refined as follows to reflect the water resources uncertainties facing the Valley:

- Meet current and future demands with a 10 percent supply buffer
- Eliminate long-term groundwater overdraft
- Manage and project water quality
- Comply with state and federal laws and regulations
- Manage future costs
- Minimize adverse environmental impacts

Bookends on Demands and Supplies: To account for the uncertainty and potential variability in demands, the 2010 WMP Update assigns bookend targets (ranges) for each of the major categories of water supplies (see **Section 6)**. The book-ends represent reasonable minimum and maximum amounts for potential supply and project development. Depending on the actual demands that are encountered in the future, the 2010 WMP Update elements can be implemented within these ranges to meet demands.

Building Block Approach: The 2010 WMP Update incorporates a flexible approach to meeting future needs that reflects uncertainties in supplies, demands and future circumstances by combinations of Plan elements. For example, the 2010 WMP Update includes an aggressive program of water conservation for urban, golf course and agricultural water users. However, there are limits in terms of cost, effectiveness, and acceptability of water conservation activities. As those limits are reached, other Plan elements for meeting future needs also can be adjusted. One source of supply is desalination of drain water, the most expensive alternative for providing new supplies. This source will only be implemented as other sources of supplies reach practical limits. Therefore, the Plan includes a range of 55,000 to 85,000 AFY for desalination of drain water. The actual amount of water from this source will depend upon how much can be obtained first from other, lower cost sources.

Enhanced Cooperation in Plan Implementation: The Plan emphasizes cooperation among municipalities, local water agencies and tribes in regional planning and implementation. This occurs through the implementation of activities described in the 2010 WMP Update, implementation of related planning activities (see **Section 1.0**), and the development of monitoring and data sharing programs among CVWD, other water agencies, cities, and tribes to better manage Valley water resources.

ES-5.4 2010 WMP Update Elements

In developing the 2010 WMP Update, CVWD evaluated the success of 2002 WMP elements and determined future needs, supplies, and uncertainties. Like the 2002 WMP, the 2010 WMP Update has the same five major elements:

- Water conservation (urban, golf course, and agricultural)
- Increasing surface water supplies for the Valley from outsides sources
- Substitution of surface water supplies for groundwater (source substitution)
- Groundwater recharge
- Monitoring and evaluation of subsidence and groundwater levels and quality to provide the information needed to manage the Valley's groundwater resources

Activities included in the 2010 WMP Update in each of these elements are described below.

ES-5.4.1 Water Conservation

New water conservation targets and actions are included for agriculture, urban, and golf course water users. In addition to the water conservation included in the baseline demand projections, the 2010 WMP Update includes a minimum water conservation target of 117,300 AFY by 2045 as shown in **Table ES-6**. This amount could increase to 147,000 AFY to provide a portion of the supply buffer.

Table ES-6
Ranges of Potential Water Conservation Savings – 2045

Type of Conservation	Low Range [1] (AFY)	High Range [2] (AFY)
Urban	82,400	106,200
Agriculture [3]	23,300	23,300
Golf Courses	11,600	17,400
Total	**117,300**	**146,900**

Notes:
1 The low range represents the minimum amount of demand reduction required assuming successful completion of the BDCP and provides a portion of the supply buffer.
2 The high range represents the amount of demand reduction required if the BDCP is not successful and provides a portion of the 10 percent supply buffer.
3 Agricultural savings decline over time as agricultural land is converted to urban uses.

Agricultural Conservation

The new agricultural conservation target is a 14 percent savings by 2020 utilizing a phased approach. The first phase will involve low cost voluntary programs. Depending on the success of those programs, more expensive and vigorous programs could be implemented, as needed. If the 14 percent target can be achieved, the agricultural conservation program is expected to save about 39,500 AFY of water in 2020, decreasing to 23,300 AFY by 2045 as agricultural land uses transition to urban uses. Progress toward meeting agricultural conservation goals will be evaluated and reported every five years.

Urban Conservation

The urban water conservation program will be expanded and enhanced in order to meet changing demands and to comply with the State's requirement of a 20 percent reduction in per capita water use by 2020 compared to average per capita usage for the period of 1995 through 2004. This program could save at least 39,700 AFY by 2020 and achieve a 39 percent reduction in per capita demand by 2030 as it is applied to new growth.

Achievement of the state's 20 percent conservation target in conjunction with on-going conservation programs could result in urban water savings of 82,400 to 106,200 AFY by 2045 depending on the water supply scenario. Progress toward achieving the urban water conservation goals will be reported in urban water management plans prepared on five year intervals.

Golf Course Conservation

The golf course conservation target is a savings of 11,600 to 17,400 AFY by 2045. For existing courses, the minimum target is a 10 percent reduction in water use through golf course irrigation system audit, and soil moisture monitoring services. The 2009 Landscape Ordinance will apply to all new golf courses with turf limitations of 4 acres of per hole and 10 acres for practice areas. Progress toward meeting golf course conservation goals will be evaluated and reported every five years.

ES-5.4.2 Additional Supplies

Table ES-7 summarizes the range of additional supplies that will be developed.

Acquisition of Imported Supplies

CVWD and DWA will continue to acquire additional imported SWP water supplies by transfer or lease where cost-effective, given Delta environmental restrictions and conveyance capacity limitations. For this update, a planning range of 50,000 to 80,000 AFY of average annual supply has been identified to meet future needs including the supply buffer. This amount includes about 35,000 AFY to meet estimated demand east of the San Andreas fault; the amount will be refined as planning proceeds for this area. Changes to the assumed call-back frequency for the MWD 100,000 AFY SWP transfer could provide up to 33,000 AFY of additional supply to the

Whitewater River Subbasin. Option-type contracts could be considered to meet a portion of the supply buffer.

Table ES-7
Range of Additional Supplies Through 2045

Action	Low Range (AFY)	High Range (AFY)
Bay-Delta Conveyance Improvements	0	33,400
Purchases and Transfers [1]	50,000	80,000
Changes to MWD Call-back Provisions [1]	0	32,700
Increased Recycled Water - East and West Valleys	14,000	63,000
Recycled Water Use East of San Andreas Fault	10,800	10,800
Canal Water Loss Reduction	0	10,000
Desalinated Drain Water	55,000	85,000
Stormwater Capture – East Valley	0	5,000
Groundwater for Non-potable Use East of San Andreas Fault	9,700	9,700
Total	**139,500**	**329,600**

Note:
1 High range represents potential supplies with Bay Delta conveyance improvements and no call-back.

Increased Recycled Water Use

Recycled water in the West Valley is currently used beneficially, either through direct non-potable use or percolation for wastewater disposal. At least 90 percent of all wastewater generated in the West Valley will be recycled for direct non-potable use. All wastewater generated by new growth in the East Valley will be recycled. All wastewater from development east of the San Andreas fault could be recycled for irrigation or groundwater recharge to meet demands in that area and reduce the need for additional imported water supplies. Up to 34,500 AFY of recycled water could be utilized in the West Valley, and 33,000 AFY of recycled water could be utilized in the East Valley. Up to 10,800 AFY of recycled water could be utilized in the new growth area east of the San Andreas fault for direct non-potable uses by 2045.

Canal Water Loss Reduction

Water losses in the All-American Canal in the first 49 miles of the Coachella Canal may be as high as 10,000 AFY. Reducing this loss could increase the amount of water delivered to the Valley. CVWD will determine water lost to leakage in the first 49 miles of the Coachella Canal, evaluate the feasibility of corrective actions to capture the lost water, implement cost-effective water saving measures, and work with IID to share losses.

Desalinated Drain Water

A demonstration scale facility will be constructed to gain operational experience in desalinating drain water and brine disposal. Between 55,000 and 85,000 AFY of drain water and shallow groundwater will be recovered, desalinated, and distributed for non-potable and potable uses in the East Valley. The amount of desalinated water needed will depend upon the resolution of Bay-Delta issues and the resulting amount of SWP water available.

Stormwater Capture

Stormwater capture has been identified as a potential method for increasing local water available for either groundwater recharge or direct use. CVWD will conduct a study to investigate the feasibility of additional stormwater capture in the East Valley. Feasible stormwater capture projects will be developed in conjunction with new flood control facilities as development occurs in the East Valley. For planning purposes, the potential yield is assumed to be 5,000 AFY based on a reduction in evaporation losses with more efficient capture and percolation.

Development of Local Groundwater Supplies for Non-Potable Use

Growth in the areas northeast of the San Andreas fault will create additional demands for both potable and non-potable water. CVWD, the City of Coachella, and the City of Indio will jointly conduct an investigation of groundwater in Fargo Canyon Subarea of the Desert Hot Springs Subbasin to determine the available supply and suitability for use in meeting non-potable demands (outdoor irrigation) of development east of the San Andreas fault. Based on assumed development, up to 9,700 AFY of groundwater could be developed in this area.

ES-5.4.3 Source Substitution

Due to the expected changes in water use patterns from continued development, source substitution will receive increased emphasis in the future to eliminate overdraft and ensure full use of the Valley's available surface water supplies. The ranges of reduction in groundwater overdraft due to source substitution programs are shown in **Table ES-8**.

Table ES-8
Range of Groundwater Pumping Reductions Due To Source Substitution

Action	Low Range (AFY)	High Range (AFY)
Mid-Valley Pipeline	37,000	52,000
Agricultural Canal Water Conversion	5,300	32,000
Oasis Area Conversion to Canal Water	0	27,000
East Valley Golf Course Conversion	43,900	51,700
West Valley Golf Course Conversion	15,200	17,800
Canal Water for Indoor Urban Use – East Valley	48,000	90,000
Canal Water Use for Outdoor Use – East Valley	95,000	115,000
Total	**244,400**	**385,500**

Mid-Valley Pipeline

The MVP system delivers Canal water and recycled water to golf courses in lieu of their pumping groundwater. Activities to fully implement the MVP include preparing an MVP system master plan to lay out the future pipeline systems, near-term expansions to connect golf courses along the MVP alignment and extensions of the existing non-potable distribution system, and completion of construction of the remaining phases of the MVP system by 2020 to provide up to 37,000 AFY of Canal water and 15,000 AFY of WRP-10 recycled water on average to West Valley golf courses.

Conversion of Agricultural and Golf Course Use to Canal Water

It is expected that agricultural use of groundwater could decrease from about 66,000 AFY in 2009 to about 7,000 AFY by 2045, a decrease of 59,000 AFY or 89 percent. A large portion of this reduction could come from the Oasis area that does not currently have access to Canal water. The Oasis area distribution system feasibility study will be updated to include future conversion to serve urban non-potable water. Cost-effective facilities will be constructed. If conversion of the Oasis system is feasible, it could deliver up to 27,000 AFY of Canal and desalinated drain water for irrigation.

In the 2010 WMP Update, it is estimated that for existing East Valley golf courses having Canal water access, Canal water use will increase to 90 percent of demand by 2015. Conversion to Canal water by East Valley golf courses will reduce groundwater use by 43,900 AFY or more.

Colorado River Water for Urban Use

In light of the projected increase in population and change of land use from agricultural to urban in the East Valley, treated Colorado River water for indoor residential use will be essential. In addition, untreated Colorado River water will be used in the future in large developments in the East Valley for outdoor purposes, i.e., lawn and park irrigation. These measures are necessary to reduce overdraft and to insure continued full use of the Valley’s Colorado River water supplies.

This program will offset the reduced Canal water use by agriculture as agricultural land use transitions to urban development in the East Valley. Canal water will be treated to meet future indoor urban water demands in the East Valley. The target for urban indoor use of Canal water ranges from 48,000 and 90,000 AFY by 2045.

Dual source plumbing systems will be a feature of new development in the East Valley to provide outdoor use of untreated Canal water. Untreated canal water should provide 67 percent to 80 percent of the landscape demand for new development. This will result in the utilization of 95,000 to 115,000 AFY of non-potable Canal water by 2045. Where found to be cost-effective, existing developments will be retrofitted with distribution systems to provide for outdoor use of untreated Canal water.

ES-5.4.4 Groundwater Recharge

Groundwater recharge will be expanded to reduce overdraft. The ranges of groundwater recharge operations at various facilities under the 2010 WMP Update are shown in **Table ES-9**.

Table ES-9
Range of Groundwater Recharge

Facility	Low Range (AFY)	High Range (AFY)
Whitewater	61,000 [1]	100,000
Levy	40,000	40,000
Martinez Canyon [2]	20,000	40,000
Indio	0	10,000
Total	**121,000**	**190,000**

Notes:
1 Recharge is limited by available supply.
2 High range will depend on overdraft conditions and implementation of East Valley source substitution projects.

Whitewater Recharge Facility

Operation of the Whitewater Recharge Facility will continue with the goal of recharging an average of at least 100,000 AFY of SWP exchange water over the long-term. Unused SWP water and available desalinated drain water from the QSA will be transferred to the Whitewater Recharge Facility. Additional water acquired by transfer or lease will augment the existing SWP exchange water.

Thomas E. Levy Recharge Facility

The Levy facility will recharge 40,000 AFY on average. A second pumping station and pipeline will be constructed if needed to achieve and sustain 40,000 AFY of deliveries for recharge.

Martinez Canyon Recharge

Siting studies, land acquisition, environmental compliance, design, and construction will be conducted for the full-scale Martinez Canyon facility. The project will be implemented in phases with an initial capacity of 20,000 AFY with potential future expansion to as much as to 40,000 AFY based on groundwater overdraft conditions and implementation of East Valley source substitution projects.

Groundwater Recharge in Indio

The City of Indio will evaluate the feasibility of a nominal 10,000 AFY groundwater recharge project in Indio and construct if feasible. The final capacity will be based on pilot studies conducted by Indio.

Investigation of Groundwater Storage Opportunities with IID

CVWD will work with IID to identify options for storing Colorado River water on behalf of IID with currently planned Valley recharge facilities or additional facilities, including facilities to recover the stored water for use by Canal water users if necessary when IID calls for its stored water.

ES-6 WATER QUALITY MANAGEMENT

ES-6.1.1 Additional Groundwater Treatment for Arsenic

CVWD will work with other agencies to assist communities having high levels of arsenic in groundwater supplies to connect to the potable water system. As needed, CVWD will expand its arsenic treatment facilities to allow treatment of additional wells and construct water transmission pipelines as needed to meet future demands.

ES-6.1.2 Development of Salt/Nutrient Management Plan

The State Water Resources Control Board (SWRCB) requires preparation of a salt/nutrient management plan by 2014 as part of the 2009 State Recycled Water Policy. As stated in the Policy, its purpose is to "establish uniform requirements for recycled water use and to develop sustainable water supplies throughout the state" (SWRCB, 2009). CVWD will work with other Valley water agencies, tribes, and stakeholders to develop a salt/nutrient management plan that meets the State requirements and allows the cost-effective recycling of municipal wastewater in the Valley.

ES-6.1.3 Drainage Control

For both basin management (groundwater level and salt export), as well as the prevention of adverse impacts, the existing drainage system should be maintained, replaced as needed, or expanded as urban development occurs. CVWD will investigate alternative methods for funding the drainage system, conduct an investigation of the improvements needed to continue system operation in the future, and maintain and expand the drainage system.

ES-7 MONITORING AND DATA MANAGEMENT

Monitoring and data management programs aid in evaluating the effectiveness of the water management programs and projects identified in the Plan and to identify needed changes in management strategy and/or implementation.

The existing hydrologic monitoring program of weather data, streamflow data, well data (drilling logs, production, water levels), surface and ground water quality monitoring, and subsidence monitoring should be maintained and expanded. Key features of the expanded program are described below.

ES-7.1 Water Quality

CVWD will work with water agencies, tribes and cities to develop a coordinated water quality monitoring program to ensure that local water quality concerns and state/federal regulatory issues are addressed.

ES-7.2 Subsidence

CVWD will continue the USGS subsidence monitoring/reporting program and construct additional extensometers at critical locations to monitor subsidence, as needed.

ES-7.3 Water Resources Database

CVWD will work with water agencies, cities and tribes to develop a shared water resources database. The database could include well ownership data, well logs, groundwater production, water level and water quality data.

ES-7.4 Groundwater Model Update and Recalibration

Prior to the next Plan update, the CVWD groundwater model will be updated, recalibrated and peer reviewed.

ES-7.5 Water Quality Model

CVWD will initiate development of a model capable of simulating the water quality changes in coordination with preparation of the salt/nutrient management plan.

ES-7.6 Water Demand and Conservation Monitoring

Water purveyors will monitor and report demands by water use sector and correlate demands with implementation of water conservation measures to determine the effectiveness of water conservation measures in achieving goals and the need for additional measures.

ES-8 PLAN COSTS

The cost of not eliminating overdraft would be far more than the cost of the actions needed for eliminating overdraft identified in the 2010 WMP Update. Cost of overdraft includes increased subsidence with its impacts on individual homes, commercial structures, and infrastructure (streets, highways, water and sewer lines, and other utilities), water quality degradation, and increased pumping costs. Colorado River supplies would go unused as agricultural land is converted to urban land, and groundwater pumping would increase without alternative sources of supplies. At some point, it would not be possible to demonstrate the availability of water supplies to support new growth.

The estimated cost to implement the 2010 WMP Update is shown in **Table ES-10** for the period 2011 through 2045. Capital, operation and maintenance cost, total cost, and average annual cost are shown for each Plan element in 2010 dollars. These are total costs, not incremental costs, and include the costs of many current activities such as groundwater pumping, acquisition of Colorado River water, current levels of recycling and water conservation, and groundwater recharge. The costs shown are the total costs for the entire Valley.

Table ES-10
Cost by Plan Component
2011-2045

Component	Total Capital Cost $millions	Total O&M Cost $millions	Total Cost $millions	Average Annual Cost[1] $millions
Water Conservation	$ 1	$ 230	$ 231	$ 6.6
Recycled Water	161	153	314	9.0
Colorado River Water		409	409	11.7
SWP Water		1,907	1,907	54.5
Delta Conveyance		472	472	13.5
Desalinated Drain Water	462	277	739	21.1
Groundwater Pumping and Treatment	135	1,950	2,085	59.6
Water Transfers	0	282	282	8.1
Other New Water		262	262	7.5
Source Substitution	1,142	782,	1,924	55.0
Recharge	48	181	229	6.5
Total Cost	**$1,949**	**$6,907**	**$8,856**	**$253.0**
Average Annual Cost [1]	$56	$197	$253	

Note:
1 Average annual cost is the total cost divided by 35 years.

The total estimated capital cost through 2045 is $1.95 billion. Total O & M cost is $6.91 billion bringing the total cost of the Plan implementation to $8.86 billion over 35 years. The average annual cost is $253 million. This annual cost does not reflect the amortized cost of capital projects that may be bond-funded over several decades, thus increasing the annual cost of capital projects.

ES-9 IMPLEMENTATION AND IMPLEMENTATION COSTS

In developing the 2010 WMP Update, CVWD relied on the latest population projections developed by Riverside County. CVWD does not develop population growth projections for use in water management planning. The 2006 Riverside County projections were prepared before the recent recession, which has slowed growth and is expected to have negative effects on growth in the near term. Over the long term, growth will continue. Future population projections will be adjusted in terms of the timing and magnitude of growth. These realities necessitate adjustment of Plan implementation to meet actual near term needs and continued updates of the Water Management Plan in the future to reflect revised population projections.

Near Term Projects to Meet Water Management Needs

Even with the current recession and lack of growth, continuation of existing projects and a few new projects are needed to reduce overdraft and its adverse affects. Ongoing projects that will be continued include:

- Whitewater Recharge with SWP Exchange Water and SWP purchases
- Implementation of the QSA
- Levy Recharge operating at current level of 32,000 AFY
- Martinez Pilot Recharge at current level of 3,000 AFY
- Water conservation programs at current levels, including implementation of the Landscape Ordinance
- Recycling in the West Valley
- Increased use of Canal water by golf courses with Canal water connections
- Conversion of East Valley agriculture to Canal water as opportunities arise
- Groundwater production/level/quality monitoring
- Cooperative subsidence monitoring with USGS

Assuming that growth remains relative low during the next five years, CVWD will focus on three new or expanded activities to reduce overdraft and comply with state regulations:

- Increased use of the Mid-Valley Pipeline project to reduce overdraft in the West Valley by connecting golf courses and reducing groundwater pumping by those courses.
- Implementation of additional water conservation measures, including the Landscape Ordinance, to meet the State's requirement of 20 percent conservation by 2020.
- Preparation of a salt/nutrient management plan for the Valley by 2014 to meet SWRCB Recycled Water Policy requirements

Long Term Projects

Projects to eliminate and control overdraft that are likely to be needed as future growth occurs are described in the 2010 WMP Update. These projects include:

- Additional water conservation.
- Desalinated drain water.
- Additional water transfers.
- Additional recycled water.
- Canal water treatment for urban indoor use.
- Canal water treatment for urban outdoor irrigation.
- Recharge in the Indio area.

As growth ramps up, the projects will be implemented based on cost effectiveness and need.

Implementation Costs

In 2010, Valley water agencies expended approximately $414 million on all water and wastewater management activities. This total cost includes approximately $106 million per year on activities associated with eliminating overdraft. Since 2002, CVWD and DWA have invested over $240 million in water conservation, supply acquisition and facilities to reduce overdraft. During the next five years (2011-2015), it is estimated that Valley water agencies will expend an additional $5.4 million on activities to eliminate overdraft, assuming growth remains slow.

As growth occurs, additional projects to control overdraft will be needed. Ultimately, costs associated with growth to eliminate and control overdraft could approach an additional $100 million per year in capital project and annual operations and maintenance costs.

Much of the future costs, both capital and operation and maintenance, will not be borne by CVWD. These costs will be borne by developers, other water organizations, and Valley municipalities. Capital costs and operation and maintenance costs associated with new growth will be paid by new growth. For example, the entire cost of systems for treating and delivering Colorado River Canal water for indoor use in East Valley developments and development of dual plumbing systems to provide untreated water to those developments for outdoor use will be paid for by new development.

ES-10 CONCLUSION

Groundwater overdraft is a significant problem in the Coachella Valley. The 2002 Water Management Plan was developed to identify and guide the long term implementation of measures to eliminate groundwater overdraft in the Valley. Since completion of the 2002 Water Management Plan, much has been accomplished by Valley water agencies and agricultural, municipal/residential, and golf course water users to reduce overdraft. Water conservation efforts have expanded, out-of-basin water supplies have increased, surface water and recycled water use is being used in lieu of groundwater, and new groundwater recharge facilities are online and an additional facility is being developed.

However, changing future demands and water supply uncertainties require additional actions to eliminate groundwater overdraft in the future, which are identified in the 2010 WMP Update. Continued implementation of the Water Management Plan will result in unavoidable costs for water users and water agencies alike. Each agency, including CVWD, will consider costs, available resources, funding mechanisms and priorities to eliminate overdraft in a timely manner. The success of the Plan to date indicates broad support for eliminating overdraft and the threats to the economy and quality of life in the Coachella Valley.

The CVWD Board of Directors certified the Supplemental Program EIR and adopted the 2010 WMP Update on January 24, 2012.

Appendix B – Evaporation Reduction Resources

Australian Government
National Water Commission

New technology to reduce evaporation from large water storages

Emma Prime, Andy Leung, Diana Tran, Harnam Gill, David Solomon, Greg Qiao, Ian Dagley

Waterlines Report Series No 80, June 2012

Waterlines

A SERIES OF WORKS COMMISSIONED BY THE NATIONAL WATER COMMISSION ON KEY WATER ISSUES

Waterlines

This paper is part of a series of works commissioned by the National Water Commission on key water issues. This work has been undertaken by the CRC for Polymers in collaboration with the National Program for Sustainable Irrigation on behalf of the National Water Commission.

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Australian Government
National Water Commission

Cooperative Research Centre for
POLYMERS

NATIONAL PROGRAM FOR
Sustainable Irrigation

Contents

Tables

Figures

Abbreviations and acronyms

C16OH	Cetyl alcohol (1-hexadecanol)
C18OH	Stearyl alcohol (1-octadecanol)
CRC	Cooperative Research Centre
CRC-IF	Cooperative Research Centre for Irrigation Futures
CRC-P	Cooperative Research Centre for Polymers
DPI	Department of Primary Industries
EX1	Evaporation suppressant 1
EX2	Evaporation suppressant 2
EX3	Evaporation suppressant 3
LOEC	Lowest observed effective concentration
NSW	New South Wales
OECD	Organisation for Economic Cooperation and Development
PVC	Polyvinyl chloride
Qld	Queensland
UniMelb	The University of Melbourne
USQ	The University of Southern Queensland
YAI	Yanco Agricultural Institute

Measurements

°C	Degrees Celsius
cm	Centimetre
$/ML	Cost (dollars) per megalitre
GL	Gigalitres
GL/year	Gigalitres per year
ha	Hectare
km	Kilometre
km/hr	Kilometres per hour

ML	Megalitre
MΩ.cm	Mega ohm-centimetre
m	Metre
m^2	Square metre
m/s	Metres per second
μL	Microlitre
mg	Milligram
mg/L	Milligram per litre
mg/mL	Milligram per millilitre
mm	Millimetre
mN/m	Milli-Newtons per metre
NTU	Nephelometric Turbidity Units
s	Second
wt%	Weight per cent

Executive summary

Evaporation from water storages is a major issue affecting agricultural regions of Australia. Annual losses potentially exceed 40 per cent of water stored. Loss of this water can lead to reduced agricultural productivity and can adversely affect the environment. Chemical ultra-thin films (monolayers) provide a method of reducing the amount of water lost, thereby increasing water security and agricultural production. Previously developed products have limitations and are not widely used. New technology recently developed in the Cooperative Research Centre for Polymers (CRC-P), however, has the potential to overcome these issues.

This report describes laboratory work carried out to evaluate and further optimise the chemical and physical formulation of the proposed new ultra-thin film product. Three chemical systems were evaluated—EX1, EX2 and EX3. These were formulated into three different physical forms; fully dissolved in organic solvent, a suspension in water, and a dry solid. The films resulting from these formulations were evaluated on their ability to control evaporation under dynamic conditions (wind), ability to maintain a surface film over time, and their spreading rate. Results from these tests demonstrated that the novel films were superior to previously researched films. Optimised products were identified to undergo field trials at various locations including Dookie (Victoria), Yanco (New South Wales) and St George (Queensland).

The summer of 2010–11 was unusually cool and wet for Australia. Rain events often interrupted field trials, making the study more challenging. Despite this, evaporation savings of 20–40 per cent were consistently observed throughout the small- and medium-scale field trials. The trials demonstrated that EX3 was the best performing chemical system, while the solid formulation showed the most promise. The suspension had numerous issues surrounding stability and ease of application, and the solvent system is impracticable for commercialisation due to health, safety and environmental issues. A patent application previously protected this chemical system (Solomon et al. 2010). Further work is needed to optimise the physical formulation. Production methods also need to be developed which can produce material for large-scale field trials, and potentially for eventual commercialisation.

A solid powder application system was identified and sourced for fieldwork. The best regime for applying the product was identified through a series of field trials. It required a large dose on the first day followed by smaller amounts applied daily to maintain the film's integrity and ability to suppress evaporation. The application system needs further testing using the optimised solid powder formulation.

Toxicity testing showed that the chemicals had no adverse effects on the key indicator species of daphnia, algae and rainbow fish, and ready biodegradability studies are currently underway. Toxicity consultants have compiled a draft toxicity report concluding that, based on published data and results obtained by further testing, no environmental concerns are expected for this product when used as an evaporation suppressant.

The next stage of this project is to complete large-scale field trials during the 2011–12 summer at St George, Queensland.

1. Introduction

Annual loss of water from storages through evaporation can potentially exceed 40 per cent of water stored (Craig et al. 2007). Nationally more than 7000 GL is stored in over two million on-farm storages, with a further 80 000 GL held in registered large dams (Craig 2008). Evaporation losses from irrigation channels can also be high, with some 70 GL/year lost from channels in northern Victoria (Winter & Albrecht 2011).

The loss of water causes lost agricultural production, leading to financial stress for some farmers particularly in times of drought, experienced frequently in Australia. Low water levels also lead to water restrictions being imposed on urban regions. Reducing the amount of water lost to evaporation would improve water security for Australia and lead to increased irrigation production.

Substantial research and commercial testing on practical methods to reduce evaporation was completed recently. This indicated that current products (shadecloth, floating and modular covers) are generally prohibitively expensive (typically $50 000 to $100 000 per ha) for large storages (>10 ha) and irrigation channels (Craig et al. 2005, Yao et al. 2009). This is a particular issue in Queensland for example, as around 80 per cent of water is held in large storages (Craig 2005). For such large storages and irrigation channels the only potentially cost-effective evaporation control option is to use chemical ultra-thin films (~2 millionths of a millimetre thick).

Previous materials have been investigated in field trials (McJannet et al. 2008). However, the performance of these chemical ultra-thin film products was compromised by wind, water quality and volatilisation of the monolayer, so water savings were low.

Research by the CRC-P has developed a novel ultra-thin film technology capable of increasing the viability of monolayers by overcoming the recognised limitations (Solomon et al. 2010, Prime et al. 2012). To be deployed, these chemicals need to be formed into a physical product, and to undergo extensive performance testing in the laboratory, and in small- and large-scale field trials.

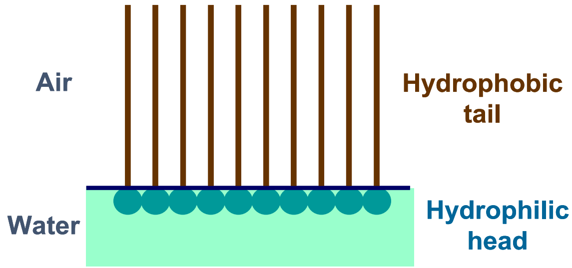
The aim of this project was to run a range of field trials to assess the effectiveness of this novel technology and to determine whether it is an improvement over previous technologies. If the technology is successful, the water savings from large on-farm storages alone could be more than 300 GL/year, with further savings expected from irrigation channels and other water storages.

2. Literature review

2.1 Monolayers

Ultra-thin surface films (often called monolayers) are typically one molecule thick and sit at the water surface as shown in Figure 1.

Figure 1: Schematic diagram of a monolayer on the water surface.



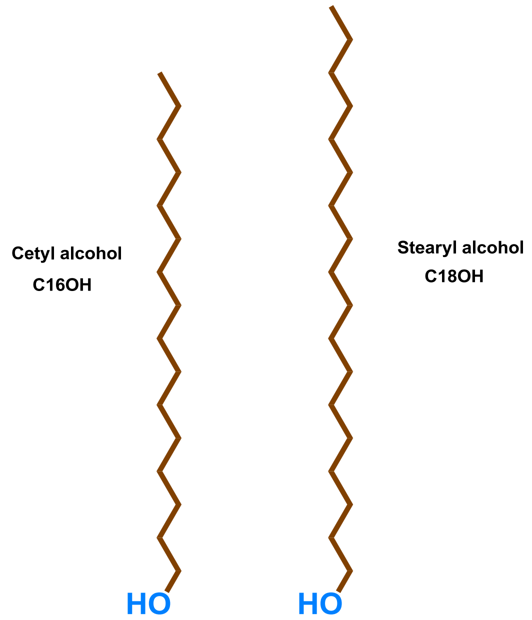
Compounds used as monolayers generally contain a hydrophilic (water-loving) head anchor into the water and a hydrophobic (water-hating) tail that packs tightly at the air/water interface. Monolayers have been used in many fields including membranes for molecular separations (Hendel et al. 1997), biomedical systems for tissue engineering and drug delivery (Vendra et al. 2007), packaging and coating materials (Lonescu et al. 2009) and water evaporation mitigation (Barnes 2008).

2.1.1 Water evaporation mitigation

Rideal first discovered that monolayers could be used to reduce water evaporation (Rideal 1925). Subsequently, Langmuir and Schaefer made the first quantitative measurements of the evaporation resistance of monolayers and demonstrated an Arrhenius-type temperature dependence of the evaporation resistance to permeation by evaporating water molecules (Langmuir & Schaefer 1943). Since these discoveries, considerable attention has been directed towards effectively suppressing water evaporation, especially from large, open water bodies (Barnes 1993, Machida et al. 2003, Gugliotti et al. 2005).

Naturally occurring fatty alcohols, cetyl alcohol (1-hexadecanol) and stearyl alcohol (1-octadecanol), have been the most commonly investigated compounds for use as evaporation suppressants (Barnes 2008, Dressler 1973, Reiser 1969). The structure of these molecules is shown in Figure 2.

Figure 2: Structure of commonly used monolayer compounds: cetyl alcohol (1-hexadecanol, C16OH) and stearyl alcohol (1-octadecanol, C18OH).



The hydroxyl group (blue in Figure 2) is the water-loving head group that sits in the water, while the hydrocarbon chain (brown in Figure 2) is the water-hating tail that packs tightly in the air, restricting the transfer of water.

To be useful evaporation suppressants, surface films need to have a high equilibrium surface pressure (an indication of how tightly packed the molecules can be without an external force), as well as the ability to reduce evaporation at this pressure (Barnes 2008). Both 1-Hexadecanol and 1-octadecanol have been shown to have these properties, saving up to 50 per cent of water lost under suitable conditions in the laboratory (La Mer & Healy 1965). Despite meeting these requirements, these molecules have generally not been considered to be sufficiently effective as water evaporation suppressants in practical situations, and have not been widely adopted. This is thought to be due to their rapid loss from the water surface, and lack of stability to wind and wave action. It is also due to the difficulty in reliably obtaining in the field the suppression performance observed under laboratory conditions—described further in Section 2.4 (Barnes 2008).

In his review of the current state of the technology, Barnes concluded that for monolayers to become viable, superior monolayer-forming materials would be needed. It would also be helpful to have better methods of deployment (2008).

2.2 Laboratory testing

For many years, important studies have been carried out in the laboratory to identify and quantify the desired chemical properties and to understand the mechanism by which monolayers reduce water evaporation (Deo et al. 1964, Barnes & La Mer 1962, Barnes 1997, Kaganer et al. 1999, Kulkarni & Katti 1982, Miller & Bavly-Luz 1962). Laboratory studies also help in selecting and developing new materials capable of reducing evaporation by providing an initial test of their effectiveness. The most commonly used apparatus for obtaining information about the properties of monolayers is the Langmuir trough, shown in Figure 3.

Figure 3: Langmuir trough—apparatus commonly used for investigating monolayer properties. (Photograph: E. Prime)

The trough is equipped with a moveable barrier, which can be used to compress and relax the surface film. A surface pressure sensor (Wilhelmy plate) at one end is used to measure the surface pressure of the water and therefore the presence and compaction of the monolayer. Information obtained from a Langmuir trough includes:

- isotherms of the surface pressure as a function of area per molecule. These provide information on the packing characteristics of the molecular film
- equilibrium surface pressure—the surface pressure at which the molecules are in equilibrium and are usually packed closely together. This is the maximum surface pressure a monolayer will achieve when used on a water body
- static evaporation suppression data (i.e. without wind effects) using the Langmuir-Schaefer method (1943)
- spreading rate on a small scale (Herzig et al. 2011).

For most experiments using the Langmuir trough, a monolayer is typically examined as a single, ideal layer. In other words, the material applied is less than is needed to completely cover the surface. The barrier is then used to compress the film to the desired surface pressure for the experiment. However, when monolayer products are used in the field, more needs to be applied to cover the surface with one ideal monolayer. This enables the film to replenish and repair if it is disrupted by wind, waves or other action, or material is lost into the atmosphere or subphase. In this report the amount of the evaporation suppressant applied to the water surface is referred to as 18x, 6x etc. This means that the amount applied is what is needed to cover the water surface with 18 (or 6) 'ideal' single monolayers. This information can be obtained from running isotherms on the Langmuir trough.

2.3 Commercial products

Two commercial products describing themselves as monolayers, or ultra-thin films to reduce water evaporation, have been released on the Australian market in recent years.

2.3.1 WaterSavr®

WaterSavr® is a solid powder, based on cetyl and stearyl alcohol mixed with a hydrated lime dispersant. Flexible Solutions International Inc market the monolayer product. Several trials have been carried out on WaterSavr®, with variable results (Morrison et al. 2008, Flexible Solutions 2006).

2.3.2 Aquatain®

Aquatain® is a silicone-based liquid which forms a film on the water surface. The film formed is not a monolayer—at 200 nm it is about 100 times thicker, based on the recommended application rates. Aquatain® is marketed by Aquatain Products Pty Ltd. Variable results have also been obtained in trials on Aquatain® (Morrison et al. 2008).

2.4 Field trials

Numerous field trials on monolayers to reduce water evaporation have been carried out over the past 60 years, good summaries of which can be found in McJannet et al. (2008) and Barnes (2008). Trials have used water bodies ranging in size from small ponds (78 m^2, Craig et al. 2005) up to large storages (970 ha, Bureau of Reclamation 1962). Most trials have used either cetyl or stearyl alcohol, predominately as a solid, and have found water savings ranging from 8 per cent up to 43 per cent.

A film that is considered stable on the Langmuir trough in the laboratory may not be stable on the surface of a water reservoir. A common problem in the field is the lack of film stability against wind and wave action. This can profoundly accelerate the loss of monolayer material as well as disrupt surface coverage (Barnes 2008). Previous research has stated that exposure to wind of a velocity greater than 10 km/hr (2.7 m/s) destroys the monolayer structure of cetyl and stearyl alcohol, thereby markedly reducing its ability to control water evaporation (Drummond et al. 1992, Grundy 1962). Wave action has also been found to influence the performance of monolayer films (Healy & La Mer 1964).

The development of new products with increased resistance to wind stress is critical if monolayers are to become viable.

2.5 Environmental implications

Before this technology is introduced widely, the environmental implication of using monolayers needs to be considered and addressed. Factors include impact on humans and animals (including aquatic, land and birds), the biodegradability of the material including toxicity of any degradation products, and any other effects on the aquatic environment. Fisk et al. provide a good summary of the physicochemical, biodegradation and acute aquatic ecotoxicity properties of long chain fatty alcohols including cetyl and stearyl alcohol (2009).

Cetyl and stearyl alcohol and their fatty alcohol ethoxylate derivatives, are extensively used as emollients, thickeners or stabilisers in the cosmetic industry. They are also used as lubricants and resins and therefore have United States Food and Drug Administration approval for use in the food, medicinal and cosmetic industries, indicating none to low toxicity to humans.

Less study has been done on the aquatic toxicity of these compounds, with the lack of water solubility cited as a difficulty encountered during this testing (Fisk et al. 2009). Nonetheless, the available data indicates low toxicity is expected (Fisk et al. 2009), although further testing should be carried out on the exact materials to be used as monolayer products.

Fatty alcohols and their derivatives such as fatty alcohol ethoxylates, biodegrade rapidly via both aerobic and anaerobic processes. Steber and Wierich (1985) proposed biodegradation pathways for these compounds in the effluent of a sewage treatment plant. Other research has found their biodegradation half-life in activated sludge to be less than one minute (Federle & Itrich 2006), while in natural river water, half-lives of 1.3–1.5 days were observed

(Larson & Games 1981) demonstrating the susceptibility of these compounds to biodegradation. It is expected, therefore, that monolayer materials will biodegrade rapidly in the aquatic environment.

Monolayers have been found to have only a small effect on the temperature of the water body on which it has formed (Saylor et al. 2000, Jarvis 1962). Previous testing at the University of Melbourne has found that monolayers have a negligible effect on the transfer of oxygen into the water body (data not published). A method to measure the effect of a monolayer on UV penetration into the water body has been developed by Schouten et al. (2011a).

3. Experimental design and data analysis

3.1 Design

Designing an experiment carefully is critical to obtaining appropriate and useful data. Generally an experiment will be structured to answer a specific question, for example—how long does the film last on the water surface, how quickly does it spread, what effect does the reapplication rate and/or frequency have on performance? Ideally one variable should be investigated, while all others are held constant. In the laboratory this is relatively straightforward as a constant experimental environment is easy to maintain. For example, ultra-purified water can be used to reduce the number of variables in any given experiment. In the field, however, many uncontrolled variables are introduced, such as temperature, humidity, wind, rain, and water quality. This makes it difficult to compare results from different trials. In the field a single trial will ideally contain all the samples needed to draw conclusions, without having to rely on data from other trials (i.e. every trial will contain a control, with no surface film).

Three areas of research ran simultaneously throughout this project: development and optimisation of the chemical system and physical formulation, laboratory testing, and field trials. It was not easy to define an overall detailed experimental plan at the start. Rather it was developed as the project progressed using results and information obtained from completed experiments to determine the best path to follow for subsequent work. For example, the general aims for the field trials were defined at the beginning (as outlined in Section 6), however, for each specific trial the latest information from formulation development, laboratory and any previous field trials, was analysed with conclusions then used in detailed planning of the next trial.

3.2 Analysis

The person undertaking the trial carefully analysed data from all experiments. In most cases other members of the project team also analysed results and discussed them in project meetings. More detailed examples of data analysis, particularly for the field trials, are discussed in the relevant sections.

3.3 Reproducibility

To be confident of results it is best to replicate experiments. This provides information on experimental uncertainty and reproducibility. In the laboratory it is straightforward to replicate experiments with accurately controlled variables (e.g. temperature, humidity, water quality). In all the laboratory experiments described in Section 5 each test was run at least twice, preferably three times. The results in Section 5 show that good reproducibility was generally achievable in the laboratory.

It is more difficult to obtain high levels of reproducibility in field trials. It is not possible to run strict replicate field trials when conditions such as temperature and wind inevitably vary between trials run at different times. Consequently reliability of the results was ensured by carefully analysing the data, estimating the likely contribution of experimental uncertainty, comparing general trends across multiple trials, (particularly those performed in the same location), and often, comparing the same chemical system with a different physical formulation run in the same trial. Data analysis for the field trials is discussed in detail in Section 6.1, where it is explained that water saving percentages obtained from the field trials generally have an error of ± 5 percentage points.

Experimental reproducibility is discussed further throughout the report.

4. Formulation

4.1 Chemical system

The CRC for Polymers has developed a superior surface film system, which is the subject of a patent application (Solomon et al. 2010). This project examines three experimental novel evaporation suppressant systems based on this technology: EX1, EX2 and EX3.

4.2 Physical formulation

The chemical system needs to be processed into a physical form that can be applied to the water surface in a controlled, reproducible and commercially viable manner. Developing these physical formulations was an ongoing, iterative process that continued throughout the entire project, in parallel with laboratory and field trials. Results were analysed and findings continually fed back into the physical formulation development program.

The requirements for a developed physical formulation were:

- to allow the chemical system to maintain good evaporation control
- ease of applying it to the water surface, both by hand and by future automatic dispensing units
- the ability to disperse and spread across the water surface promptly
- the ability to meet any likely environmental, health and safety requirements for future end-users
- the potential to scale up and eventually commercialise a suitable product.

Three different classes of physical formulation were identified and a range of formulations developed in each class, namely:

- **Solvent**—when testing in the laboratory the preferred solvent system is one in which both components are fully dissolved. This allows the amount of material applied to the water surface to be precisely measured, especially for the smaller laboratory-scale experiments (where 1–2 mg of material is required, making it difficult to weigh the precise amount of a solid product). These solutions can contain between 0.1–10 wt% active components. However, using solvent for a commercial product is impracticable, given the potential health, safety and environmental issues.
- **Suspension**—suspensions were prepared using a high speed mixer to suspend the active components in water at a solids loading of 10 wt%. Various mixing speeds, time, and additives were investigated.
- **Solid powder**—the product has also been made into a fine solid powder by grinding. The solid may require additives to obtain a final product with the desired physical properties, therefore the products contained between 50–100 wt% of the active components.

5. Laboratory testing

5.1 Introduction

Most of the formulation work was conducted at the University of Melbourne—as was the first stage of testing for any new chemical or physical formulation. The most important test was for wind resistance. This measured the ability of the surface film to control evaporation when exposed to wind, a critical parameter if these films are to be commercially viable. Other tests to further evaluate the formulations could also be carried out in the laboratory to assess spreading rate, longevity of the film on the water surface (under controlled conditions) and static evaporation control.

Following evaluation in the university's laboratories, the most promising formulations were then tested at larger scales including field trials (as described in Section 6) or testing in the specially-developed wind and wave tank at Griffith University (Gold Coast) as described in Section 5.5.

5.2 Wind resistance—small scale

A significant failing of previous monolayers was lack of resistance to wind stress (Barnes 2008). A major focus of this research has been to improve this shortcoming. A novel laboratory test needed to be developed to measure the ability of a film to control evaporation when exposed to wind stress. This test became the cornerstone of the laboratory testing procedure, as it was used to screen a wide range of chemical systems while searching for the optimal one. It also proved invaluable in screening various physical formulations of the potential commercial product.

5.2.1 Method

A gravimetric method was used to measure evaporation reduction under exposure to wind by monitoring the change in weight of the water over time. The wind was generated by a centrifugal fan connected to a custom-made wind tunnel (60 cm long, 21 cm wide and 9 cm high at the mouth) as shown in Figure 4. The wind tunnel directed the wind over the surface of the water, with a wind speed of 25 km/hr (7.0 m/s, as measured by a hot wire anemometer placed at the mouth of the wind tunnel). The mouth of the tunnel was positioned at the end of a digital weighing balance. Two wind attack angles were investigated to determine if the direction of wind affected the performance of the surface film:

- parallel attack—where the wind is directed horizontally across the water surface.
- angular attack—where the wind hits the water surface at an angle of 25°.

A plastic rectangular container filled with ultra pure water (distilled, UV-treated and filtered water from a Milli-Q system; resistivity of 18.2 MΩ/cm) was placed on top of the balance. The digital balance was connected to a computer, which was set to log the mass of the container and water every minute. Three times the amount of material required to completely cover the water surface with a monolayer was applied and left for 30 minutes to allow for solvent to evaporate and the film to equilibrate before turning on the fan. The solvent formulation was applied with a microsyringe to gently distribute droplets of material at multiple locations across the water surface, while the fine powder solid was gently placed on the water surface in the centre of the container. The change in weight of the containers was then monitored over 12 hours. If the experiment was continued after this time the level of water in the containers dropped low enough to affect the results. A container of water with no monolayer was used as the control. All experiments were repeated three times. The entire experimental system was

LIGHT-PROOF ENCLOSURE

CAMERA

located in a controlled room set with ambient temperature 25°C and relative humidity 45–50 per cent.

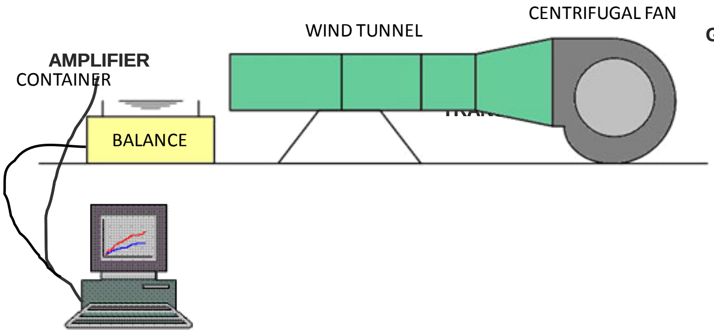
DIGITAL VOLTMETER

CELL

Figure 4: Schematic diagram of wind tunnel set-up for parallel attack.

FUNCTION GENERATOR

AMPLIFIER



POWER AMPLIFIER

5.2.2 Results

The parallel wind test was the first test carried out on all new chemical and physical formulations during extensive, iterative and ongoing product development. Information from these tests fed back into the product design loop to enable further improvement and optimisation of the chemical and physical formulation.

While the results obtained from the parallel wind test are too numerous to display, Figure 5 shows a typical result for the different chemical systems (EX1, EX2 and EX3) in solvent (1 mg/mL), along with the accompanying control (no monolayer), for a container initially holding 800 mL of water.

Figure 5: Mass of water lost over time for EX1, EX2 and EX3 (1 mg/mL solutions) compared to a control with no monolayer, under exposure to parallel wind at 25 km/hr.

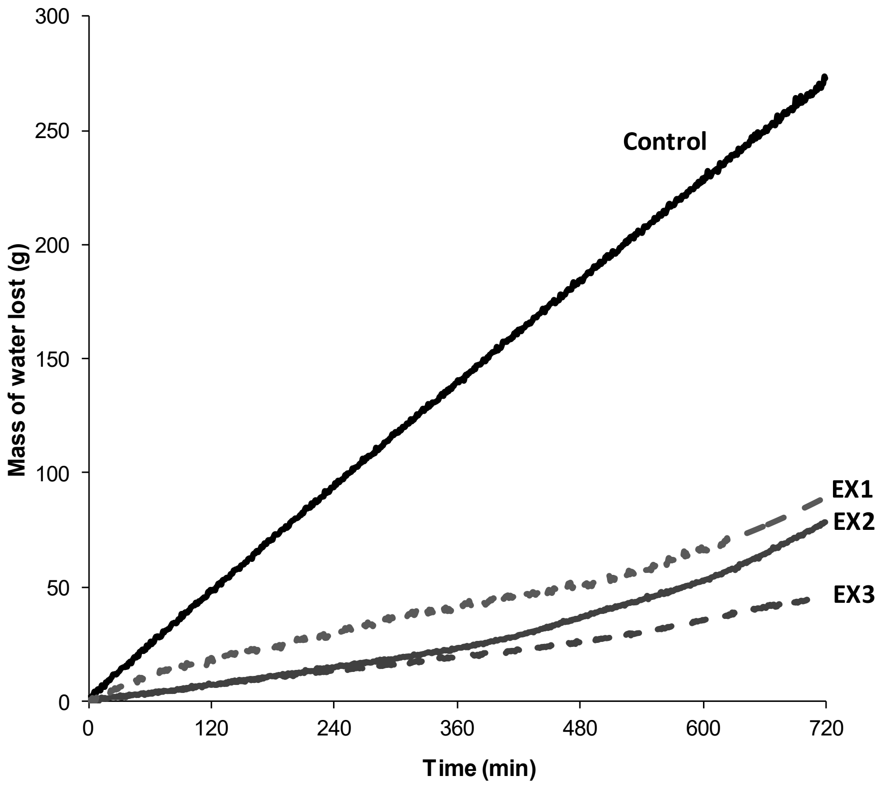
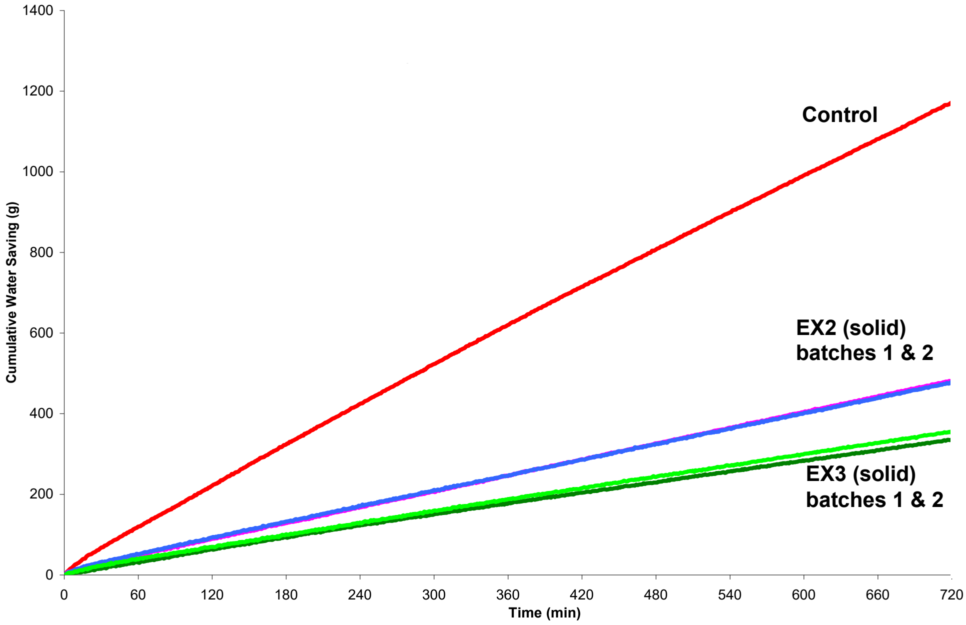


Figure 5 shows that all chemical systems suppress evaporation to some extent, as the mass of water lost is less than the control. The EX3 suppressant shows a greater ability to control evaporation under wind stress than EX1 or EX2 with 84 per cent of water saved (compared with 67% for EX1 and 72% for EX2). Repeated experiments produce very similar results with an error of ± 2 per cent.

In the open world environment the product will experience a limitless array of wind conditions so the angular wind test was introduced to provide information on the effect of the wind's angle of attack on performance. This test was also used as the main tool to assess initially the evaporation-suppressing performance of various physical formulations. Again, extensive testing was carried out in the angular wind system. Figure 6 shows a typical result for the solid formulations EX2 and EX3 for a container holding 2.6 L of water (EX1 was not tested in this experiment). In this case two batches of each formulation had been included to demonstrate repeatability of results for both the wind test experimental technique and the formulation method used to make these materials.

Figure 6: Mass of water lost over time for EX2 and EX3 solid formulations compared to a control with no monolayer, under exposure to angular wind at 25 km/hr.



The two different batches of EX2 performed equally well, demonstrating the reproducibility of both the wind testing and production methods for this solid formulation. Similarly the two batches of EX3 had reproducible results.

The angular wind test results showed the same trends as the parallel wind test, with EX3 performing better than EX2. In the two examples presented here, however, the actual savings were slightly lower in the angular wind test: 64 per cent for EX2 compared with 72 per cent, and 72 per cent for EX3 compared with 84 per cent. This is due partially to the difference in performance for the solvent and solid formulations. Typically solvent demonstrates the best performance, however, it is not a commercially viable formulation option due largely to environmental implications. A major aim of the formulation development work therefore, has been to improve the suspension and solid formulations so they perform at high levels, compared with the solvent system. It was also found that the evaporation suppressant systems showed greater savings in the parallel wind test than the angular system. This is believed to be due to the larger angle of wind attack in the angular system increasing the turbulence of the water and providing greater disturbance to the surface film, thus decreasing performance.

The wind test developed at the University of Melbourne to investigate the evaporation control performance of surface films when exposed to wind at either a parallel or angular attack angle has proved valuable as a first screen of new formulations. A formulation must have shown savings of at least 50 per cent in these tests to proceed to the next stage of testing: field trials, and/or the larger-scale wind and wave tank at Griffith University.

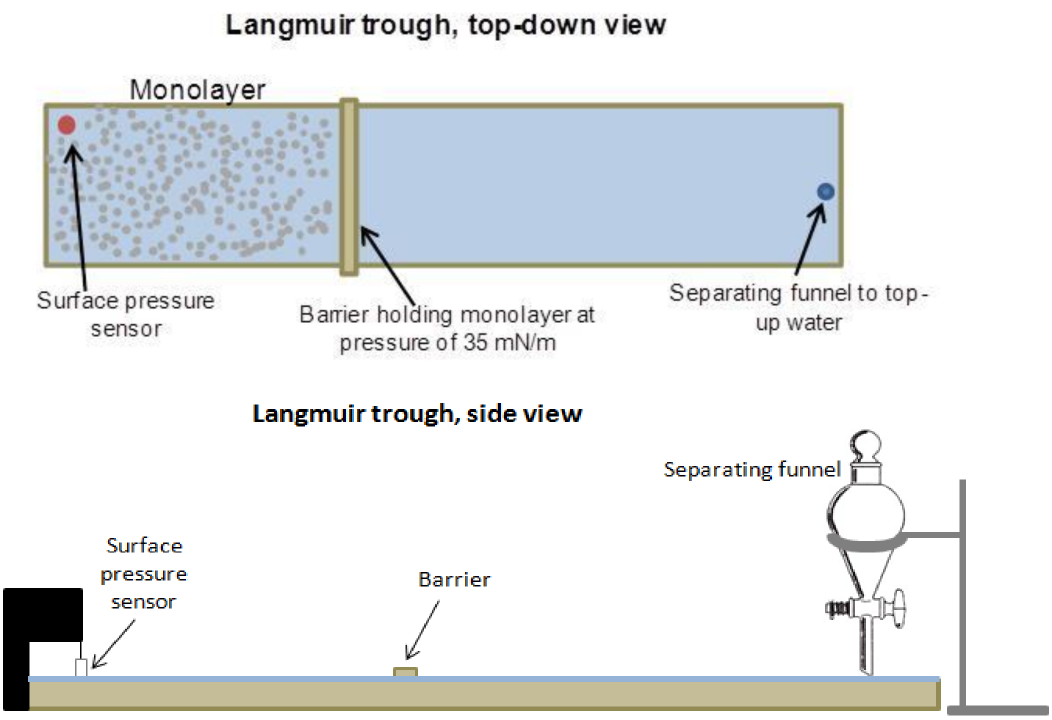
5.3 Longevity of film

If a film is to be commercially viable it needs to be able to remain on the water surface for an acceptably long time. An initial screening test can be carried out in the laboratory to determine the stability of a surface film under controlled, ideal conditions. If a film is not stable under these conditions it is not investigated further.

5.3.1 Method

A Teflon® Langmuir trough (76 cm x 10 cm) with a single barrier measured the longevity of the film on the water surface. The trough was filled with ultra pure Milli-Q water and allowed to equilibrate with the air at a temperature of 25 ± 1°C. A quantity of 50 µL of the monolayer forming material in solvent was applied to the water surface and left for 30 minutes to allow the solvent to evaporate. The barrier was then used to compress the monolayer to a surface pressure of 35 mN/m, after which the barrier was instructed to hold the monolayer constant at that pressure. As the monolayer material was lost from the water surface either by volatilisation into the atmosphere or dissolution into the water subphase, the barrier was forced to compress the monolayer to maintain this surface pressure. The change in surface area over time was recorded continuously for 24 hours. This was subsequently correlated to the rate of loss of monolayer material, and the results were presented as the percentage of monolayer material remaining on the water surface as a function of time. The water level in the trough was maintained by placing the tip of a separating funnel (held by a retort stand) filled with Milli-Q water, on the side of the barrier without monolayer. The change in height allowed water in the separating funnel to flow, thus maintaining the water level within ± 2 mm. A schematic of the test set-up is shown in Figure 7.

Figure 7: Langmuir trough set-up to measure longevity of the surface film, showing top-down and side views.



5.3.2 Results

The stability of the novel film technology was compared to the compounds most commonly investigated in previous studies 1-hexadecanol (cetyl alcohol, C16OH) and 1-octadecanol (stearyl alcohol, C18OH). All samples were in solvent at a concentration of 1 mg/mL. The results are shown in Figure 8.

Figure 8: The percentage of monolayer film remaining on the water surface as a function of time.

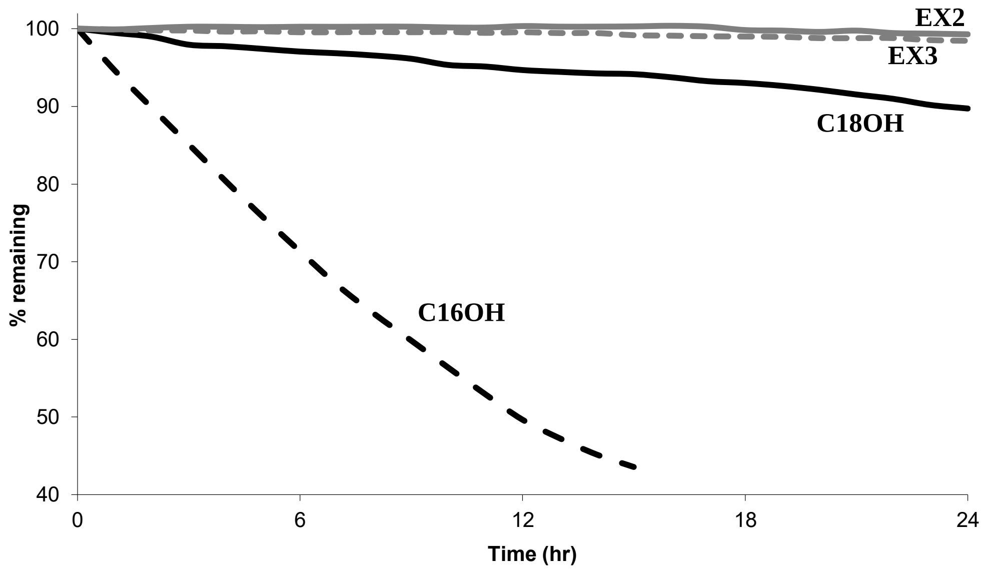


Figure 8 shows that EX2 and EX3 both have significantly improved longevity on the water surface when compared to cetyl alcohol (C16OH) and stearyl alcohol (C18OH). It is believed that if a film does not demonstrate sufficient stability under the controlled conditions used here (air and water temperature 25 ± 1°C, ultra pure water and no wind), then it has little chance of surviving for long in the field where conditions vary widely and are more extreme.

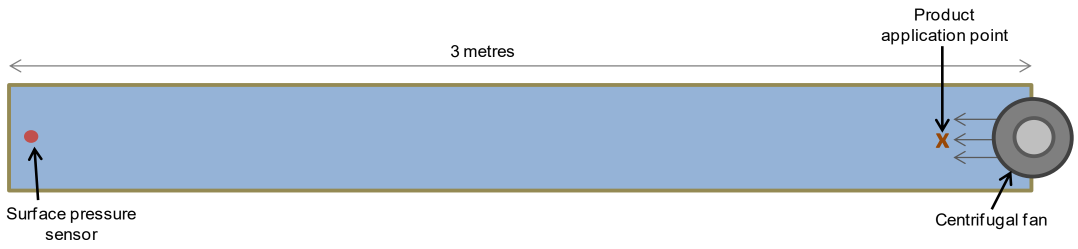
5.4 Spreading rate

For this technology to be successful it is crucial that the surface film formulation is able to spread across the water surface and self-assemble into an equilibrium close-packed film that is capable of controlling water evaporation. Ideally a product will reach this closely-packed equilibrium pressure quickly, both initially and also after disturbance by wind, birds, boats and other factors. Therefore a custom-designed system has been developed to test the spreading rate of various formulations as well as the ability to re-spread following disturbance.

5.4.1 Method

A 3 m length of PVC (polyvinyl chloride) tubing (30 cm diameter) was cut open and sealed at both ends. A surface pressure sensor (Wilhelmy plate) was installed at one end and a centrifugal fan was installed at the other. The tube was in a room where the temperature was controlled at 25 ± 1°C, and was filled with tap water. The surface film formulation was applied at the end of the tube closest to the fan and the surface pressure at the opposite end was recorded over time. Also recorded was the time taken for the film to reach equilibrium. Once the surface pressure had reached equilibrium the centrifugal fan was turned on for 30 minutes. The ability of the surface film to re-equilibrate was monitored. The fan was cycled on and off every 30 minutes for 24 hours. Each sample was repeated three times. A schematic of this set-up is shown in Figure 9.

Figure 9: Schematic diagram of the spreading rate test.



5.4.2 Results

The spreading rate of the various experimental formulations has been tested. Initially the formulations were applied as solid powders to measure the spreading rate of the actual material, without influence from solvent or other potential additives. The next stage will involve testing the developed physical formulations to ensure the formulation method and any additives do not compromise the spreading rate. The initial time taken for the surface film to equilibrate was recorded, before the film was disturbed and then re-equilibration time recorded. Replicated results obtained for two solid formulations of EX2 and EX3 are shown in Table 1.

Table 1: Results from the spreading test showing the equilibrium pressure reached, time taken to reach this pressure initially and to re-equilibrate after disturbance.

Product	*Equilibrium pressure (mN/m)*	*Time to initially reach equilibrium pressure (s)*	*Time to re-equilibrate after fan switched off (s)*
EX2 (solid) run 1	25	500	500
EX2 (solid) run 2	28	600	500
EX3 (solid) run 1	35	100	200
EX3 (solid) run 2	37	120	200

The solid formulations spread to reach their equilibrium pressure with EX3 demonstrating a superior spreading rate. It was also found that following disturbance from the fan, all experimental formulations were able to reform a film reaching equilibrium. This indicates they should be capable of self-repair following wind, boat, or animal disruption. The replicated samples had good reproducibility in the spreading test.

5.5 Wind/wave resistance—medium scale

As well as the laboratory tests conducted under controlled conditions at the University of Melbourne, field trials are also needed in outdoor environments to evaluate formulations under more realistic open conditions. It is a large step from the laboratory to field trials with many variables being introduced at once, including size of experiments, fluctuating ambient temperature, varied wind speed and direction, and impure water. Using a unique wind and wave tank facility (water surface ~6.9 m^2) housed in an atmospherically-controlled environment within the School of Engineering at Griffith University's Gold Coast Campus, and in a collaboration with the Urban Water Security Research Alliance, different formulations were evaluated to increase the size of the experiments without also introducing a wide range of uncontrolled variables. This work was done alongside developing formulations, laboratory testing and outdoor field trials so the experimental design was finalised for each trial immediately prior to testing.

5.5.1 Aims

The samples tested in the Griffith University wind and wave tank facility had two aims:

- quantify the performance of the three novel evaporation suppressants—EX1, EX2 and EX3, in reducing evaporation
- compare the evaporation suppressing capabilities of different formulation methods—solvent, suspension and solid.

5.5.2 Method

The team in the School of Engineering at Griffith University (Charles Lemckert, Peter Schouten and Sam Putland) had previously designed and constructed the wind and wave tank facility for other projects. A temperature-controlled enclosure (set to a constant temperature of 23°C) was built around a rigid wave basin (dimensions: 15 m x 0.46 m x 0.85 m) to maintain consistent temperatures and a stabilised humidity range throughout each experiment. Figure 10 shows the custom built set-up, which had been designed to test the effect of wind and wave action on the water surface.

Figure 10: The wind and wave tank set-up showing the external structure enclosing the tank and the blower situated above the water surface. (Photograph: P. Schouten).

Wind was delivered inside the tank via a blower and was straightened by a cylindrical honeycomb unit before coming into contact with the water surface. After applying the product, evaporation was measured over the experimental time interval by recording the change in water level using a pulse altimeter. Atmospheric parameters such as relative humidity, air temperature and water temperature were also monitored for each trial.

The tank was filled with potable tap water and all trials were carried out for 24 hours. These trials deduced the influence of wind upon the monolayers up to approximately 3 m/s (equivalent to 11 km/hr) incident at 0° to the horizontal water surface plane (parallel). The waves had amplitudes ranging from 0.2 to 0.5 cm and frequencies of up to 0.1 s.

The amount of material applied for all samples was enough to cover the entire water surface with 18 monolayers (designated 18x monolayers). The products were applied by hand at four evenly-spaced locations along the length of the water tank. The tank was emptied between each trial and rinsed to ensure any remnants were removed. It was then refilled with fresh water. Each sample was repeated twice. More specific details on the setup and operation of the wave tank can be found in Schouten et al. (2012) and Schouten et al. (2011b).

5.5.3 Results

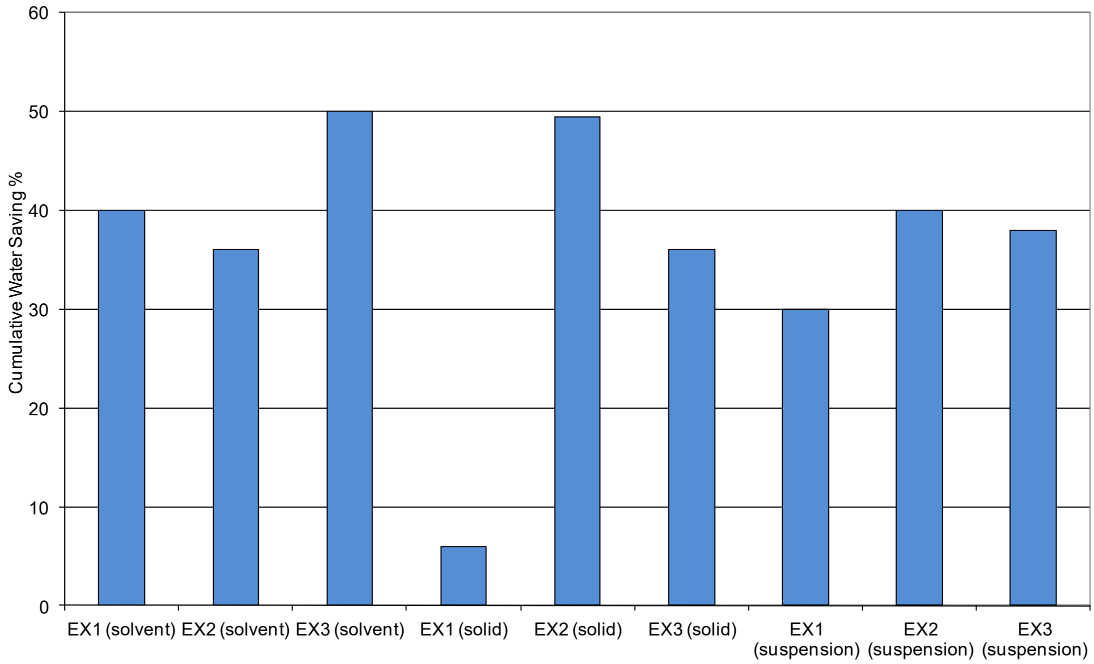
A wide range of samples was tested throughout the project. Table 2 presents a selection of results showing the performance of all combinations of chemical system and physical formulation.

Table 2: Details of samples tested in the wind and wave tank facility at Griffith University.

Experiment	*System*
1	Control
2	EX1 (solvent)
3	EX2 (solvent)
4	EX3 (solvent)
5	EX1 (solid)
6	EX2 (solid)
7	EX3 (solid)
8	EX1 (suspension)
9	EX2 (suspension)
10	EX3 (suspension)

The cumulative savings of different formulations compared to the control run (no monolayer) after 24 hours testing with parallel wind are shown in Figure 11.

Figure 11: Cumulative water saving of different formulations compared to the control (no monolayer) after exposure to 24 hours of parallel wind.



In general, the wind testing results demonstrate that the films save 30 to 50 per cent of water compared with the control run.

In most cases EX2 performed the same or better than EX1 across these tests. When considering the wind testing results for the solvent system, EX3 outperformed EX2. This agrees with laboratory results obtained at the University of Melbourne (Section 5.2.2). A comparison should not be made with the solid and suspension formulations, as the formulations used in this trial were in an early stage of development. Information gained from the performance of samples in this trial was fed into the design loop to improve subsequent solid and suspension formulations.

The solvent system gave the most consistent results throughout this trial. The solid and suspension samples performed inconsistently as already explained because these samples were at an early stage of development and were not yet fully optimised.

Overall, the wind and wave tank was able to show that the chemical system and physical formulation reduces evaporation on a larger scale than had been demonstrated in previous laboratory work (6.9 m^2 compared to 0.017 m^2). These results also show that scaling up the wind testing, under controlled conditions, provides additional information compared with what could be obtained in small-scale testing. For example, the EX1 (solid) formulation performed well in the small-scale testing but failed in the medium scale. This provides important information for feeding back into the iterative design loop.

6. Field trials

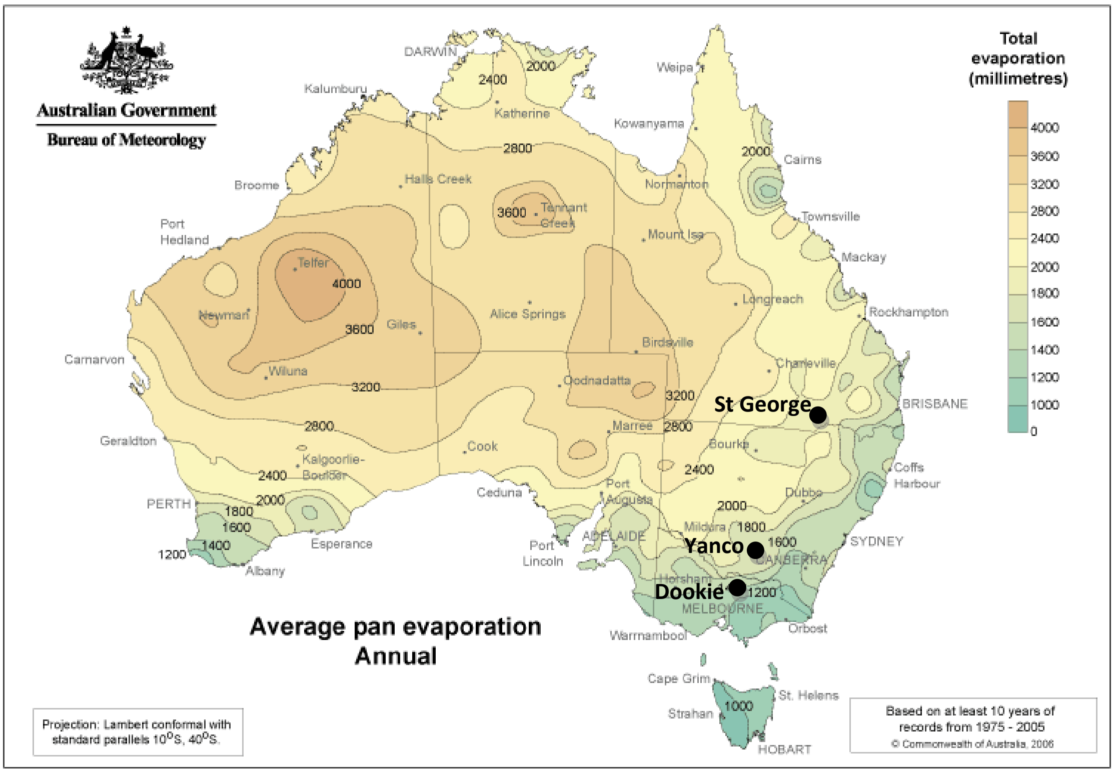
Various field trials in a range of locations tested effectiveness across a variety of Australian climatic and environmental conditions. The trials aimed to:

- determine whether CRC-P technology can be effective in reducing evaporation in an outdoor setting
- test the relative performance of different chemical systems in reducing evaporation to allow selection of the optimal formulation to take to commercialisation
- compare the performance of different physical formulations—solid, suspension and solvent. Information gained from each trial, including performance in reducing evaporation and any observations (e.g. spreading), can be fed back into the design loop to optimise the formulation
- investigate and optimise the application regime—application frequency and dose amount
- begin building a library of suppressant performance information over a range of environmental conditions and locations to assist future development, modelling and commercialisation.

While the general aims, outlined above, were clearly identified before the trials, the specific aims and plans for individual trials were developed immediately before starting work. This meant that the latest information from concurrent laboratory work and any previous field trials could be analysed with conclusions then being applied to the planning. This ensured that each trial was designed as well as possible to provide the desired information, leading to the selection of the most appropriate chemical system, physical formulation and application regime.

The availability of potential testing sites and appropriate personnel were considered when choosing field trial locations. The sites selected were Victoria (Dookie), southern NSW (Yanco) and South East Queensland (St George). The location of these is shown in Figure 12 along with average evaporation levels across Australia.

Figure 12: Location of field trial sites and average evaporation levels across Australia.

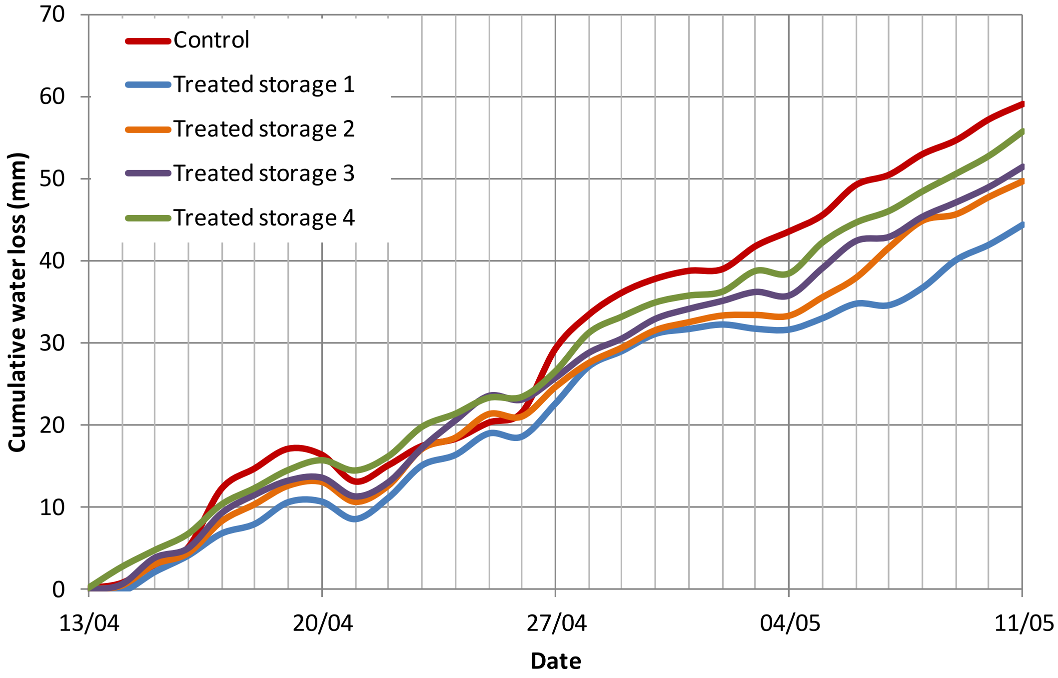


6.1 Data analysis

In the first two field trials at Dookie, Victoria, rulers were used to determine the change in water level over time. Due to the inaccuracy of taking readings only once a day by eye (as discussed in Section 6.2.1.2) all subsequent trials used automatic, data-logging water level sensors. Before being analysed, data was processed to remove interferences from rainfall. Stronger, less stable weather conditions occurred during the day generating higher amplitude waves, so the night-time water level values (21:00 to 3:00) were averaged to obtain meaningful results.

To illustrate this, the data for Trial 2 at Yanco (Section 6.3.1.2) is presented below. Figure 13 shows the cumulative water loss (mm) from all channel sections, after data processing described above.

Figure 13: Cumulative water loss (mm) from all channels in Trial 2 at Yanco.



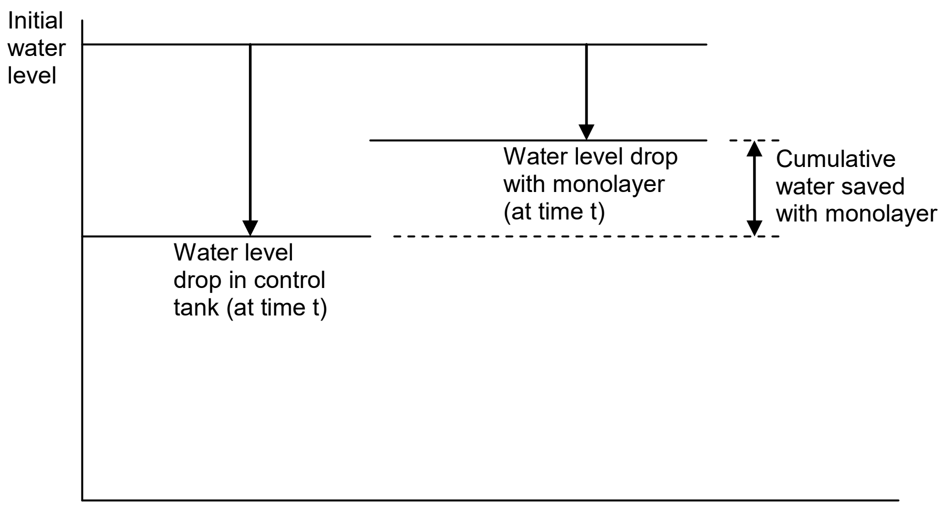
All treated channels lost less water than the control channel indicating all products worked to some extent. The next step in data analysis was to plot the cumulative water saving percentage compared to the control, which at any particular time *t*, should be:

$$\frac{\left[(Loss)_{Control} - (Loss)_{Monolayer}\right]}{(Loss)_{Control}} \times 100$$

Where: $(Loss)_{Control}$ = total water loss of control up to time *t*
$(Loss)_{Monolayer}$ = total water loss with monolayer up to time *t*

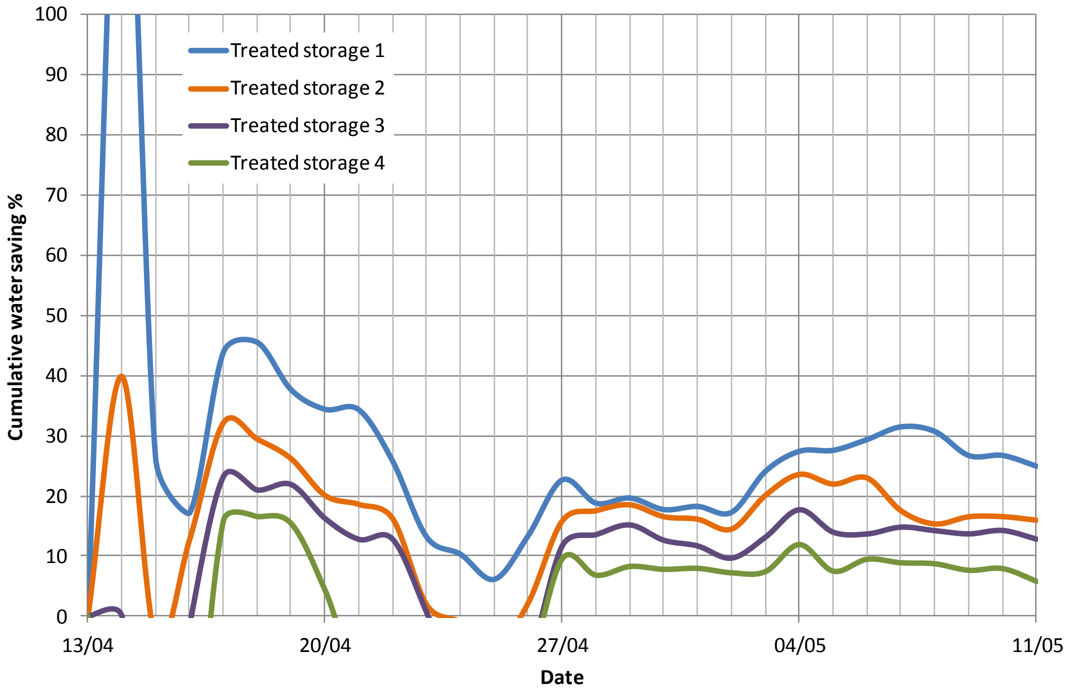
This can also be explained diagrammatically as in Figure 14.

Figure 14: Schematic showing how water savings were calculated for field trials using automatic water level sensors.



For Trial 2 at Yanco the cumulative water saving percentage is shown in Figure 15.

Figure 15: Cumulative water saving percentage of different formulations compared to the control channel.



The first four days of data shows significant fluctuations due to the small water level differences being measured and the inherent errors in the measurement system. However, over time the cumulative water saving percentage stabilizes and meaningful results can be obtained. For example treated storage 1 showed up to 30% savings, while other products showed 10-20% savings. With careful analysis of the data from the automatic water depth sensors and by excluding rain events, reliable data can be obtained from which cumulative water saving percentages can be concluded, generally with an error of ± 5 per cent.

6.2 Dookie, Victoria

The University of Melbourne has a campus at Dookie, 35 km east of Shepparton, where a field trial site was developed. This site was relatively close to the Melbourne-based research team, enabling members to visit and monitor regularly.

Six small troughs (3.7 m^2) and three larger evaporation ponds (135 m^2) were installed at this site and several trials were run.

6.2.1 Small troughs (2010)

The small troughs at Dookie provided the first scaled-up, outdoor testing site for the new surface film technology. The main aim of this site was to provide initial feedback on the performance of various formulations to allow optimisation before undertaking larger-scale field trials. Multiple troughs allowed for several samples to be tested and compared at one time, and under the same climatic conditions, while the small size of the troughs meant only small amounts of each formulation needed to be prepared for this initial field testing.

Six polyethylene troughs (water surface 3.7 m^2, diameter 2.1 m, height 0.6 m, volume 2000 L) were placed 5 m apart on a cleared patch of earth in April 2010, as shown in Figure 16.

Figure 16: Layout of the six troughs for the first series of small-scale field trials at Dookie. (Photograph: E. Prime)

For the first series of trials in these troughs two 30 cm plastic rulers were glued to the inside of opposite sides of each trough using Dunlop Tile-All Plus—a silane modified polymer adhesive recommended for swimming pools. This product was unlikely to leach into the water due to its single component, water insoluble polymeric system. The water level was then manually recorded from both rulers at 9 am each day of the trial. The two rulers in each trough helped improve accuracy, however, the error involved in measuring the water height using this method was estimated to be ± 1 mm per day from multiple readings taken from the same ruler over a short time. This was caused predominately by the wind making the water level fluctuate.

The troughs were filled with water to a depth of 0.5 m. In between trials more water was added so the troughs would overflow, removing any residual monolayer material.

Dookie campus has an on-site weather station from which rain and evaporation for the previous 24 hours is recorded manually at 9 am each workday. For the first series of trials this data, was used along with temperature and wind information from the Bureau of Meteorology.

6.2.1.1 Trial 1—different water sources (19–27 April 2010)

The first trial on the six troughs was designed to determine whether the novel surface film was effective on water from different sources. Laboratory testing to date had used ultra pure water, or tap water. To be widely effective in the field the product had to work sufficiently well on water from different sources and of differing qualities, potentially including static water (dam) and flowing water (irrigation channels). The trial tested water from three different sources: dam water, river water, and river water treated for domestic use within the Dookie campus. This treatment employed alum to settle suspended clay, flocculation and sedimentation, addition of chlorine, pH adjustment using soda ash solution (which also has the effect of reducing hardness) and passage through a sand filter. Samples of these waters were taken and analysed by EML (Chem) Pty Ltd, with results outlined in Table 3.

Table 3: Water sample analyses for water used in trough Trial 1.

Analyte	*Unit*	*Dam water*	*River water*	*Treated water*
Total dissolved solids	mg/L	110	220	280
Turbidity	NTU	6.0	36	9.6
pH		8.4	8.5	7.9
Total alkalinity as $CaCO_3$	mg/L	77	89	67
Total organic carbon	mg/L	9.8	6.0	4.1
Calcium as Ca	mg/L	12	22	16
Magnesium as Mg	mg/L	6.1	13	4.4
Total hardness as $CaCO_3$	mg/L	55	110	57

In general, the dam water was lower in total dissolved solids than the other water types, while the river water had significantly higher turbidity and was considerably harder.

Various application regimes were investigated throughout the field trials. The application regime refers to the amount of product applied (in terms of how many monolayers as described in Section 2.2) and the frequency with which it was applied. In this trial a large initial dose of the evaporation suppressant EX1 (suspension) was applied on day 0 with no subsequent reapplications. The aim was to determine how long a single dose of product maintained efficacy. The details for this trial are shown in Table 4.

Table 4: Trough Trial 1 set-up.

Trough	*System*		*Application regime*
1	River water	Control	-
2		EX1 (suspension)	18x monolayers (on day 0)
3	Treated river water	Control	-
4		EX1 (suspension)	18x monolayers (on day 0)
5	Dam water	Control	-
6		EX1 (suspension)	18x monolayers (on day 0)

The average maximum temperature was 27°C for the first four days of the trial, dropping to 18°C for the second four days. The total amount of water lost from the tanks at the end of this trial ranged between 8 and 14 mm. The effect of rain events on days 2, 5 and 8 (total of 12 mm rain) makes it difficult to interpret the results, however, the tanks with the product applied lost less water over the first two days of the trial than the control tanks, with savings of 30–60 per cent observed. After two days this effect was no longer observed. It is unclear whether this was due to the monolayer deteriorating after this time, or the rain event on day two making subsequent results hard to interpret. As a result, this trial was repeated.

6.2.1.2 Trial 2—different water sources (29 April–7 May 2010)

The second trial was a repeat of Trial 1 with the same set-up used as shown in Table 4. There were no significant rain events throughout the second trial and the maximum temperature was around 20°C over the duration of the trial.

The total amount of water lost from the tanks at the conclusion of this trial ranged between five and 20 mm. All tanks lost 1–2 mm of water daily, the accurate reading of which is likely to be within human error (as described in Section 6.2.1). Savings observed were around 60 per cent for the dam water, 30–40 per cent for treated water and 20–30 per cent for river water, however, given the error inherent in reading the water depth and the low levels of evaporation, these figures are unreliable.

These two trials demonstrated that, as expected, the EX1 suspension product performs similarly on water from different sources, including untreated river water, dam water and treated water. Savings were around 30–60 per cent, compared to the water lost in the control troughs. The product performed best over the first two to three days after being applied. Some inaccuracy is expected in the results due to the relatively low levels of evaporation observed for this time of the year, generally about 1–2 mm per day according to data obtained from the weather station at Dookie campus. As a result, no further trials were carried out in these small troughs until the following summer (2010–11). It was also concluded from these trials that taking a single daily water depth reading by eye from a ruler attached to the side of the troughs was not a sufficiently accurate way to obtain water loss data. The human error involved in this method was too large to provide reliable results. As a result a more sensitive method for measuring water loss was sourced and used in subsequent trials.

6.2.2 Small troughs (2011)

In 2011 the six water troughs (water surface 3.7 m^2) were transported to a new testing area at Dookie as shown in Figure 17 (shown alongside the new larger evaporation ponds described in Section 6.2.3).

Automatic water depth measuring devices (Odyssey's capacitance water level sensor probe with an interval accuracy ± 1 mm shrouded in a slotted PVC tube, recording at 10 minute intervals) were installed as shown in Figure 18. The PVC slotted shroud can shield the water around the probe from wind-induced wave action, making the system more accurate. Taking regular readings over the length of the trial also improved accuracy.

Figure 17: New layout of the six troughs for Trial 3 onwards (shown alongside the three large evaporation ponds). (Photograph: A. Leung)

Figure 18: Odyssey's capacitance water level sensor probe and the PVC shroud installed in the evaporation ponds and water troughs. (Photograph: A. Leung)

6.2.2.1 Trial 3—different physical formulations (8–15 February 2011)

The first trial using the automatic water level sensors took place in February with the set-up and application regime for the troughs outlined in Table 5. The aim of this trial was to test various physical formulations such as solids with/without additives (to improve the physical properties), and a suspension (10 wt%). Product was applied every three days as it was found in the first series of trials in the troughs that the performance started to deteriorate after that time. For these trials the troughs were filled with untreated water direct from the river system, and ran for seven days.

Table 5: Trough Trial 3 set-up.

Trough	*System*	*Application regime*
1	Control	-
2	EX3 (solid)	18x monolayers (every 3 days)
3	EX1 (solid) 1	18x monolayers (every 3 days)
4	EX1 (solid) 2	18x monolayers (every 3 days)
5	EX3 (suspension)	18x monolayers (every 3 days)

The weather was warm over this period with an average daily maximum of 27°C. However, significant rain events on days two and three (total 48 mm rain) disrupted the measurements and made it difficult to interpret the results. Analysing the data as described in Section 6.1, did show that the solid powders based on EX1 both saved considerably less water than the solid and suspension, based on EX3 (10–15% compared to 30–35%), indicating that EX3 is superior to EX1.

6.2.3 Large ponds

To further test the evaporation control system, field trials were carried out on larger bodies of water. Three evaporation ponds were set up using commercial above-ground oval swimming pools (18 x 7.5 m) and installed at Dookie as shown in Figure 17 above, and Figure 19 below. Each pond has a surface area of about 135 m^2 and a height of 1.32 m.

One pond was used as a control while the other two tested two formulations in identical conditions, making them directly comparable. It can be difficult to compare results across different trials given diverse climatic conditions during each trial period.

Figure 19: Large evaporation ponds installed at Dookie. Each pond has a surface area of 135 m^2. (Photograph: A. Leung)

The same automatic water depth measuring devices that were installed in the troughs were also put into the three ponds. A blank trial using these sensors was carried out initially to ensure all ponds lost water at the same rate, and that the sensors were accurate.

On the day before the trial started, the three evaporation ponds were filled with untreated river water to the same height (20 cm from the top, approximately 1.3 m deep). In between trials the ponds were cleaned by flooding with fresh river water, meaning any residual material on the surface would be drained out from the skimmer box overflow (positioned near the top of the pond). Product was applied to the upwind side of the ponds by hand.

6.2.3.1 Trial 1—different chemical systems (1–15 March 2011)

The first trial looked at the suspension formulation (10 wt% solid loading) with two different products tested. The application regime for this trial was deliberately designed to have a higher initial dose (18x) to clean the water surface and establish a good film. Subsequent applications were then at a lower rate (6x) to maintain the film coverage at a more economically viable cost. The trial was run for two weeks (14 days). The different treatments used in the evaporation ponds for Trial 1 are shown in Table 6.

Table 6: Evaporation ponds Trial 1 set-up.

Pond	*System*	*Application regime*	
		Initial	*Subsequent*
1	Control	-	-
2	EX3 (suspension)	18x monolayers	6x monolayers (every 3 days)
3	EX1 (suspension)	18x monolayers	6x monolayers (every 3 days)

The weather was warm throughout this trial with an average daily maximum of 26°C, and only two periods of rain towards the end of the trial (total 25 mm). Excluding the rain-affected days, the overall result showed that EX3 (suspension) formulation had water savings of 50–60 per cent (± 5% as described in Section 6.1), whereas EX1 (suspension) formulation showed negligible water saving. This correlates well with the results found in Trial 3 in the small troughs where formulations based on EX1 showed a much lower water saving level than formulations based on EX3. In both these trials EX3 (suspension) showed promising performance.

The trial also revealed that the regime of applying a large dose initially followed by reapplication at lower levels (6x) was enough to maintain a surface film capable of reducing evaporation.

6.2.3.2 Trial 2—different reapplication dose (8–22 April 2011)

Trial 2 looked at the effect of the different reapplication dose (6x) used in Trial 1 with good results, when using EX3 as a solid. The details for this trial are shown in Table 7.

Table 7: Evaporation ponds Trial 2 set-up.

Pond	*System*	*Application regime*	
		Initial	*Subsequent*
1	Control	-	-
2	EX3 (solid)	18x monolayers	6x monolayers (every 3 days)

The weather was significantly cooler during this trial with the average maximum temperature of only 19.5°C, meaning lower evaporation. A total of 35 mm of rain fell at the start of the trial.

The EX3 (solid) formulation was shown to have an evaporation mitigation effect of around 50 per cent water saving with the new application regime of an initial dose of 18x and subsequent doses of 6x every three days. This result is comparable to that obtained from the EX3 (suspension) formulation under the same application regime in Trial 1 (50–60%), although it is difficult to directly compare these results due to differences in climatic conditions across the two trials.

6.3 Yanco, New South Wales

Yanco Agricultural Institute (YAI) is part of the NSW Department of Primary Industries (DPI) and is located between Leeton and Narrandera in the Murrumbidgee Irrigation Area. The site has previously been used by the CRC for Irrigation Futures (CRC-IF) for trials on evaporation mitigation products and therefore the staff had established capability and experience in carrying out these tests. Lined sections of an old irrigation channel were used to test the products. This work was undertaken by Harnam Gill from the NSW DPI.

6.3.1 Water channels

Five sections of an old irrigation channel were created (water surface of ~220 m^2) and each lined with a single piece of polypropylene to eliminate seepage, as shown in Figure 20. The liner is held in place by the water in the pond, and secured at the edges above the water level using nails.

Figure 20: Lined sections of an old irrigation channel at Yanco Agricultural Institute. (Photograph: A. Leung)

Automatic water depth measuring devices (Odyssey's capacitance water level sensor probe logging every hour) were installed. A blank trial was run to ensure the accuracy of the sensors and the integrity of the linings to prevent seepage. From this blank trial all channels were shown to have consistent water losses indicating that seepage was not an issue. For all trials the channels were filled with untreated water from a nearby flowing irrigation channel. Between trials the channels were emptied, the liners scrubbed, and then refilled with fresh water from the nearby irrigation channel.

6.3.1.1 Trial 1—different chemical and physical formulations (8 February–30 March 2011)

This 50-day trial compared the solid and suspension formulations of EX1 and EX3. Details of the samples tested are shown in Table 8. The suspension was 10 wt% solid loading.

Table 8: Water channel Trial 1 set-up.

Channel	*System*	*Application regime*
1	EX3 (solid)	18x monolayers (every 3 days)
2	EX1 (solid)	18x monolayers (every 3 days)
3	EX3 (suspension)	18x monolayers (every 3 days)
4	EX1 (suspension)	18x monolayers (every 3 days)
5	Control	-

The average daily maximum during the trial period was 26°C, with many small rain events bringing over 66 mm of rain over the trial. Low evaporation savings were observed during this trial. The solid formulations saved 10 per cent while the suspensions showed negligible savings. These low savings, lower than those generally obtained in trials run at Dookie during similar time periods, could be due to a number of factors including: the numerous rain events which occurred throughout this trial, the larger scale of these water surfaces compared with Dookie, and other differences inherent between the two locations, such as weather, water quality and spatial configuration. The impact of these factors may be narrowed down following many further field trials at various locations, allowing a library of performance information and conditions to be built. However, it was found during this trial that solid formulations perform better than suspension formulations.

6.3.1.2 Trial 2—different reapplication doses (13 April–10 May 2011)

A second trial was run in April 2011 for 21 days to investigate the effect of various application regimes for the EX3 solid formulation. The initial dose of 18x monolayers was maintained while subsequent application amounts were reduced to 2, 3 or 6x monolayers every three days. A solvent formulation was also included for comparison because to-date this had been the best performing system and was therefore the benchmark. The details of samples and application regime used in Trial 2 are shown in Table 9.

Table 9: Water channel Trial 2 set-up.

Channel	*System*	*Application regime*	
		Initial	*Subsequent*
1	EX3 (solid)	18x monolayers	2x monolayers (every 3 days)
2	EX3 (solid)	18x monolayers	6x monolayers (every 3 days)
3	EX3 (solid)	18x monolayers	3x monolayers (every 3 days)
4	EX3 (solvent)	18x monolayers	3x monolayers (every 3 days)
5	Control		-

The average daily maximum temperature for this trial was 22°C with no significant rain falling throughout the exercise. The products all worked well with savings generally ranging from 10 to 35 per cent during the trial. All samples appeared to perform similarly, indicating that topping up with a small amount of fresh product after a large initial dose, was sufficient to maintain the performance of the surface film. Subsequent trials will now generally focus on using an application regime that involves smaller reapplication amounts.

6.3.1.3 Trial 3—different reapplication frequency (16–25 May 2011)

A third trial was run for seven days in May 2011. This trial focused on the solvent formulation and looked at increasing the frequency of reapplications as well as the effect of using EX2 compared with EX3. Following the discovery in Trial 2 that reapplying lower amounts of product was more effective than reapplying large doses, these application doses were used in this trial with applications reapplied daily instead of every three days. The details are shown in Table 10.

Table 10: Water channel Trial 3 set-up.

Channel	*System*	*Application regime*	
		Initial	*Subsequent*
1	EX3 (solid)	18x monolayers	3x monolayers (daily)
2	EX2 (solvent)	18x monolayers	2x monolayers (daily)
3	EX2 (solvent)	18x monolayers	3x monolayers (daily)
4	EX3 (solvent)	18x monolayers	3x monolayers (daily)
5	Control	-	-

The weather was cooler in late May with an average daily maximum of 17°C. A total of 25 mm of rain fell during this trial with 19 mm recorded on one day late in the process. Therefore no significant data could be obtained from this trial.

6.3.1.4 Trial 4—different application regimes (24 June–13 July 2011)

A fourth trial was conducted in the water channels in late June/July 2011. This trial used the same sample, EX3 (solvent), in three channels. Different application doses, both initial and subsequent, were tested to determine the most effective regime for obtaining high water evaporation savings. The solid powder was used in channel 1 as a comparison. The sample and application regime details for this trial are shown in Table 11.

Table 11: Water channel Trial 4 set-up.

Channel	*System*	*Application regime*	
		Initial	*Subsequent*
1	EX3 (solid)	18x monolayers	3x monolayers (daily)
2	EX3 (solvent)	18x monolayers	3x monolayers (daily)
3	EX3 (solvent)	1x monolayer	1x monolayer (daily)
4	EX3 (solvent)	2x monolayers	2x monolayers (daily)
5	Control	-	-

As this trial was carried out in the winter months, the cooler weather (average daily maximum of 14°C) meant low evaporation rates of 1 mm/day. Several small rain events brought a total of 10 mm.

The trial showed that if the product was applied at 1x monolayer initially and subsequently (channel 3), then the product did not work at all, with zero water savings. However the larger dosage regimes, 2x and 18x initially, work similarly to each other and to the solid formulation. The large rain interruptions made it difficult to draw quantitative conclusions from this work, so a large amount of data was excluded from analysis. The very low levels of evaporation during this period also magnified errors. Further trials to obtain the optimum application regime will take place once the weather has improved in late spring/summer 2011–12.

6.4 St George, Queensland

St George is located in southern Queensland, 500 km inland from Brisbane, and is a region with a strong agricultural base. Large-scale field trials will be undertaken at this site over the summer of 2011–12 using three dams of about 12 ha each.

6.4.1 Dams

The three dams have been selected based on a range of selection criteria:

- similar in size
- located close together to minimise location variations
- low likelihood of the farmer needing to use water from the dams over the summer period
- uniformity of dam shape and surrounding vegetation.

Photos of two of the three dams are shown as Figure 21.

Figure 21: Two of the three dams selected for large-scale field trials at St George, Queensland. (Photographs: A. Leung).

The University of Southern Queensland (USQ) team took background readings of evaporation and seepage from the three selected dams over the summer of 2010–11 using pressure sensitive transducers to monitor the water depth over time (Craig et al. 2007). Seepage was minimal compared with evaporation rates and the three dams all had similar seepage levels, making them ideal for evaporation studies.

Two types of depth sensors (pressure sensitive transducers (USQ) and capacitance) were installed (two of each) in each dam to provide data on the changing water depth. Also an automatic weather station was installed by USQ to provide data on environmental conditions throughout the trial.

Trials at St George will be undertaken using the approach to experimental design outlined in Section 3 and the beginning of Section 6. An overall general plan for the trials will be developed initially, however, for each specific trial the latest information from laboratory, small-scale field trials, any previous St George trials and modelling will be analysed and conclusions from these applied to the planning.

This will ensure that each trial is designed as well as possible to provide the desired information, with the most appropriate systems being chosen. This may or may not include the application regime, the chemical system and formulation used, the possible use of automatic applicators and the location of application points across the dams.

6.5 Field trial conclusions

Evaporation savings of 20–60 per cent have been observed from the field trials carried out at Dookie, Yanco, and Logan's dam using the novel evaporation suppression products. The error determined during data analysis was found to be five percentage points.

Further conclusions that can be drawn from the field trials are:

- Two small-scale field trial options set up in two locations ran smoothly: six identical small troughs (3.7 m^2), three identical ponds (135 m^2) at Dookie, Victoria, and five lined channel sections (220 m^2) at Yanco, NSW. Several trials were carried out across these sites throughout the project, with results showing that evaporation savings of 20–60 per cent are obtainable.
- A large-scale field trial site was set-up. Three dams at St George, Qld (12 ha) were set-up with trials starting January 2012. A wet and cool summer in 2010–11 made interpreting field trial results difficult as rain events occurred in almost every trial. Also the cooler weather meant evaporation levels were lower than normal, so the savings obtained with the surface film product were hard to detect and measure.
- Formulations based on EX1 demonstrated moderate water savings in the smaller field trials. However, they were not as effective as formulations based on EX2 and EX3. Therefore EX2 and EX3 are the preferred products for future development.
- The method used to formulate the product affects the results, with the solvent and solid formulation generally showing superior results to the suspension. As the solvent system is unlikely to be commercially acceptable, work is focusing on the solid formulation for future development.
- The application regime used had a large effect on the results. The preferred regime was found to be a larger initial dose (18x monolayers) followed by a daily reapplication of a smaller amount (2–3x) which would maintain surface coverage and supress evaporation.

From the extensive field trial work carried out, the formulation that will be the focus of further development as the most likely commercial product is EX3 (solid). However, further field work is needed to fully understand the peformance of the system and to optimise the formulation.

7. Product deployment

An applicator is needed to provide a cost-effective way to distribute the surface film material over the water surface. The type of applicator will depend on the formulation used, whether solid powder or liquid suspension. Initial work has investigated a range of options. An application system also needs to have applicators located at optimal positions and programmed to give the best coverage of the water surface. Initially modelling the system is the best way to understand the best dispensing protocol.

7.1 Solid applicator

A commercially available dispensing system, designed by a local Melbourne engineer for applying WaterSavr® (a solid powder monolayer system described in Section 2.1) onto the water surface, has been identified and purchased, and is shown in Figure 22. The applicator is capable of being programmed to dispense specific amounts of material at certain times. It is solar powered with a back-up battery supply. The system will be trialed with the EX3 solid powder formulation in the summer of 2011–12.

Figure 22: Solid application system identified and purchased. (Photograph: Osprey Pty Ltd).

7.2 Liquid applicator

In the case of a suspension product, a different type of dispensing system would be required. The CRC for Irrigation Futures (CRC-IF) and the National Centre for Engineering in Agriculture (at USQ) have developed a smart application system to use with liquid evaporation suppressant products. The dispensing units have been developed to allow dosage at a prescribed rate and frequency, and the system is designed for autonomous operation. Atmospheric sensors and a coordinator unit can be used to analyse and implement appropriate dispensing decisions (Brink et al. 2009 & 2011).

Once the final physical formulation is optimised, work will progress to extensive testing and optimising the appropriate delivery system.

7.3 Modelling

Modelling the application of product to the water surface can be used to develop the best strategy for applying it including identifying where the applicator should be located and protocols for dispensing the product. The National Centre for Engineering in Agriculture, USQ conducted a modelling study to look at these issues.

The objective of the study was to estimate (at a first approximation) the optimal number and arrangement of applicators, plus the application rate and duration required to most ensure a high degree of surface coverage of the monolayer surface on three square storages (50 m x 50 m; 500 m x 500 m; and 5 km x 5 km) which was also cost effective.

The modelling considered data on historical wind speed and direction frequency intervals for two sites, a low wind site (Mungindi, NSW) and a high wind site (Scoresby, Victoria). The outputs were: coverage achieved, application rate, time to reach a steady state, and coverage maps. An example result for a 5 km x 5 km storage at Mungindi showed that if 121 applicators were used (arranged in a 11x11 grid with 500 m between) and product was applied at a certain rate over six hours then 40 per cent of the surface could be covered for 40 per cent of the time. If 441 applicators are used (in a 21x21 grid with 250 m between) with the same application rate and time then 97 per cent of the surface could be covered 90 per cent of the time. However, in the latter case approximately three times the amount of product was required compared with the 11x11 grid, increasing the cost of achieving this high level of coverage. The final application strategy will therefore be a trade-off between the cost and maintenance of extra applicators and product, and the value of extra water that could be saved.

As the final chemical and physical formulation of the evaporation suppressant is refined throughout the field trials and other testing, further information on its characteristics such as spreading rate will be determined and fed back into the developed application model. This will enable the model to be tweaked to provide more accurate information on the best application strategy for the selected product.

8. Environmental testing and approvals

Before these chemical films can be commercialised, appropriate environmental testing needs to be carried out to ensure they have no negative impacts. A testing regime has been developed to examine toxicity and ready biodegradability.

The contents of the evaporation control product currently under development are widely and commonly used in products including those involving human exposure, such as detergents and cosmetics. They are well-known products for which there is considerable publically available data. All components of the product are currently used within Australia and are listed on the Australian Inventory of Chemical Substances. The product does not fall under the definition of an Ag & Vet chemical, meaning it is not subject to regulation under the *Agricultural and Veterinary Chemicals Act 1994*. This product could also be used on potable water storages—the regulation of drinking water falls under state jurisdiction. Therefore relevant state departments will be kept informed of the project's progress.

8.1 Toxicity testing

A National Association of Testing Authorities (NATA) accredited independent laboratory has tested the toxicity of this product using internationally accepted methods. The tests have been conducted to evaluate the toxicity on three standard environmental indicator species: *Ceriodaphnia* (water flea), fish (rainbow fish) and algae.

If the product was applied to a water body that was 1 m deep, at a dose of 18x monolayers, the highest dose tested in field trials; then the concentration would be 0.45 mg/L. In toxicity testing, the lowest observed effective concentration (LOEC) is the concentration of material that induces a response in the species. For all three indicator species the LOEC was found to be considerably higher than the expected concentration in the water body, 0.45 mg/L. This indicates that the evaporation suppressant exhibits low toxicity and suggests that the product will be suitable for its intended use as an ultra-thin film used to suppress evaporation on water bodies.

8.2 Ready biodegradability

Ready biodegradability testing measures how long the substance takes to degrade under standard conditions. Substances are considered to be readily biodegradable if CO_2 production exceeds 60 per cent of the theoretical maximum within 28 days and if this level of CO_2 production is attained within ten days of degradation exceeding 10 per cent. The testing protocols used have been developed by the Organization for Economic Cooperation and Development (OECD) and are currently considered the world standard for ready biodegradation studies. The evaporation suppressant is currently undergoing ready biodegradability testing. However, previous studies on a similar monolayer-forming compound, 1-octadecanol, concluded that it was considered to have ready biodegradability with 67 per cent of the material disappearing after 28 days (UNEP 1995).

8.3 Environmental report

An independent toxicologist has prepared a draft dossier to review the literature, toxicity and ready biodegradability results and to evaluate the use of the evaporation control product in water intended for agricultural and potable use. The draft report concluded that the components within the product are rapidly biodegradable and exhibit low toxicity. A final report will be prepared once results from the ready biodegradability testing are received.

9. Economic analysis

Economic analysis is a useful tool as it can inform the end-user whether there is value in applying an evaporation suppressant. Product would be applied if the value of the water saved exceeded the cost of saving the water.

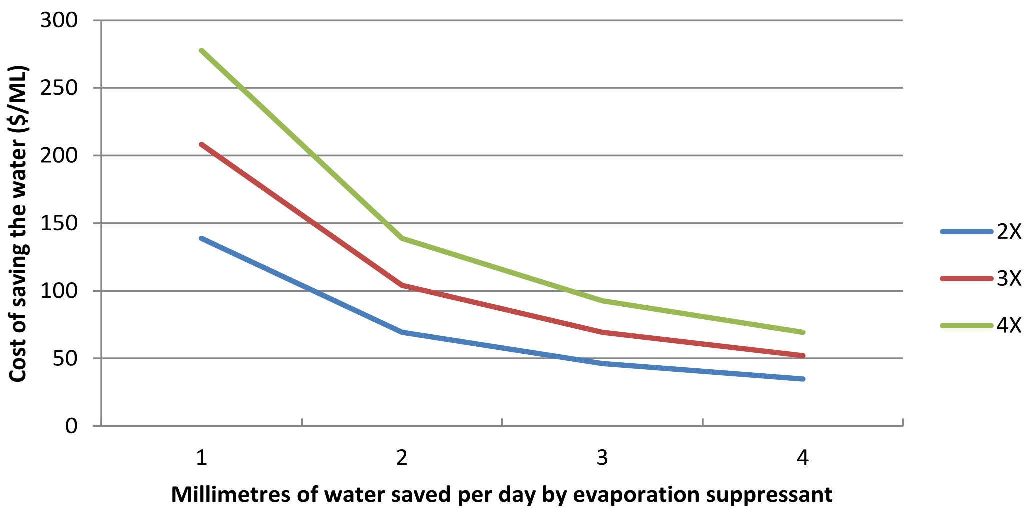
9.1 Cost of saving water

To determine the economic benefits the following assumptions have been made:

- after initial application, the product is reapplied once a day in the range of 2x to 4x monolayers (the application rates looking most promising in field trials to date)
- product pricing has been reasonably estimated based on current chemical manufacturing price information
- the cost of saving the water ($/ML) equals the cost of buying the suppressant product. Capital costs are not included in this analysis as they are difficult to estimate at this stage, however they are anticipated to be low and are dependent on how each individual end user chooses to manage the system.

A graph showing the cost of saving the water versus the millimetres of water saved from evaporation per day for different daily application rates is shown in Figure 23.

Figure 23: Plot of the cost of saving the water in $/ML versus the millimetres of evaporation suppressed for daily addition of three different levels of monolayers.



This analysis considers the cases of evaporation savings of 1, 2, 3 and 4 mm/day. For example if the evaporation suppressant is 50 per cent effective and is applied once a day when the evaporation rate is 6 mm/day then the water saved by the suppressant is 3 mm/day. If evaporation rates are lower, at 2 mm/day, then the water saved is 1 mm/day.

The analysis shows that the product provides benefits for savings of 1 mm/day for the following combinations of water saving costs and daily addition rates:

- $138/ML for 2x application

- $208/ML for 3x application
- $278/ML for 4x application.

For savings of 3 mm per day the corresponding combinations of water saving costs and daily addition rates are:

- $46/ML for 2x application
- $69/ML for 3x application
- $93/ML for 4x application.

Therefore if the end-user values the saved water at a level higher than this cost they may consider it beneficial to use the product.

9.2 Water market analysis

Australian water allocation trading prices can vary dramatically across seasons and locations depending on the weather, rainfall and other factors. Table 12 shows the average allocation trading prices for the southern connected Murray–Darling Basin, the main connected water market in Australia, over the past four seasons (National Water Commission 2008–11).

Table 12: Average water allocation trading prices for the southern connected Murray–Darling Basin over recent years.

Season	*Average trading price ($/ML)*
2007–08	650
2008–09	350
2009–10	150
2010–11	32

Combining the information from Figure 23 and Table 12 shows that in some years the average water trading price is well above the highest water saving costs. However, in other years the average water trading price is considerably lower. The end user therefore needs to take into account their position and the value of water to them before deciding whether to use the evaporation suppressant product at a particular time.

10. Commercialisation plan

Large-scale field trials will be carried out as described in Section 6.4 for St George. If successful results are obtained in these trials an extended series of large-scale field trials will be conducted in different locations around Australia. This will determine whether the technology works at a large scale, in various locations, and in a range of environmental conditions.

If necessary further development work will continue to optimise the physical formulation with laboratory studies being undertaken on any improved formulations. These would then continue through the small and medium field trials before progressing to the large-scale trials.

If satisfactory results are obtained in the planned large-scale field trials then an evaporation suppressant product will be made available to selected end users in 2012–13. These may be end users who have been involved in field trials of this, or previous monolayer products. They may also be end users who have a relationship with project partners and have demonstrated an interest in the evaporation suppressant product.

If continuing field trials demonstrate sufficient water savings, then a more rigorous economic analysis and detailed marketplace evaluation would be undertaken. A commercial product based on this research may then be developed.

11. Glossary

Monolayer	An extremely thin (one molecule) film formed at the air/water interface.
18x, 6x	Different application amounts, equivalent to 18 or 6 times the amount needed to completely cover the water surface with one monolayer.
Ready biodegradability	The degradability of a compound under standard conditions. Substances are considered to be readily biodegradable if CO_2 production exceeds 60 per cent of the theoretical maximum within 28 days and if this level of CO_2 production is attained within ten days of degradation exceeding 10 per cent.

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12.1 Further information

Several resources and case studies related to managing evaporation on farm water storages can be found on the National Program for Sustainable Irrigation website (www.npsi.gov.au — search for ‘evaporation’).

Evaluation of Evaporation Suppression Tests on Lake Arrowhead, Texas

Analysis Paper 15-1
January 27, 2015
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Surface Water Resources Division
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Key Points

- During the summer of 2014 Wichita Falls responded to declining reservoir levels by implementing several strategies to extend its water supplies, including attempts to reduce evaporation losses by application of an evaporation suppressant on Lake Arrowhead.
- During a span of ten weeks from July 23, 2014, through October 2, 2014, the city of Wichita Falls applied an evaporation suppressant on Lake Arrowhead.
- We analyzed both historical and recent reservoir and meteorological data to determine the effectiveness of the suppressant in reducing evaporation from Lake Arrowhead.
- Our analysis suggests that, with an 87 percent statistical level of confidence, the suppressant reduced evaporation.
- Our analysis also suggests that the suppressant was effective in reducing evaporation by about 15 percent, although statistically there is about a 74 percent probability that the reduction lies between 0 percent and 26 percent.
- Although the data suggests that the suppressant was effective, we are unable to state this with a higher level of confidence because of the small amount of useable data. The level of confidence could be improved if additional data were collected in the future.
- This study did not consider the influence of evaporation suppression on water supply nor the economic costs and benefits of evaporation suppression. These analyses are needed prior to fully considering evaporation suppression as a water supply strategy.

Introduction

As of early November 2014, water stored in three reservoirs that supply water to the city of Wichita Falls, Lake Arrowhead, Lake Kickapoo, and Lake Kemp, had fallen to 19 percent, 26 percent, and 26 percent of conservation capacity, respectively. Continued decline, and the potential complete loss of water in these reservoirs, threatens the city's water supply. In response to low reservoir levels and in an attempt to extend its water supplies, the city applied an evaporation suppressant on Lake Arrowhead for nearly ten weeks from July 23, 2014, to October 2, 2014. This analysis attempts to evaluate the effectiveness of the suppressant in reducing evaporative losses from Lake Arrowhead.

Evaporation Suppression with Monolayers

Certain chemicals when released on a water surface will spread spontaneously into a very thin film that can act to reduce evaporation. Commonly tested chemicals for reducing evaporation include long chain fatty alcohols and acids such as cetyl alcohol, stearyl alcohol, and palmitic acid (these are also known as octadecanol, hexadecanol, and hexadecanoic acid, respectively). Cetyl alcohol was first isolated from whale oil; stearyl alcohol is produced from stearic acid which is found in many animal and vegetable fats and oils; and palmitic acid is found in palm trees, meats, and dairy products. All take the form of a white solid or flakes at room temperature and are used in the cosmetic industry in shampoos, skin creams, and lotions.

Applications of Evaporation Suppressants and Their Effectiveness

Evaporation suppressants have been shown to be effective in the laboratory and at small scales such as on swimming pools, ponds, and small lakes. Commercial vendors claim reductions in evaporation from 35 percent (Flexible Solutions 2010) to 75 percent (PRWeb 2010) for small bodies of water such as these, although it is not clear under what conditions or time frames these reductions were achieved.

La Mer (1962) provides an excellent summary of monolayers and their use to suppress evaporation. This collection of papers presented at the American Chemical Society Annual Meeting in September 1960 describes technical issues associated with monolayers, laboratory tests of the technology, and several field tests conducted in the late 1950s. Field tests were conducted on larger bodies of water in Australia, Africa, and several states in the United States including Colorado, Arizona, Oklahoma, Illinois, and Texas. Researchers in some of these studies conducted tests to evaluate the spreading and coverage efficiencies of evaporation suppressants and in other studies attempted to evaluate the effectiveness of the suppressants in reducing evaporation. The reservoirs ranged in size from as small as 2.8 acres (Illinois Department of Conservation Fish Hatchery, central Illinois) to as large as 40,000 acres (Boulder Basin of Lake Mead). The studies reported a wide range of effectiveness in reducing evaporation, ranging from about 9 percent in Lake Hefner, Oklahoma, to up to 63 percent for a 50-acre reservoir near Eagle Pass, Texas. The Texas results were based on a short period of only 10 hours and were considered ideal and similar to results for controlled tests under favorable conditions for the suppressant used, octadecanol.

The above studies reported wind to be a common issue in reducing the effectiveness of suppressants for nearly all the field tests at larger scales. Wind can move the suppressant to one side of a reservoir, reducing the spatial coverage and overall effectiveness of the suppressant. Evaluating the effectiveness of suppressants in the field presents a second challenge due to the difficulty in obtaining accurate measurements of all the factors required to complete a water budget for a reservoir.

Approach to Evaluating the Effectiveness of the Evaporation Suppressant

We tried two approaches for evaluating the effectiveness of the evaporation suppressant on Lake Arrowhead. The first approach was to compute a water budget for Lake Arrowhead alone based on measurements or estimates of (1) precipitation on the reservoir, (2) evaporation, (3) inflows, (4) withdrawals, and (5) seepage. In principle this approach would allow one to differentiate evaporation rates that occur when the suppressant is applied from rates when it is not applied, and thus would allow one to evaluate the effectiveness of the suppressant. However, this approach was problematic primarily because the water budget did not balance well enough to detect the small changes in evaporation that were expected due to application of the suppressant. Changes in evaporation due to the suppressant were lost in the noise mainly due to uncertainty in estimates of rainfall and inflow when rainfall occurs and due to uncertainties in estimating lake evaporation. This approach to evaluating the effectiveness of evaporation suppressants would likely not work in the future without significant improvements in determining inflows, rainfall on the reservoir, and evaporation from the reservoir.

An alternate approach we used in this study considers Lake Kickapoo evaporation as a reference for comparison to Lake Arrowhead evaporation. Because of their proximity to each other (being only about 25 miles apart) and because they experience similar meteorology, we assumed that evaporation from both reservoirs would be similar. We were also able to reduce noise in the data significantly by considering only days when rainfall and inflows are small or zero and only when reservoir levels in both lakes are declining. We computed evaporation for both lakes based on lake levels and withdrawals and then computed the ratio of evaporation from Lake Arrowhead to that for Lake Kickapoo. Finally, we compared the evaporation ratios for the period prior to application of the suppressant and during the application of the suppressant by applying a Student's t-test. We provide additional details of this approach in Appendix A.

Background Conditions

During the testing period from July 23, 2014, to October 2, 2014, daily average elevations in Lake Arrowhead declined by 1.08 feet from 907.68 feet to 906.60 feet. During the same period storage declined from 51,040 acre-feet to 45,015 acre-feet while the surface area decreased from 5,753 acres to 5,373 acres. Lake Kickapoo elevations declined 1.48 feet from 1,031.40 feet to 1,029.92 feet during the testing period. Storage in Lake Kickapoo declined from 27,759 acre-feet to 23,787 acre-feet, and surface area fell from 2,796 acres to 2,562 acres.

Both lakes lie within Quadrangle 409 in Texas (TWDB 2014) and experience similar evaporation and precipitation rates. Historical average lake gross evaporation for this area of the state for July, August, September, and October declines from 8.73 inches in July to 4.97 inches in October (TWDB 2014). Evaporation for a given month is variable from year to year. For example, observed July evaporation ranges from 5.48 inches to 12.82 inches, and October evaporation ranges from 4.97 inches to 7.18 inches (Table 1). Precipitation in July, August, September, and October averages 2.07 inches, 2.20 inches, 3.24 inches, and 3.12 inches, respectively. Precipitation for a given month is also highly variable (Table 2) from year to year.

Table 1. Historical (1954 to 2013) gross lake evaporation for Quadrangle 409 in Texas, representing Lake Arrowhead and Lake Kickapoo.

Month	Average (inches)	Minimum (inches)	Maximum (inches)
July	8.73	5.48	12.82
August	8.15	5.09	13.35
September	6.11	3.16	9.10
October	4.97	2.20	7.18

Table 2. Historical (1954 to 2013) precipitation for Quadrangle 409 in Texas, representing Lake Arrowhead and Lake Kickapoo.

Month	Average (inches)	Minimum (inches)	Maximum (inches)
July	2.07	0.01	8.32
August	2.20	0.00	7.42
September	3.24	0.19	8.95
October	3.12	0.00	12.47

Application of Evaporation Suppressant to Lake Arrowhead

The City of Wichita Falls applied WaterSavr^{TM}, a commercially available evaporation suppressant, to Lake Arrowhead during these tests (references to brand names in this report does not imply endorsement by the Texas Water Development Board or staff). WaterSavr^{TM} is a patented mix of hydrated lime powder with food grade stearyl and cetyl alcohols (Flexible Solutions 2014). It spreads spontaneously on water to form a monomolecular layer to inhibit evaporation.

The suppressant was distributed by boat at various locations in the reservoir. The suppressant was applied from July 23, 2014, through October 2, 2014, typically by applying two days in a row and then skipping application for one or two days. Reapplication is needed because the suppressant biodegrades over the span of a few days and because on windy days it is blown to the edge of the reservoir, rendering it ineffective.

Results

Following the approach described above, we determined that changes in elevation due primarily to evaporation alone were similar in both lakes in earlier years when no suppressant was applied and that the suppressant was effective in altering the elevation changes of Lake Arrowhead relative to those of Lake Kickapoo. Results of the analysis suggest that, with an 87 percent statistical level of confidence, the suppressant was effective in reducing evaporation. Although we were not able to reach this conclusion at a higher level of confidence because of the small data set available, the data suggests that the evaporation suppression did reduce evaporation from Lake Arrowhead. Our analysis also suggests that the suppressant was effective in reducing evaporation by about 15 percent, although statistically there is about a 74 percent probability that the reduction lies between 0 percent and 26 percent.

This study was focused on estimating how much of an impact the suppressant had on evaporation from the reservoir. We did not do an analysis of the influence of evaporation suppression on water supply nor the economic costs and benefits of evaporation suppression. These analyses are needed, presumably on a case-by-case basis, prior to fully considering evaporation suppression as a water supply strategy.

Reducing Uncertainty in Results

Uncertainty in the results arises from the small amount of data that was available for the analysis. We deemed only 10 data points of historical data and 4 data points of recent data, during which the suppressant was applied, of sufficient quality to be used in our analysis. An increase in the number of data points collected while the suppressant was applied would help to increase confidence in the results. A repeat of the application of the suppressant in the future during the June to September time frame, as in the current study, would help provide additional data. As in the current analysis, lake levels for both lakes and daily diversion data would also be needed. Also, as in the current analysis, only periods during which inflows to the lakes and rainfall on the lakes were small or zero would be used in the analysis, so a repeat of the study during low-rainfall and low-flow conditions would be required.

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Appendix A

This analysis was based on a comparison of evaporation from Lake Arrowhead and Lake Kickapoo during two time periods. The first data set is composed of data collected in 2012 and 2013 prior to application of evaporation suppressant to Lake Arrowhead. This data set is the control group and will be referred to as the **Prior** data set in the remainder of this appendix. The second data set is composed of data collected in July to October 2014 at a time when evaporation suppressant was applied to Lake Arrowhead. This data set will be referred to as the **During** data set in the remainder of this appendix. The analysis attempts to identify changes in the ratio between evaporation from Lakes Arrowhead and Kickapoo prior to and during the application of the suppressant.

We used a mass balance to calculate evaporation from both lakes. To carry out those calculations, we estimated the volume of each lake for each day. Volumes were estimated using the average elevation for the lake for the particular day (as reported by U.S. Geological Survey Gage 07314800 Lake Arrowhead near Henrietta and U.S. Geological Survey Gage 07314000 Lake Kickapoo near Archer City) and interpolating the associated volume from the most recent elevation-area-capacity table. TWDB staff surveyed both lakes in 2013. We used the 2013 elevation-area-capacity tables for both lakes for all volume estimates, including 2012 data, in order to maintain consistent elevation-area-capacity relationships for all the data. We used the following mass balance formula to evaluate changes in volume from day i to day i+1 for each lake:

$$Volume_{i+1} = Volume_i + Inflow_i - Diversion_i + Precipitation_i - Evaporation_i - Seepage$$

We assumed seepage to be small and therefore ignored it. The City of Wichita Falls provided diversion data (either weekly or daily data). Precipitation can vary significantly across each lake and between lakes and is difficult to measure accurately. Therefore, we selected days when precipitation was zero or near zero in order to allow removal of this term. We looked at National Weather Service radar data for each date in order to identify days with zero or near zero precipitation within the watersheds of the two lakes.

Inflows to each lake are also difficult to estimate and may vary considerably from Lake Arrowhead to Lake Kickapoo. Only one tributary to Lake Arrowhead is gaged, U.S. Geological Survey Gage 07314500 Little Wichita River near Archer City. This gage has an upstream watershed area of 481 square miles, 59 percent of the total watershed area of Lake Arrowhead (822 square miles). There are no gages upstream of Lake Kickapoo, which has a contributing area of 275 square miles. Ungaged tributaries above Lake Kickapoo include Godwin, Brier, and Kickapoo creeks. Ungaged tributaries above Lake Arrowhead include Bluff, Deer, Onion, West Little Post Oak, and East Little Post Oak creeks.

Table A1. U.S. Geological Survey gages and characteristics.

Gage Number	Description	Type of Gage	Drainage Area[$mile^2$]	Period of Record
07314000	Lake Kickapoo near Archer City, TX	Lake Elevation	275	1946 to present
07314500	Little Wichita River near Archer City, TX	Stream	481	1932 to present
07314800	Lake Arrowhead near Henrietta, TX	Lake Elevation	822	1967 to present

To get around the difficulty of estimating inflow to the lakes, we calculated evaporation only for days when average daily inflow was below 5 cubic feet per second based on U.S. Geological Survey Gage 07314500. For these days, we assumed inflows (both gaged and ungagged) would be only a small percentage of diversions or evaporation and could therefore be ignored.

We made another check related to inflow and precipitation based on changes in lake elevations. We considered days when lake elevation did not decrease from the previous day to be days when inflows or precipitation had occurred and therefore eliminated such days from the calculations. Based on this parsing of the data, it was possible to consider Inflow, Precipitation, and Seepage to be zero or near zero. The mass balance equation for suitable dates becomes:

$$\text{Volume}_{i+1} = \text{Volume}_i - \text{Diversion}_i - \text{Evaporation}_i$$

Rearranging terms,

$$\text{Evaporation}_i = \text{Volume}_i - \text{Volume}_{i+1} - \text{Diversion}_i$$

In this equation, Evaporation has units of volume. We converted evaporation to units of depth by dividing by the area of the lake (interpolated from the most recent elevation-area-capacity table using the average of the elevations for the two days).

Step 1. Assemble Lake Arrowhead and Lake Kickapoo evaporation data prior to application of suppressant

The City of Wichita Falls provided diversion data for Lake Arrowhead and Lake Kickapoo for the time period June 2012 through July 2014 in weekly time steps. We divided weekly diversion data by seven in order to estimate daily diversions. However, based on daily data obtained in 2014, diversions throughout the week are not uniform. Therefore, we do not believe evaporation rates for individual days are accurate; however, estimates for the entire seven-day period should be accurate. We parsed the Lake Arrowhead and Lake Kickapoo data to find weekly periods within the months of June, July, August, or September when (1) elevations for both lakes were decreasing from day to day, (2) there was little to no precipitation in the upstream drainage areas of each lake, and (3) flow at U.S. Geological Survey gage 07314500 was less than 5 cubic feet per second (Figures A1 and A2; Appendix B includes sample calculations for evaporation). There are 10 available data points with suitable characteristics, 6 from 2012 and 4 from 2013 (Table A2).

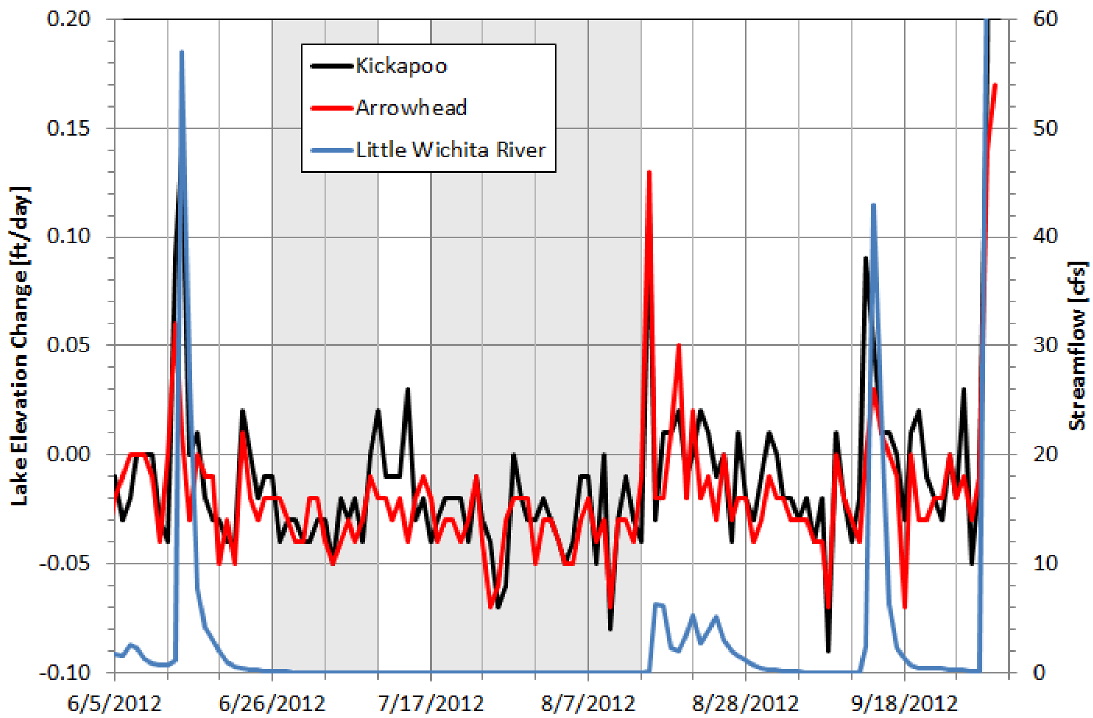

Figure A1. Daily change in lake elevation and streamflow of Little Wichita River June through September 2012. Suitable time periods for lake evaporation calculation are highlighted. (ft = feet; cfs = cubic feet per second)

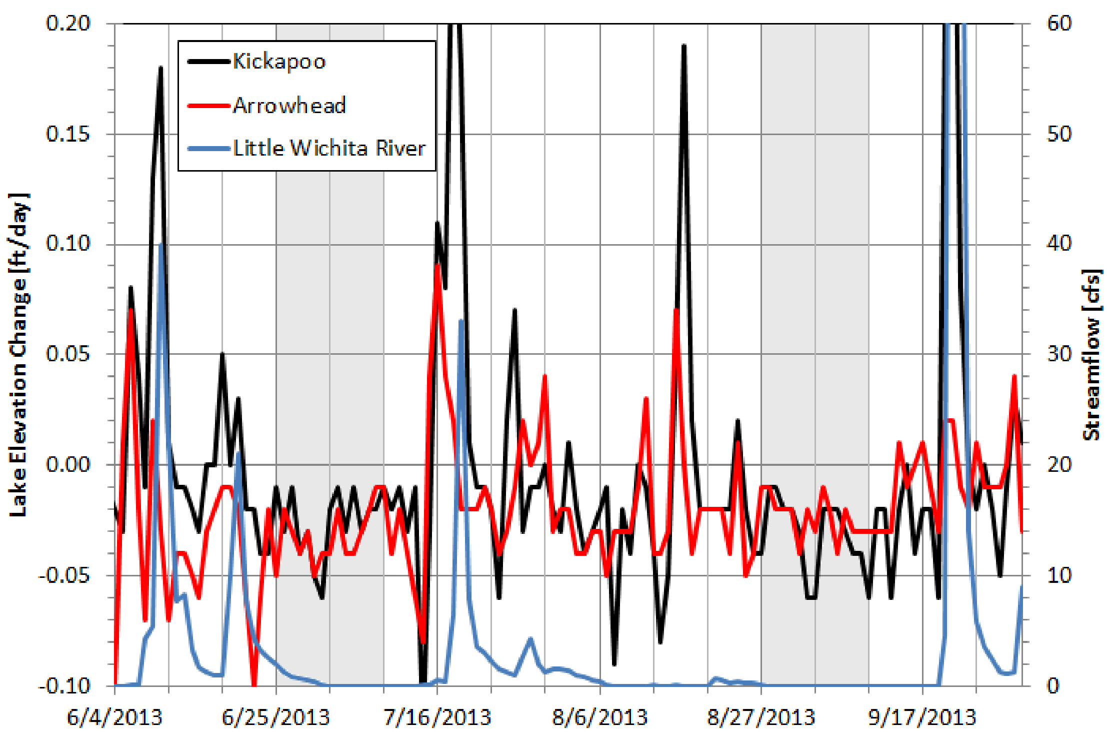

Figure A2. Daily change in lake elevation and streamflow of Little Wichita River June through September 2013. Suitable time periods for lake evaporation calculation are highlighted. (ft = feet; cfs = cubic feet per second)

Table A2. Evaporation data for period **Prior** to application of evaporation suppressant to Lake Arrowhead.

Date	Time Period [days]	Lake Kickapoo Evaporation [inches]	Lake Arrowhead Evaporation [inches]	Ratio of Evaporations (Arrowhead/Kickapoo) [unitless]
June 26 to July 2, 2012	7	2.53	1.71	0.678
July 3 to 9, 2012	7	2.15	2.26	1.052
July 17 to23, 2012	7	2.07	1.73	0.834
July 24 to 30, 2012	7	2.91	2.42	0.831
July 31to Aug.6, 2012	7	2.54	2.61	1.029
August 7 to 13, 2012	7	2.43	2.07	0.851
June 25 to July 1, 2013	7	2.66	2.56	0.962
July 2 to 8, 2013	7	1.63	1.84	1.130
Aug. 27 to Sept. 2, 2013	7	1.34	1.61	1.205
September 3 to 9, 2013	7	1.63	1.99	1.223

Step 2. Assemble Lake Arrowhead and Lake Kickapoo evaporation data during application of suppressant to Lake Arrowhead

Evaporation suppressant was applied to Lake Arrowhead from July 23 to October 2, 2014. The City of Wichita Falls recorded daily diversion data for each lake during this time period, allowing lake evaporation to be calculated on a sub-weekly time step (Appendix B includes sample calculations). To find periods when unmeasured inflow and outflow would be minimized, we again considered lake elevations and streamflow at U.S. Geological Survey Gage 07314500 as shown in Figure A3. In order to maintain similar temporal sampling periods for the **Prior** and **During** data sets, we only considered time periods longer than three days. There are four available data points with suitable characteristics (four or more continuous days with little to no precipitation and inflow; Table A3).

Table A3. Evaporation data for period during application of evaporation suppressant to Lake Arrowhead.

Date	Time Period [days]	Lake Kickapoo Evaporation [inches]	Lake Arrowhead Evaporation [inches]	Ratio of Evaporations (Arrowhead/Kickapoo) [unitless]
July 24 to 27, 2014	4	0.88	0.93	1.061
August 18 to 26, 2014	9	3.64	3.22	0.886
September 2 to 6, 2014	5	2.39	1.55	0.649
September 22 to 27, 2014	6	2.02	1.63	0.808

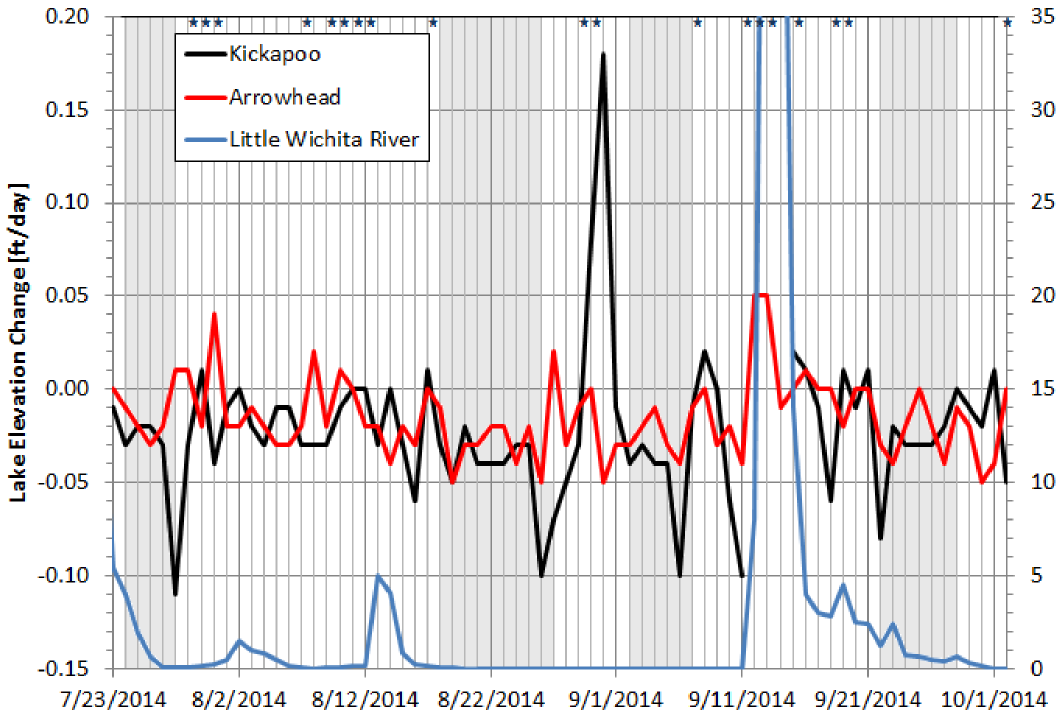

Figure A3. Daily change in lake elevation and streamflow of Little Wichita River in 2014 during application of evaporation suppressant to Lake Arrowhead. Asterisks at top of chart denote days when precipitation was detected on regional radar. Suitable time periods are highlighted. (ft = feet; cfs = cubic feet per second)

Step 3. Test if Lake Kickapoo and Lake Arrowhead evaporation rates are equal prior to application of suppressant.

We performed a rank-sum test on the paired evaporation data for Lake Kickapoo and Lake Arrowhead for the 10 data pairs from the **Prior** data set. We completed the test as described by Helsel and Hirsch (2002) and made no assumptions about the distributions of the data. Table A4 shows the ranks of the **Prior** data. Figure A4 plots the data along with a 1:1 line.

Table A4. Evaporation data and ranks for period prior to application of evaporation suppressant .

Date	Lake Kickapoo Evaporation [inches]	Rank	Lake Arrowhead Evaporation [inches]	Rank
June 26 to July 2, 2012	2.53	15	1.71	5
July 3 to 9, 2012	2.15	11	2.26	12
July 17 to 23, 2012	2.07	9½	1.73	6
July 24 to 30, 2012	2.91	20	2.42	13
July 31 to Aug.6, 2012	2.54	16	2.61	18
August 7 to13, 2012	2.43	14	2.06	9½
June 25 to -July 1, 2013	2.66	19	2.55	17
July 2 to 8, 2013	1.63	3½	1.83	7
Aug. 27 to Sept. 2, 2013	1.34	1	1.61	2
September 3 to 9, 2013	1.63	3½	1.99	8
Sum of Ranks		112½		97½

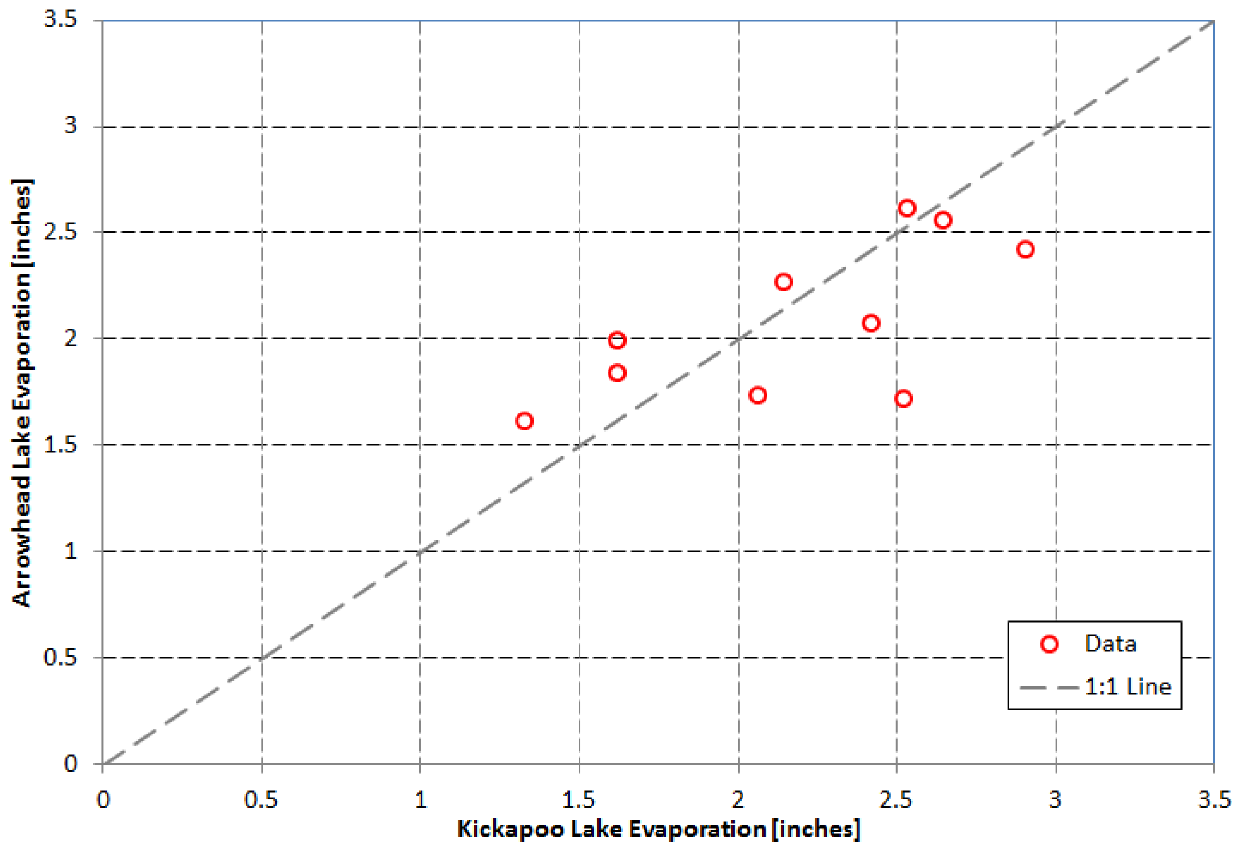

Figure A4. June through September lake evaporation data for Lakes Arrowhead and Kickapoo prior to application of suppressant to Lake Arrowhead.

As provided by Helsel and Hirsch (2002, Appendix B.4), the smallest critical values for the sum of ranks when comparing two sets of data with 10 data points each would be 91 and 119. Since the sum of ranks for both sets falls within this range, we accept the hypothesis that the probability of the evaporation rate of Lake Kickapoo being less or more than the evaporation rate of Lake Arrowhead (during the months of June and September and without application of evaporation suppressant to Lake Arrowhead) is 50:50. In other words, Lake Kickapoo makes a good “Control” for evaporation suppression studies of Lake Arrowhead. Essentially, prior to application of evaporation suppressant to Lake Arrowhead, for the June through September timeframe, it’s a coin flip as to which lake will have the higher evaporation rate.

Step 4. Test if Lake Kickapoo and Lake Arrowhead evaporation rates are equal during application of suppressant to Lake Arrowhead.

We performed a rank-sum test on the paired evaporation data for Lake Kickapoo and Lake Arrowhead for the four data pairs from the **During** data set. We completed the test as described by Helsel and Hirsch (2002) (Table A5, Figure A5).

Table 5. Evaporation data and ranks for period during to application of evaporation suppressant to Lake Arrowhead.

Date	Lake Kickapoo Evaporation [inches]	Rank	Lake Arrowhead Evaporation [inches]	Rank
July 24 to 27, 2014	0.88	1	0.93	2
August 18 to 26,2014	3.64	8	3.22	7
September 1 to 6, 2014	2.39	6	1.55	3
September 22 to 27, 2014	2.02	5	1.63	4
Sum of Ranks		20		16

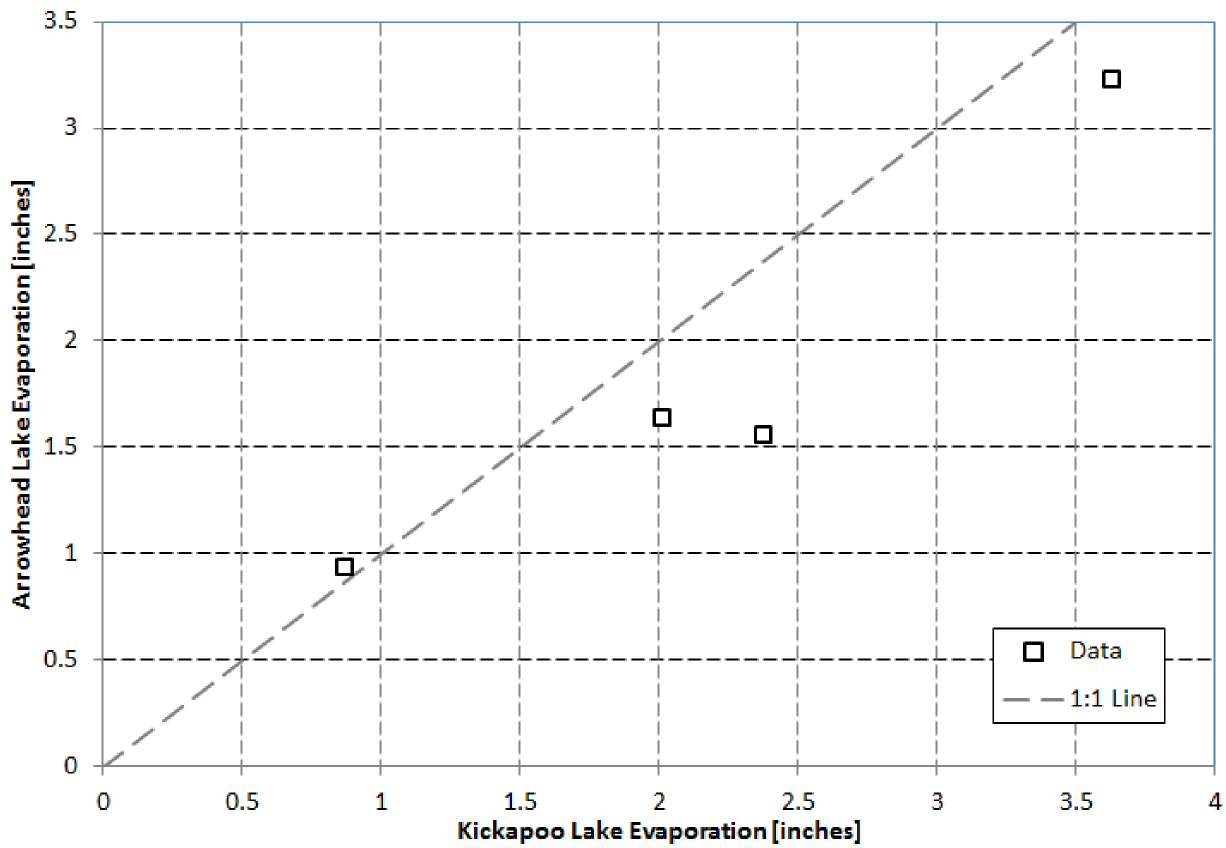

Figure A5. Lake evaporation data for Lakes Kickapoo and Arrowhead during application of suppressant to Lake Arrowhead.

As provided by Helsel and Hirsch (2002, Appendix B.4), the smallest critical values for the sum of ranks when comparing two sets of data with 4 data points each would be 14 and 22. Since the sum of ranks for both sets falls within this range, we cannot reject the hypothesis that the probability of the evaporation rate of Lake Kickapoo being less or more than the evaporation rate of Lake Arrowhead during the application of evaporation suppressant to Lake Arrowhead is still 50:50. The data (Figure A5) seem to present some evidence that Lake Arrowhead evaporation was reduced (in 3 out of 4 pairs Lake Arrowhead evaporation is less than that for Lake Kickapoo), but there is not enough data to prove this point conclusively. Therefore, we are in a similar situation to flipping a coin. A standard coin would have a 50:50 chance of being heads or tails (**Prior** data indicates that without evaporation suppressant applied to Lake Arrowhead, there's about a 50:50 chance that Lake Kickapoo evaporation is greater than that from Lake Arrowhead). If we flipped the coin 100 times and it came up heads 75 times, we'd have enough information to reject the hypothesis that the coin has a 50:50 chance of being heads or tails. But if we flip the coin four times and it comes up heads three times, that's not enough trials to prove there's anything unusual going on with our coin.

Step 5. "Normalize" both data sets and investigate further

In comparing the two data sets, there is a little bit of a mismatch as the **Prior** data set provides evaporation data for seven day periods while the **During** data set provides data on a mixed duration of time periods, from 4 to 9 days. Also, there is some concern that weather conditions in 2014 may have been different than in previous years (for example, 2014 may have been more humid than 2012 or 2013). In order to account for both these concerns, we "normalized" lake evaporation data in both data sets by dividing lake evaporation for Lake Arrowhead by that of Lake Kickapoo for the same time period. This minimizes the impact of differences in time period or weather conditions on the two data sets.

We carried out further analysis on the ratio of Lake Arrowhead to Lake Kickapoo evaporation (Table A6 Figure A6)..

Table A6. Statistics calculated for ratio of lake evaporation data sets.

Ratio of Lake Evaporation (Arrowhead/Kickapoo)	**Prior**	**During**
Count	10	4
Mean	0.979	0.851
Standard Deviation	0.180	0.171
Minimum	0.678	0.649
25th Percentile	0.839	0.769
Median	0.995	0.847
75th Percentile	1.110	0.929
Maximum	1.223	1.061

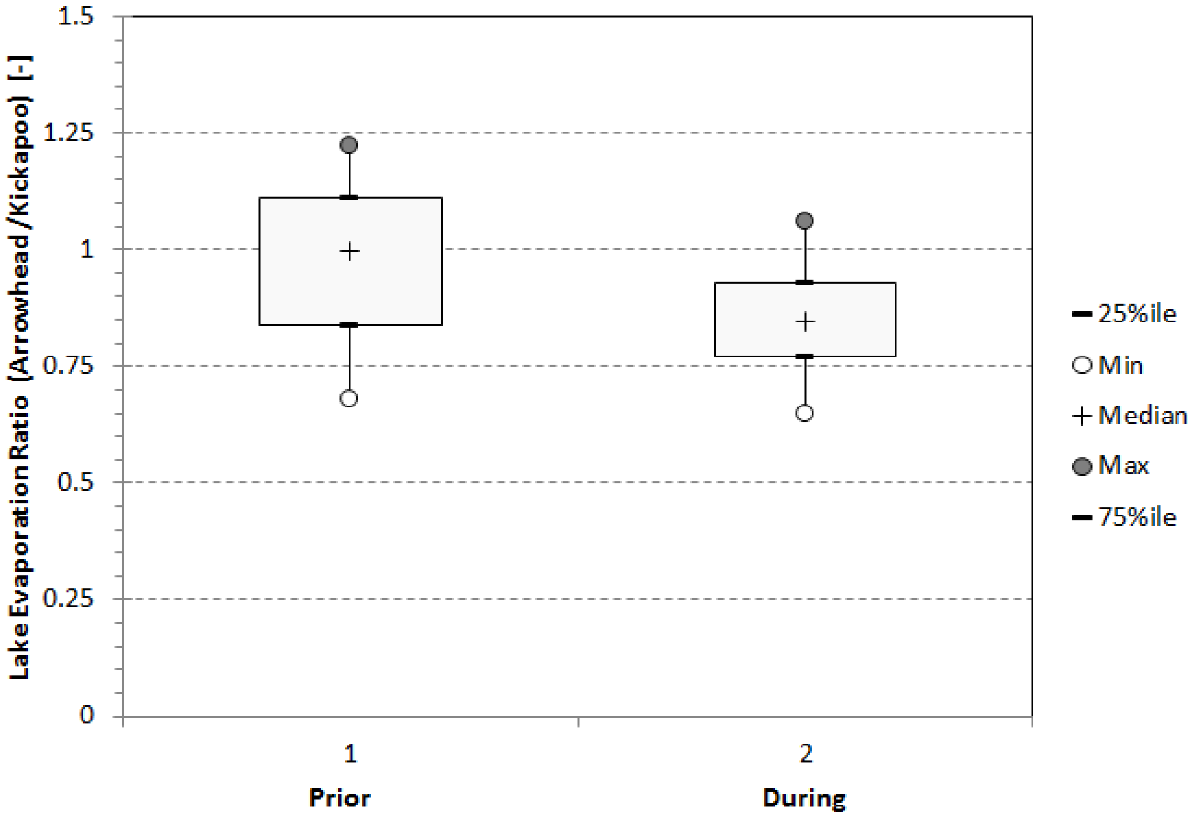

Figure A6. Box plots of two lake evaporation data sets. (25%ile = 25th percentile; Min = minimum; Max = maximum; 75%ile = 75th percentile)

We developed a Q-Q plot (quantiles of one data set versus the quantiles of another) following the procedures of Helsel and Hirsch (2002) (Figure A7). As noted by Helsel and Hirsch (2002), if the data sets come from the same distribution, the quantile pairs would plot along a straight 1:1 line. Additionally, if the data sets differ only by an additive amount, the pairs will fall along a line parallel to but offset from the 1:1 line. This appears to be the case with the **Prior** and **During** data sets, suggesting that the ratio between Lake Arrowhead and Lake Kickapoo evaporation is reduced by a relatively constant amount during application of the suppressant.

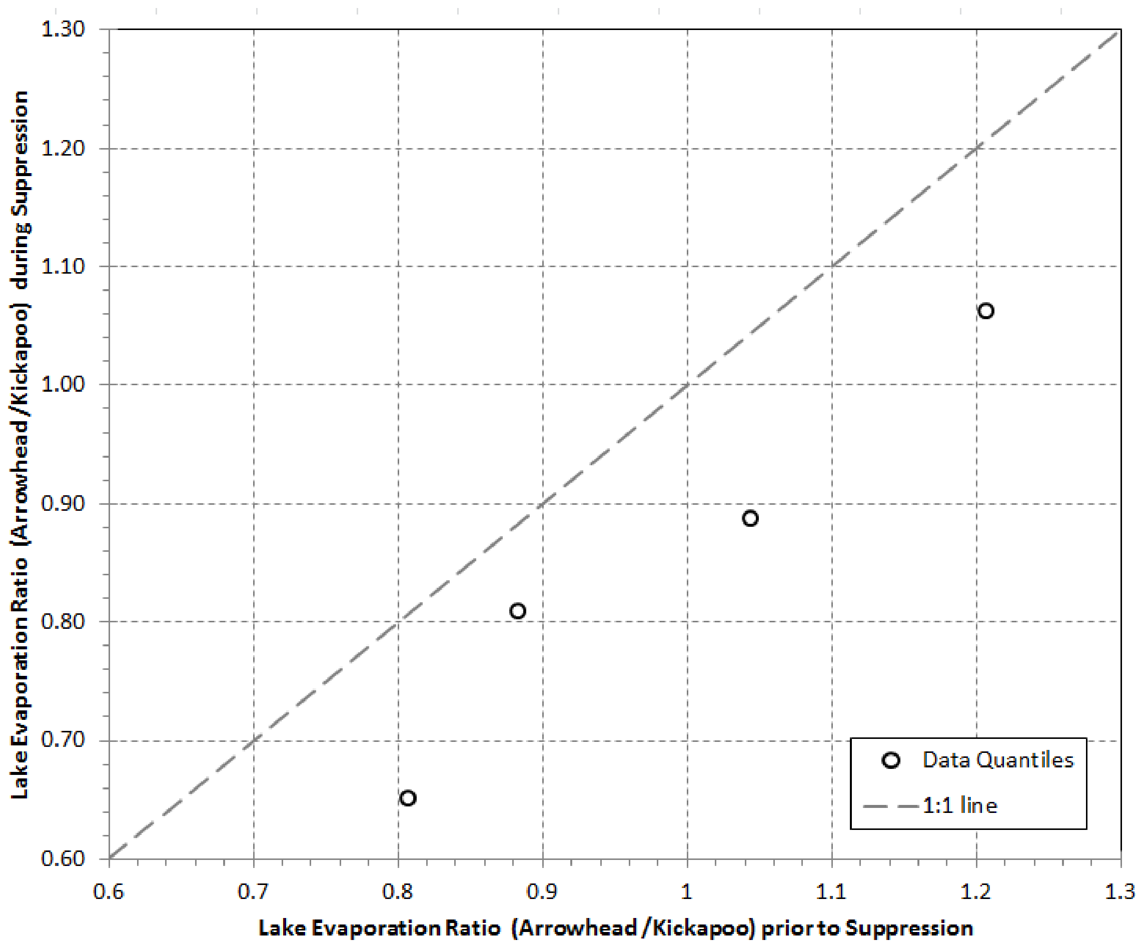

Figure A7. Q-Q plot of lake evaporation ratios (Arrowhead/Kickapoo) prior to and during application of suppressant to Lake Arrowhead.

Step 6. Determine if the ratio data are normally distributed

We examined both ratio data sets to see if they were normally distributed. We began by plotting the data against normal quantiles (Figure A8; also plotted on this figure is a line where the data would be expected to fall if the data were normally distributed with the same mean and standard deviation as each data set). The correlation coefficient between the **Prior** and **During** data sets and a corresponding normal distribution with the same mean and standard deviation are 0.982 and 0.996, respectively. Based on a probability plot correlation coefficient test (described in Helsel and Hirsch 2002), both data sets are deemed to be normally distributed. This is good news as it allows us to do some additional tests on the data. Note: Both a Kolmogorov-Smirnov Comparison Test and a Lilliefors Test for Normality point to the larger data set (**Prior** with n=10) being normally distributed. However, the **During** data set (n=4) is too small to be tested for normality with these methods.

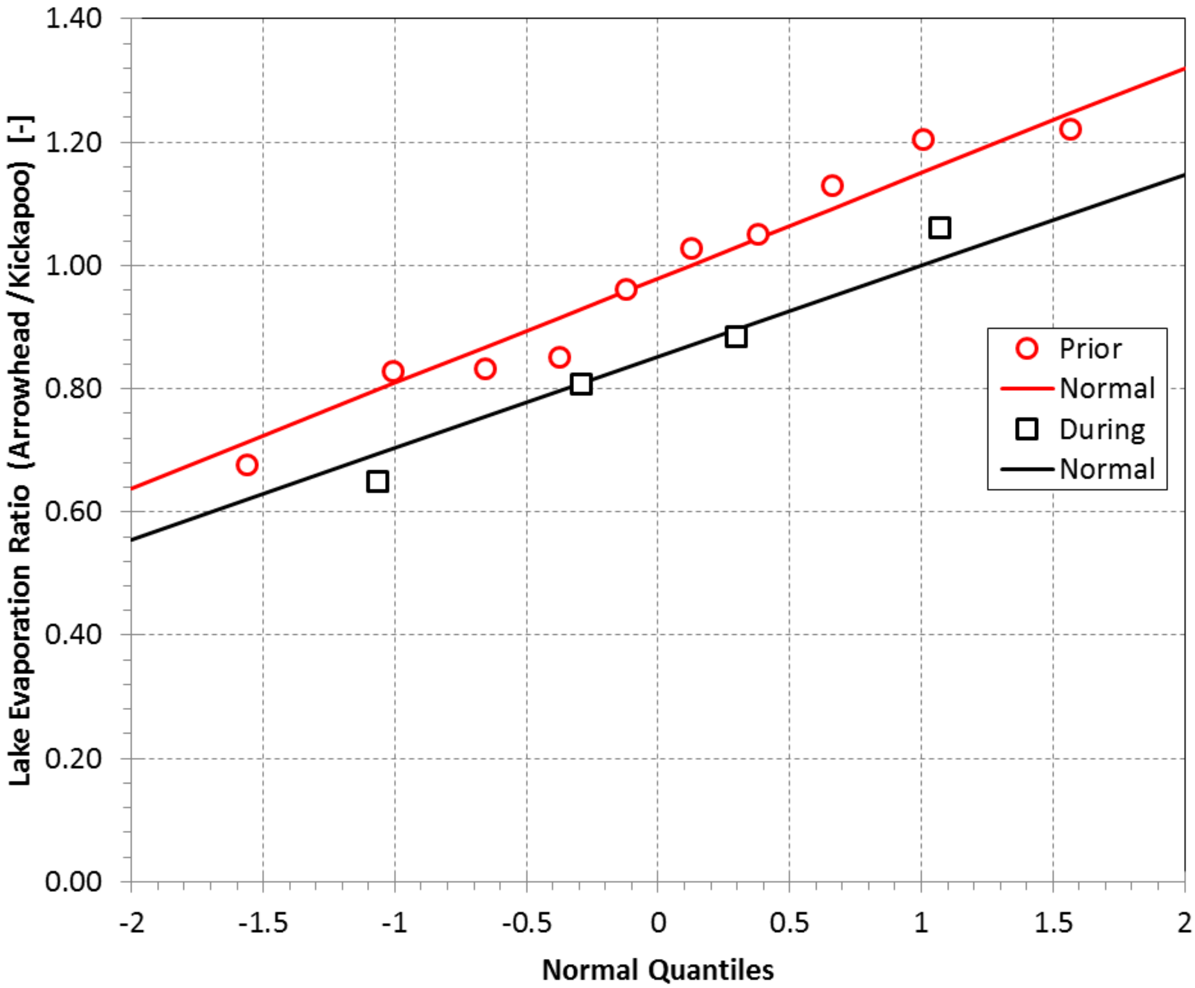

Figure A8. Lake evaporation data plotted against normal quantiles.

Step 7. Use Student's t-test to test if application of suppressant lowered evaporation of Lake Arrowhead

Since we can assume the ratio between Lake Arrowhead and Kickapoo evaporation is normally distributed (both prior to and during the application of suppressant to Lake Arrowhead), we can apply Student's t-test. This test has more investigational power to compare two data sets than the rank-sum test, but the data must be normally distributed. The t-test followed procedures described by Helsel and Hirsch (2002) for data sets with different variances. We computed the t statistic to be 1.249 and the degrees of freedom to be 5.853. If there is no real difference in the evaporation rate from Lake Arrowhead with and without the suppressant, there is only a 13 percent chance that we could have gotten the same four ratios (or lower) by randomly sampling the data. We are therefore 87 percent confident that evaporation from Lake Arrowhead has been reduced by the application of the suppressant. Note that some observers may desire a confidence level of 95 percent or greater to declare a result "statistically significant." Due to the small number of data points in the **During** and **Prior** data sets, that level of confidence is not achieved. However, at a lesser confidence level (87 percent) the data does support the hypothesis that application of the suppressant has reduced evaporation from Lake Arrowhead.

Step 8. Confidence interval on difference between the means

As noted by Helsel and Hirsch (2002), the most efficient estimator of the difference between two normally distributed data sets is just the difference of the means. In our case, prior to application of suppressant to Lake Arrowhead, the mean of the ratio of Lake Arrowhead to Lake Kickapoo evaporation was 0.979. During the application of suppressant, the mean of the ratio was reduced to 0.851. The reduction in evaporation ratio is therefore 0.128. We calculated confidence intervals on this reduction as described by Helsel and Hirsch (2002). The 50 percent confidence interval for the reduction of Lake Arrowhead to Lake Kickapoo evaporation ranges from 0.054 to 0.202. Alternatively, there's a 50-percent chance that similar data could have been obtained even though the suppressant accounts for greater than a 0.202 reduction in the ratio of Lake Arrowhead to Lake Kickapoo evaporation or the reduction is less than 0.054 (including actually increasing the evaporation ratio).

The confidence interval is large for a very low degree of confidence because there are only 10 data points in the **Prior** data set and 4 in the **During** data set. Increasing the confidence to 74 percent requires moving the upper and lower limits of the change in ratio out even farther to between 0 (no change in the ratio) to 0.256. In other words, there is a 74 percent chance that the real change in the mean of the evaporation ratio is between 0 and 0.256. There would also be a 13 percent chance that the change in evaporation ratio is less than zero (the suppressant actually caused an increase in the evaporation ratio and our data points were just too few to pick this up) and a 13 percent chance the change of evaporation was even greater than 0.256 (again because our data points were just too few to pick this up).

For higher levels of confidence (such as 90 and 95 percent), the range of possible changes in the ratio of evaporation from lakes Arrowhead and Kickapoo becomes larger, including negative values. At these very high levels of confidence, it is not possible to eliminate the possibility that the suppressant had no effect or may even have increased evaporation. Nevertheless, at a more modest confidence level, the data does support the hypothesis that application of the suppressant reduced evaporation from Lake Arrowhead.

Tabel A7. Confidence intervals for the change in lake evaporation ratio (Arrowhead/Kickapoo) from the periods prior to during application of suppressant.

	Change in Ratio of Arrowhead to Kickapoo Evaporation (Prior – During)	
Confidence	Lower Bound	Upper Bound
50 percent	0.054	0.202
74 percent	0.000	0.256
90 percent	-0.072	0.328
95 percent	-0.125	0.381

Data Sources

Lake Kickapoo elevation
U.S. Geological Survey Gage 0731400, Lake Kickapoo near Archer, TX
http://waterdata.usgs.gov/tx/nwis/uv/?site_no=07314000&PARAmeter_cd=00062,72020,00054

Lake Kickapoo elevation-area-capacity table
2013 TWDB survey
http://www.waterdatafortexas.org/reservoirs/individual/kickapoo/rating-curve/twdb/2013-09-01

Little Wichita River flow data
U.S. Geological Survey Gage 07314500, Little Wichita River near Archer City, TX
http://waterdata.usgs.gov/tx/nwis/uv/?site_no=07314500&PARAmeter_cd=00065,00060

Lake Arrowhead elevation
U.S. Geological Survey Gage 0731400, Lake Arrowhead near Henrietta, TX
http://waterdata.usgs.gov/tx/nwis/uv/?site_no=07314800&PARAmeter_cd=00062,72020,00054

Lake Arrowhead elevation-area-capacity table
2013 TWDB survey
http://www.waterdatafortexas.org/reservoirs/individual/arrowhead/rating-curve/twdb/2013-09-01

Precipitation maps from weather radar
http://water.weather.gov/precip/

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Helsel, D.R., and Hirsch, R.M., 2002, Statistical methods in water resources, Chapter A3: *in* Techniques of water-resources investigations of the United States Geological Survey, Book 4, Hydrologic analysis and interpretation, U.S. Geological Survey, 522 p. http://pubs.usgs.gov/twri/twri4a3/pdf/twri4a3-new.pdf

Appendix B

ac-ft = acre-feet
Δ = change

Example calculation of Lake Arrowhead evaporation for **Prior** data set.

Date	Lake Elevation [feet]	Lake Volume [ac-ft]	Δ Volume [ac-ft]	Diversions [ac-ft]	Evaporation [ac-ft]	Lake Area [acres]	Evaporation [inches]
6/25/2012	916.77	118,441					
6/26/2012	916.75	118,246	195	65.5	129.5	9,735	0.16
6/27/2012	916.73	118,051	195	65.5	129.5	9,725	0.16
6/28/2012	913.70	117,759	292	65.5	227.5	9,709	0.28
6/29/2012	916.66	117,372	387	65.5	322.5	9,688	0.40
6/30/2012	916.62	116,985	387	65.5	322.5	9,668	0.40
7/1/2012	916.60	116,791	194	65.5	128.5	9,657	0.16
7/2/2012	916.58	116,598	193	65.5	127.5	9,647	0.16
6/26–7/2/2012							1.71

Example calculation of Lake Kickapoo evaporation for **Prior** data set.

Date	Lake Elevation [feet]	Lake Volume [ac-ft]	Δ Volume [ac-ft]	Diversions [ac-ft]	Evaporation [ac-ft]	Lake Area [acres]	Evaporation [inches]
6/25/2012	1,035.88	42,318					
6/26/2012	1,035.87	42,280	38	5.1	33	3,789	0.10
6/27/2012	1,035.83	42,129	151	5.1	146	3,780	0.46
6/28/2012	1,035.80	42,015	114	5.1	108	3,773	0.34
6/29/2012	1,035.77	41,902	113	5.1	108	3,766	0.34
6/30/2012	1,035.73	41,752	150	5.1	145	3,757	0.46
7/1/2012	1,035.69	41,602	150	5.1	145	3,748	0.46
7/2/2012	1,035.66	41,489	112	5.1	107	3,741	0.34
6/26–7/2/2012							2.53

Example calculation ratio of Lake Arrowhead to Lake Kickapoo evaporation for **Prior** data set.

Date	Lake Arrowhead Evaporation [inches]	Lake Kickapoo Evaporation [inches]	Ratio of Arrowhead to Kickapoo Evaporation [-]
6/26–7/2/2012	1.71	2.53	0.678

Example calculation of Lake Arrowhead evaporation for **During** data set.

Date	Lake Elevation [feet]	Lake Volume [ac-ft]	Δ Volume [ac-ft]	Diversions [ac-ft]	Evaporation [ac-ft]	Lake Area [acres]	Evaporation [inches]
7/23/2014	907.68	51,040					
7/24/2014	907.67	50,982	57	3.3	54	5,751	0.11
7/25/2014	907.65	50,867	115	3.7	111	5,745	0.23
7/26/2014	907.62	50,695	172	3.8	169	5,737	0.35
7/27/2014	907.60	50,580	115	3.8	111	5,731	0.23
7/24–27/2014							0.93

Example calculation of Lake Kickapoo evaporation for **During** data set.

Date	Lake Elevation [feet]	Lake Volume [ac-ft]	Δ Volume [ac-ft]	Diversions [ac-ft]	Evaporation [ac-ft]	Lake Area [acres]	Evaporation [inches]
7/23/2014	1031.40	27,759					
7/24/2014	1031.37	27,675	84	18.0	66	2792	0.28
7/25/2014	1031.35	27,619	56	0.8	55	2789	0.24
7/26/2014	1031.33	27,564	56	21.1	35	2786	0.15
7/27/2014	1031.30	27,480	84	35.2	48	2782	0.21
7/24–27/2014							0.88

Example calculation of ratio of Lake Arrowhead to Lake Kickapoo evaporation for **During** data set.

Date	Lake Arrowhead Evaporation [inches]	Lake Kickapoo Evaporation [inches]	Ratio of Arrowhead to Kickapoo Evaporation [-]
7/24–27/2014	0.93	0.88	1.061

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Evaporation Retardation by Monomolecular Layers: An Experimental Study at the Aji Reservoir (India)

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Abstract

It is an established fact that huge quantities of water are lost from lakes, reservoirs and soils by evaporation. This assumes greater significance in arid and semi-arid regions around the globe when a general scarcity of water is compounded by high evaporation loss from the open water surfaces of lakes and reservoirs. The use of surface covering by a monomolecular film to reduce evaporation loss from large open water surfaces offers the greatest promise among all currently available techniques. This is the only system that retains the water surface in a state that does not interfere with other uses of the body of water such as boating, navigation recreation, fish, and wildlife propagation. Various experiments and field trials worldwide have proven conclusively that the fatty alcohols and their emulsions effectively retard water evaporation and result in saving to the tune of about 20% to 50%. An experiment was carried out at the Aji Reservoir (India) using a mixture of Cetyl and Stearyl alcohol that confirmed 19.26% saving in evaporation loss. During this six-month trial, about 0.18 mcum of water was saved which otherwise might have evaporated.

Keywords

Evaporation, Water Evaporation Retardant, Monomolecular Layer, Cetyl Alcohol, Stearyl Alcohol

1. Introduction

The rapid increase in world population and per capita consumption of water due to rising standards of living and other levels of activity have greatly intensified the demand for water all over the world. Evaporation plays a

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major role in the hydrologic cycle, and about 50% to 75% of total rainfall lost to the atmosphere [1]-[3]. This assumes greater significance in arid and semi-arid regions. The situation becomes grave, especially during droughts, when a general scarcity of water is compounded by high evaporation losses from the open water surfaces of lakes and reservoirs [4]. The National Water Commission (Australia) Waterlines Report Series No. 80, June 2012, documents annual evaporation losses in Australia as potentially exceeding 40% of total water storage.

Evaporation is a type of vaporization of water that occurs on the surface of liquid. Water evaporation is the process of escaping water molecules from the water surface into the atmosphere. The major factors that influence this process are temperature, humidity, the wind and exposed surface area [5]-[7]. As the process of evaporation is invisible, these losses in water are often not recognized. Evaporation is greatest during the driest seasons which are also the peak periods of water use [8] [9]. Management of water by reducing the evaporation rates will optimize the amount of water that may support the ever-growing domestic, agricultural and industrial demands. Hence, potentially all of the evaporation controlling methods can be of great economic significance [10]-[13].

Among the various techniques for reducing evaporation loss, mechanical devices, such as shed clothes and floating covers, have demonstrated the effectiveness for small storages, but they are not feasible for large areas of water such as reservoirs [14]-[17]. For large storage, the use of mono-molecular layers has the potential to be an attractive and cost-effective solution to reduce evaporation [18]-[20]. Mono-molecular layers are films that have the thickness of one molecule and form at the phase boundary of the air/water interface.

Many organic compounds, such as surfactants, detergents, bile salts or Phospholipids are amphiphilic, which combine a hydrophilic and a hydrophobic moiety within one molecule. This means that one end of the molecule has a great affinity for water (hydrophilic), and another end repels the water (hydrophobic) [21] [22]. When spread over the water surface, molecules are released over the water surface to form a film of one molecule thickness [23]. These molecules stand on one end and provide an effective lid on the water surface [24] [25]. **Figure 1** shows the amphiphilic molecules standing vertically on their polar head over the water surface.

Hexadecanol (Cetyl alcohol) $CH_3(CH_2)_{14}CH_2OH$ and octadecanol (Stearyl alcohol) $CH_3(CH_2)_{16}CH_2OH$ are suitable fatty alcohols to use for monolayers [22] [26]-[28]. These alcohols are derived from coconut or palm oil and are tasteless, odorless, non-toxic and inflammable. Cetyl and stearyl alcohol and their derivatives are biodegradable and innocuous to humans and animals. The United States Food and Drug Administration have approved them for use in the cosmetic, food and medicinal and industries indicating none to low toxicity [29]. When these materials are applied to the water surface, they self-spread to create a monomolecular surface film that provides an evaporative resistance [30]-[33]. A mixture of Cetyl alcohol and Stearyl alcohol in 1:1 ratio is found to be more effective than a monolayer consisting of any single material [18] [34] [35].

The mixture of Cetyl alcohol and Stearyl alcohol can be spread on the water surface in a powder form or an emulsion form, but the powder form has shown better results. This mixture forms a tight monomolecular layer on the water surface with the maximum surface pressure 40 mNm^{-1}. The layer allows oxygen and carbon dioxide to pass through but it is tight enough to prevent water molecules from escaping. The film formed does not resist sunlight and thus does not affect aquatic life [35]-[37].

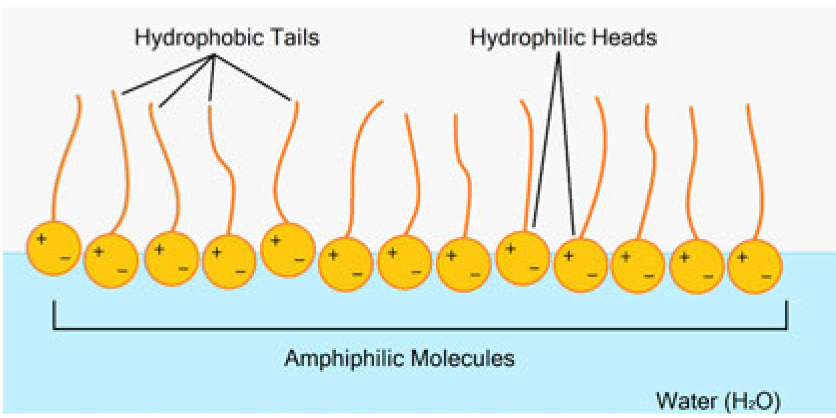

Figure 1. Amphiphilic molecules over water surface.

When formed, this film has liquid-like properties, and if ruptured, the molecules flow towards the ruptured areas and repair the film. The film expands at the water surface as waves are formed while the surface pressure is decreased [38]. As the film is transparent and invisible, indicator oils are used on large water surfaces to detect a monolayer which involves placing some drops of the indicator oil on the surface. If the film is formed and has acquired sufficient surface pressure, the oil drop will stand erect on it else it will sink in the water [23]. Numerous field trials on monolayers to reduce water evaporation have been carried out over the past 60 years. Most trials have used either Cetyl or Stearyl alcohol predominately and have found water savings ranging from 8 percent up to 43 percent [32] [39].

The main purpose of the present investigation was to develop a practical, safe and effective method of treating the surface of reservoir water with a monomolecular chemical film to reduce evaporation loss. An experiment was carried out at the Aji reservoir by using a mix of Cetyl and Stearyl alcohol, which confirmed a saving of 19.26% in evaporation loss. During this six-month trial, 0.18 mcum of water was saved from being evaporated.

2. Material and Method

Many organic compounds composed of long chain molecules having unsaturated valences at one end are easily attracted by water molecules and hence, lead to their spreading over a clean water surface [32]. The molecules encored to the water surface constitute a mono-molecular film. The longer the chain of the molecules, the greater is the sidewise attraction between the above water portions of the molecules. This sidewise attraction needs to be able to overcome random movements of the water attached ends if a stable, coherent, compact and mono-molecular film is to provide an effective lid onto the water surface [31] [40].

An ideal material which can spread over water the surface and act as a sealant should possess the following properties:

- Tasteless, odorless, non-toxic and nonflammable.
- Form a compact mono-molecular film and develop a surface pressure of more than 20 dynes to prevent water molecules from escaping.
- Pervious to oxygen and carbon dioxide but tight enough to prevent the escape of water molecules. It should not resist the passage of sunlight: in other words, it should not affect the aquatic life.
- Economical and relatively stable.

Hexadeconal (Cetyl alcohol) and octadecanol (Stearyl alcohol) have been studied extensively to determine their effectiveness as a film forming agent to reduce evaporation from water surfaces [15] [22] [41]. This material is a white, waxy, crystalline solid and generally available in flakes or powder form. It is relatively tasteless and odorless. It is derived from Tallow, sperm oil, coconut oil or palm oil.

The monomolecular film formed by a mixture of Cetyl and Stearyl alcohols in 1:1 ratio provides a stronger and more stable film on water surfaces than single Water Evaporation Retardant (WER) material [34] [35]. This film offers a barrier to prevent water molecules from escaping from the water body due to evaporation; the film can be penetrated by raindrops which break the film, but it closes again. It is flexible and moves with the motion of the water surface. It does not easily break up as do thick films formed by heavy oils. The theoretical quantity of Cetyl/Stearyl alcohol required to cover 1 ha of the open water surface is 21 gm under calm laboratory conditions.

2.1. Methods of Spreading the Material

There are three methods to spread the WER material over the open water surface.

1) The material Cetyl/Stearyl alcohol is available in flakes and lumps. This is pulverized in a cold grinding process as their melting point is about 49˚C. The pulverized material should be 60 to 100 mesh size for spreading over the water surface, and its dusting should be carried out by the help of a motor-driven boat and a powder duster. The material should be spread uniformly all over the water surface.
2) Cetyl/Stearyl alcohol is dissolved in kerosene or turpentine and applied over the water surface. The solution spreads rapidly and as the solvent evaporates this result in a one-molecule-thick lipid film at the air/water interface. Kerosene and Turpentine being less volatile may leave a lasting odor and hence they should not be preferred. Ether can be used because after application it evaporates quickly, leaving the monomolecular layer of Cetyl/Stearyl alcohol over the water surface [42]. In this case, the cost of the solvent adds to the cost of spreading.
3) The attempt to spread the material in the form of an emulsion over water surface is found favored in some

countries, but the conclusion regarding this simpler and cheaper technique is yet to be determined. The emulsion may be spread over the water surface by boat or by stationary rafts carrying an emulsion container with an arrangement to feed drop by drop emulsion on the water surface.

The research conducted by Yan *et al*. (2009) [43] shows that the dry dusting method results in a better monomolecular film than spreading the material in soluble or emulsion form. **Figure 2** displays the pictures of dry dusting over the water surface of the Aji reservoir using a motor driven boat and a stationery raft with the container carrying WER material in emulsion form with an arrangement to slowly release it over the water surface of the Nyari dam (India).

2.2. Measurement of Surface Pressure

There are many sophisticated techniques to measure the surface tension of monomolecular films such as photographic techniques, microwave techniques, thermal techniques etc. [44]. One simple technique that has been used on large water surfaces to identify a monolayer involves placing drops of indicator oil on the surface. As the naked eye can not see the film, its formation and surface pressure on the field can be measured by oil drops. If the film is formed and has acquired sufficient surface pressure, the oil dropped on the water surface will stand erect on it. But if the film is not there or it has not acquired sufficient surface pressure, the oil drops will sink in the water and immediately spread [23] [45].

For testing the film pressure, the following indicator oils are used:

1) Shell vitea 13 16 dynes.
2) Shell vitrea 21 24 dynes.
3) Shell exists fluid 250 40 dynes.

2.3. Effect of Cetyl/Stearyl Alcohol Film on Reservoir Water

Extensive studies in U.S.A., Australia, and other countries have been conducted on the biological effects of fatty alcohol and these studies have established that there are no adverse effects (short and long term) on the suitability of water for human consumption where reservoir surfaces are treated [29] [46]. Field and laboratory investigations have shown that both hexadecanol and octadecanol pose a very minimal toxicological threat to both aquatic and terrestrial life forms such as fish, ducks, insects, and plants [23] [41] [47]. As the film permits oxygen and sunlight to pass, it does not affect the aquatic life [36].

2.4. Dependence of Evaporation Control on Temperature

Laboratory Experiments at Poona (India) showed that the percent of evaporation control due to the monomolecular film of Cetyl/Stearyl alcohol decreases from 60 percent at a water surface temperature of 20˚C to 13 percent at 60˚C [48]. **Table 1** shows the effect of temperature on the resistive capacity of the monomolecular film.

Figure 2. Pictures showing dry dusting over lake surfaces by motor driven boat and stationary raft carrying a container with an arrangement to feed emulsion drop.

Table 1. Effect of temperature over evaporation resisting capacity of the film.

Water surface temperature (˚C)	Reduction in evaporation (%)		
	Cetyl alcohol	Stearyl alcohol	Cetyl-Stearyl alcohol
20	60.1	82.5	80.3
30	35.8	70.5	64.7
40	24.7	55.9	54.7
50	18.6	42.9	40.7
60	13.8	30.9	29.1

2.5. Dependence of Evaporation Control on the Wind

Monomolecular films applied to lake surfaces for evaporation retardation are greatly affected by the local wind speed and direction [49]-[52]. In field studies at Lake Hefner in Oklahoma, the U. S. Bureau of Reclamation researchers found the wind to be the most important single factor in the application and maintenance of a film When the wind velocity increases beyond 12 to 15 km. per hour, the scraping action of wind on the monomolecular film on the water surface sets in [39] [53] [54]. This decreases the film cover on the foreshore and heaps it up on the wind-wend side, even depositing a part of it on the offshore of the reservoir. Much larger rates of dispensing of the film, sufficient to obviate the effect of the wind will thus be needed to maintain the film cover as effectively as possible. Under these conditions the amount of Cetyl or Stearyl alcohol that goes as unavoidable waste increases several fold. The amount of the alcohol to be spread may have to be increased under little or no wind conditions. If more wind is observed on a particular day spreading should be cancelled to avoid waste [55].

2.6. Life of Monomolecular Film over Water

Experiments in the laboratory with distilled water have shown that the lifespan of such films is about three days. But under field conditions, it is reduced to one to two days. The destruction of material takes place by the effect of chemical bacteria's and wind action. [56] [57]. The solubility of heavy alcohols in the water is very low. There is a reason to believe that the ultraviolet sun rays break down the heavy alcohols into substances of shorter chain lengths, which are then lost. Experiments carried out in different parts of the world show that in the arid or semi-arid areas where human, animal and bird life are extremely scarce, as in the arid zone of Australia, bacterial action on the film is very rare. But in thickly populated areas in the tropics and subtropics the bacterial destruction plays a more prominent part [58].

Any foreign substance which is absorbed by the film restricts its movement by rendering it inelastic. In this state, the film instead of flowing easily tends to be crumpled by the wind and gets washed away from the surface. The crumpled film clogged with impurities is ineffective and does not spread again, and it may sink.

2.7. Spreading Procedure

When Cetyl/Stearyl alcohol is spread over the water surface, molecules of the alcohol are released and spread over the water surface to form a film of one molecule thickness [40]. The rate of spreading depends on the composition of alcohol, the temperature of the water surface and prevailing wind velocity. As the spreading proceeds, the surface pressure gradually increases until an equilibrium pressure of 40 dynes is reached and at this stage, the film is condensed and provides maximum resistance to the evaporation of the water. The equilibrium film has the properties of a liquid, and if ruptured, the molecules will flow towards the rupture and repair the film. The film expands with the water surface as waves are formed but the pressure is decreased.

During periods of normal temperature and low wind, the film of Cetyl/Stearyl alcohol develops a surface pressure up to 40 dynes. Subsequent feeding can be done only to replenish the damaged portion of the film. It is advisable to have the film spread on the water during cooler and calmer hours of the day; the film, by its own presence, will reduce the waves and lessen the destructive effects of the wind. From meteorological studies, it can be seen that wind and temperature increases during the afternoon hours. Thus, it is better if the film is formed in the early hours of the day. The surface pressure of the film should be tested at intervals, and additional quantities should be added to make up the deficit. Field studies suggest that a fresh film has to be formed every day [55].

2.8. Assessment of the Evaporation from a Reservoir and the Saving Due to Film

Water evaporation is one of the obscure components of the hydrological cycle to measure accurately. There are two basic reasons for this obscurity. First, no instrumentation exists which can truly measure evaporation from a natural surface. Second, none of the indirect methods used for estimating evaporation are universally accepted. Estimation of reliable or acceptable values of evaporation requires either a detailed instrumentation or a judicious application of climatic and physical data.

Thornthwaite and Benjamin (1942) [59] proposed a recondite technique of an aerodynamic method whereby the evaporative loss is correlated with the transfer of water vapour by turbulence into the air layers near the surface. This in turn, may be assessed from the vertical gradients of wind velocities and vapour pressure. But this technique needs specialized equipment and skills which are ordinarily beyond the reach of engineers working in the field.

2.8.1. Pan Evaporimeter Method

The simple two pan method can be used to assess the water saved from evaporation loss as a result of covering the water surface of one pan with a monomolecular layer. The difference in evaporation depths by two panevoporimeters kept side by side, with the water of one pan dusted with WER material will provide the depth of water saved. Kohler *et al*. (1955) [60] suggested that lake evaporation (E) is 0.70 times the standard pan evaporation (Es).

2.8.2. Water Balance Method

The basic water balance equation can be written as

$$F = W + E + S \tag{1}$$

where F = Fall of level, W = Water drawn for supply, E = Reservoir evaporation and S = Seepage and absorption losses.

The calculation of seepage loss 'S' is a very difficult task. Floating pans can be used for directly measuring E, but this is often beset with difficulties particularly during windy weather. It is more practical to determine the relation between E & Es, where Es is a standard land pan evaporimeter well away from the direct influence of the reservoir.

Another practicable approach is to have alternating periods of "No Treatment" and "Treatment", where the estimation of savings becomes a simple matter as one may assume that in adjoining weekly or 10 day intervals, the value of 'S' may not change materially, and one may reasonably compare the evaporation in a treated week with that in the previous untreated week. In actual practice, great care is necessary in arriving at representative values of water levels by using a number of gauges.

3. Experiment on the Aji Reservoir

The Aji reservoir is located at 22.3˚N 70.78˚E near Rajkot city in Gujarat state (India) and has an average elevation R.L 134 metre. It is the main source of the municipal water supply for the city of Rajkot. The main spillway portion of the Aji dam and its geographic location is shown in **Figure 3**.

Rainfall in the year 1985-86 in the western Gujarat region was very scanty, and only 195 mm of rain was recorded which was well below the annual average of 900 mm. This too was spread over 33 rainfall days. The maximum rainfall in any day was reported to be a meager 18 mm. As a result, the lakes and reservoirs of the area received very little, or no replenishment and a very grave situation arose in supplying water supply to Rajkot city with a population of about a million people. Therefore, it was decided to carry out an experiment in the Aji Reservoir to conserve available water storage.

3.1. Weather Pattern of the Aji Reservoir

The monthly average maximum temperature varies from 25˚C to 42˚C and the minimum temperature varies between 8˚C to 27˚C. Usually, the daytime temperature rises from forenoon to the afternoon and then gradually falls. During the summer months where the maximum daytime temperature ranges from 40˚C to 45˚C, evaporation losses from the reservoir are at their maximum. As far as wind and temperature conditions at Aji reservoir are concerned, during the summer months of high daytime temperatures, wind velocities are also higher. In the

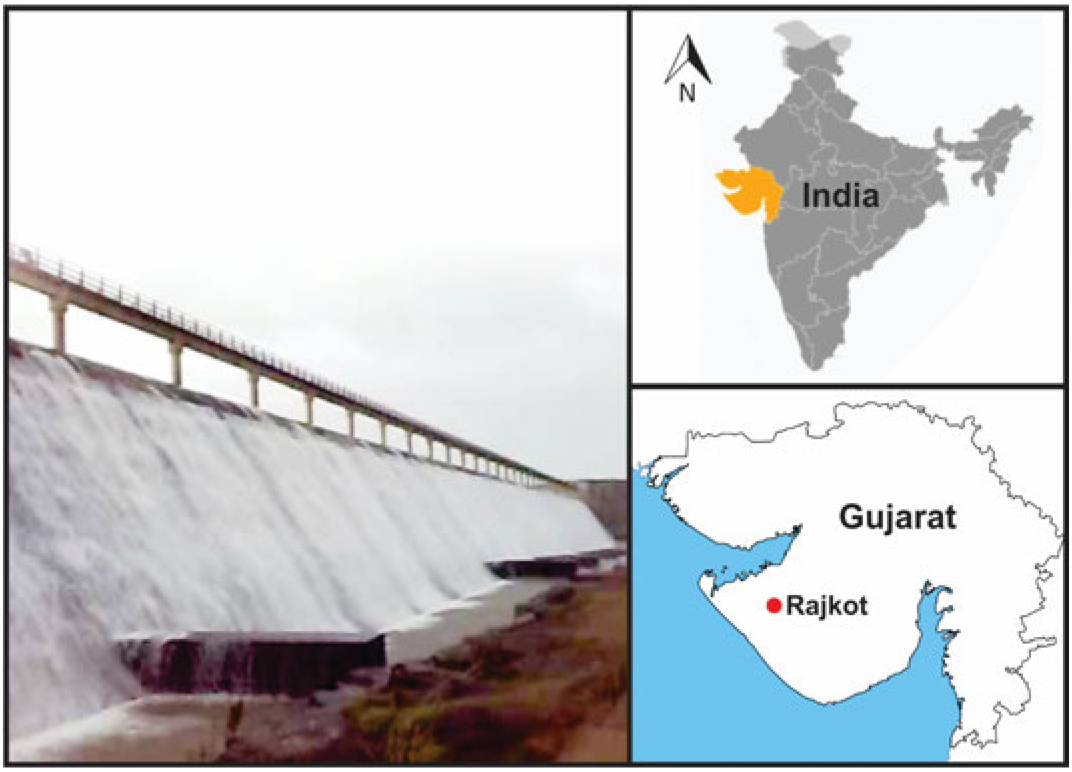

Figure 3. Aji dam near Rajkot city (India).

months of October and November although the daytime temperature is high, wind velocities are comparatively less. During the winter season, wind and temperature conditions are comparatively better.

It was observed that the wind velocities on the Aji reservoir were less in winter than in the summer season. The maximum wind velocity recorded during December was 9 km/hr and linearly increased to 15 km/hr in the month of June. Also, wind velocity during the day was at its maximum between 12.00 to 16.00 hrs.

3.2. Dusting Operations

The experiment was carried out from December 15, 1985, to May 31, 1986, and within this period; the mixture of Cetyl alcohol and Stearyl alcohol in 1:1 ratio was used. The chemical was pulverized daily up to 100 microns in a special mill in the laboratory of Pharmacy College located about 1 km from the Aji reservoir. It was observed that if the pulverized powder was stored for 2 to 3 days, it converted to lumps due to the high summer temperatures; hence, grinding was carried out daily.

The required quantity of powder was calculated daily according to the decreasing water spread area due to a decrease in the reservoir level. The dusting operation in the reservoir was carried out using a gasoline-driven motor boat. The dusting men sit in the rear of the boat and spray the powder by slowly rotating the handle of the dusting bin. The funnel of the bin was kept reasonably near the water surface. The dusting was carried out by running the boat in the opposite direction of the wind to ensure that the wind-blown particles of powder were able to fall on the water surface and not be wasted. The dusting operation was carried out in strips, and great care was taken to spray powder evenly on the entire surface of the water.

The dusting operations were carried out in the early hours of the morning from 4.00 AM to 7.00 AM as the weather conditions were calm during this period. The film formation was then checked at regular intervals by using castor oil drops at several points in the reservoir, and if needed, additional feeding was carried out during the day to replenish the damaged portion of the film.

Two Class A evaporation pans with a Stevenson screen were kept just in d/s of the Aji reservoir. In one pan, the water surface was dusted with Cetyl/Stearyl alcohol powder and evaporation readings were taken from these two pans at regular intervals.

3.3. Seepage Loss and Saving in Evaporation Loss Calculation

The six-month period from Jan 01, 1985 to June 30, 1985, was chosen to determine the seepage loss of the reservoir. The reservoir was not treated during this period.

Equation (1) can be rewritten as

$$(F - W) = E + S \tag{2}$$

If P is the evaporation loss from evaporation pan. Then

$$m = E/P \text{ or } E = mP \tag{3}$$

From Equations (2) and (3)

$$(F - W) = mP + S \tag{4}$$

The graph is a straight line

$$Y = mX + C$$

The intercept on the Y-axis in **Figure 4** represents the seepage and absorption losses. These losses ‘S’ are assumed to be constant for a given condition in the reservoir. Data for calculation of seepage and absorption loss of the Aji reservoir is shown in **Table 2**.

Figure 4 shows the graph of $\Sigma F - W$ versus cumulative evaporation ΣmP. In this straight line graph, the intercept C of trend line denotes total seepage and absorption loss “S” = 0.07 m/month. **Table 3** and **Table 4** show the data and effect of the use of WER material for the experimental period, of six-months.

The calculations show that an average of 19.26% savings of water was achieved during the experimental period and 0.18 mcum water was saved by the treatment.

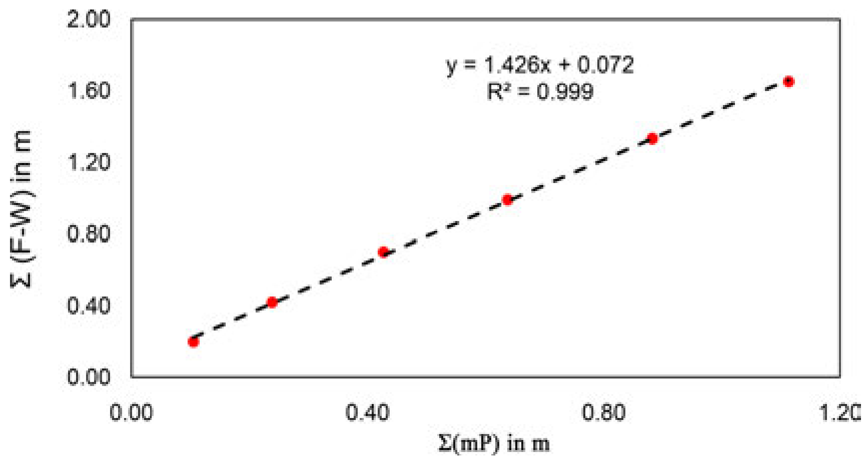

Figure 4. The straight line graph to calculate seepage and absorption losses of Aji reservoir.

Table 2. Statement for computation of seepage and absorption losses of the Aji reservoir.

Period	Drop in water level	Withdrawal for water supply	Total lake loss	Cumulative lake loss	Evaporation from pan	Evaporation from lake	Cumulative lake evaporation
	(F)	(W)	(F-W)	Σ (F − W)	(P)	mP = P × 0.70	Σ(mP)
	(m)	(m)	(m)	(m)	(m)	(m)	(m)
Jan ‘85	0.80	0.60	0.20	0.20	0.15	0.11	0.11
Feb ‘85	0.90	0.68	0.22	0.42	0.19	0.13	0.24
March ‘85	1.00	0.72	0.28	0.70	0.27	0.19	0.43
April ‘85	1.11	0.82	0.29	0.99	0.30	0.21	0.64
May ‘85	1.27	0.93	0.34	1.33	0.35	0.25	0.88
June ‘85	1.29	0.97	0.32	1.65	0.33	0.23	1.11

Table 3. Saving (%) in evaporation by application of Cetyl/Stearyl alcohol treatment over the water surface.

Period	Drop in water level	With-drawal for water supply	Total lake loss	Seepage loss 0.07 m/month	Evapo. loss from pan	Lake evapo. loss	Evapo. loss without treatment	Evapo. loss during treatment period	Saving in evaporation loss due to treatment	
	(F)	(W)	(F-W)	(S)	(P)	(P*0.70)		(F-W-S)		
	m	m	m	m	m	m	m	m	m	%
16-Dec-85 to 31-Dec-85	0.30	0.23	0.07	0.03	0.07	0.05	0.05	0.04	0.01	18.37
Jan-86	0.53	0.37	0.16	0.07	0.16	0.11	0.11	0.09	0.02	19.64
Feb-86	0.39	0.21	0.18	0.07	0.20	0.14	0.14	0.11	0.03	21.43
Mar-86	0.43	0.18	0.25	0.07	0.31	0.22	0.22	0.18	0.04	17.05
Apr-86	0.43	0.17	0.26	0.07	0.34	0.24	0.24	0.19	0.05	20.17
May-86	0.45	0.17	0.28	0.07	0.37	0.26	0.26	0.21	0.05	18.92
							Average saving in evaporation loss (%)			19.26

Table 4. Quantity of water saved by treatment.

Period	Water level at the beginning	Water level at the end	Storage at the beginning	Storage at the end	Average water spread area	Saving in evaporation due treatment	
	(m)	(m)	(mcum)	(mcum)	(msqm)	(m)	(mcum)
16-Dec-85 to 31-Dec-85	140.78	140.48	2.53	2.06	1.55	0.01	0.01
Jan-86	140.48	139.96	2.06	1.24	1.43	0.02	0.03
Feb-86	139.96	139.56	1.24	0.79	1.15	0.03	0.03
Mar-86	139.56	139.13	0.79	0.36	0.98	0.04	0.04
Apr-86	139.13	138.70	0.36	0.00	0.84	0.05	0.04
May-86	138.70	138.25	0.00	−0.17	0.38	0.05	0.02
				Total saving in evaporation			0.18

3.4. Economics of the Experiment

Due to very scanty rainfall in the region around Rajkot city during 1985 monsoon, water supply lakes, and reservoirs received very poor replenishment. A very grave situation arose in the municipal water supply to one million residents of Rajkot with the summer months still ahead. The situation was so critical that authorities had to arrange for water by any means of transportation or to evacuate the city. To cope with this situation water was transported from distant places by road and by special trains. The cost for the transportation of 10,000 of litres water came to $7.0 by road and $3.0 by rail while the cost of water savings by this experiment was $0.45. Thus, the cost of saving water from this experiment was insignificant compared to the cost of other arrangements to bring water from distant sources.

Apart from the economics of the cost, there is a deeper human value which cannot be measured in terms or money. For instance in the case of Rajkot City, there were anxious moments when considering the question of evacuating the city due to a very acute shortage of water. The experiment on the Aji reservoir saved about 0.18 mcm of water which lasted for a further 15 days. Thus, the experiment was partially instrumental in saving Rajkot from the grueling experience of evacuation.

4. Conclusions and Recommendations

On the basis of this water saving experiment, the following conclusions were drawn:

- Though evaporation cannot be controlled fully in field conditions, partial control can be achieved with satisfactory results.
- The efficiency of evaporation retardation in terms of percent of water saved from evaporation losses decreases with increases in temperature and wind velocities at the reservoir site.

- The cost of chemical must be taken into account in the routine treatment, but in the case of extreme circumstances it should not govern the consideration for saving water.

These conclusions point to the fact that efficiency of the control operation varies from site to site. In extreme circumstances, there cannot be any norm of the economy, but for the general year to year treatments, the merit of the site conditions of the lake governs. A lake encircled by high hill ranges in the wind direction is recommended as it will calm the conditions even if wind velocities are higher in the region. It can be achieved by planting huge trees all around the periphery of the reservoir. This green belt of trees will also help to reduce evaporation by increasing the moisture content of the air by the process of transpiration. The root system of these trees will resist erosion and help to reduce the rate of silting of the reservoir.

Monomolecular films of Cetyl/Stearyl alcohol offer the prospect of an economical solution to the evaporative loss of water from large storage sites. There is scope for further research for more improved formulations with increased resistance to high temperatures and wind stress.

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3. FACSIMILE TO: 702-293-8418

Option Submittal Form

Contact Information (optional): ☐ **Keep my contact information private.**

Contact Name: Title:

Affiliation:

Address:

Telephone: E-mail Address:

Date Option Submitted: February 1, 2012

Option Name:

Eliminating Water Loss by Cutting Evaporation by 50%

Description of Option:

Every year the Colorado Basin Reservoirs lose 2,466,000 acre-feet of water to evaporation. Lake Mead accounts for over 900,000 acre-feet or around 7.5 feet depth loss to surface level. From the start of the recent drought in 2000, if the water loss strictly to evaporation was added together, a total of 82 feet of water loss would have occurred during this 11 year period. This is if no water was going out of the reservoir and no water was coming into the reservoir. Evaporation cannot be ignored any longer. Using all the tools for water conservation is the best avenue to having this water last beyond 2050. In 2003, a new solution to decrease evaporation was invented and has been used on reservoirs with great success. The product branded, Aquatain reduces evaporation by 50%. Thus if Aquatain had been used from the year 2000, it would have saved 41 feet of water depth from the Lake.

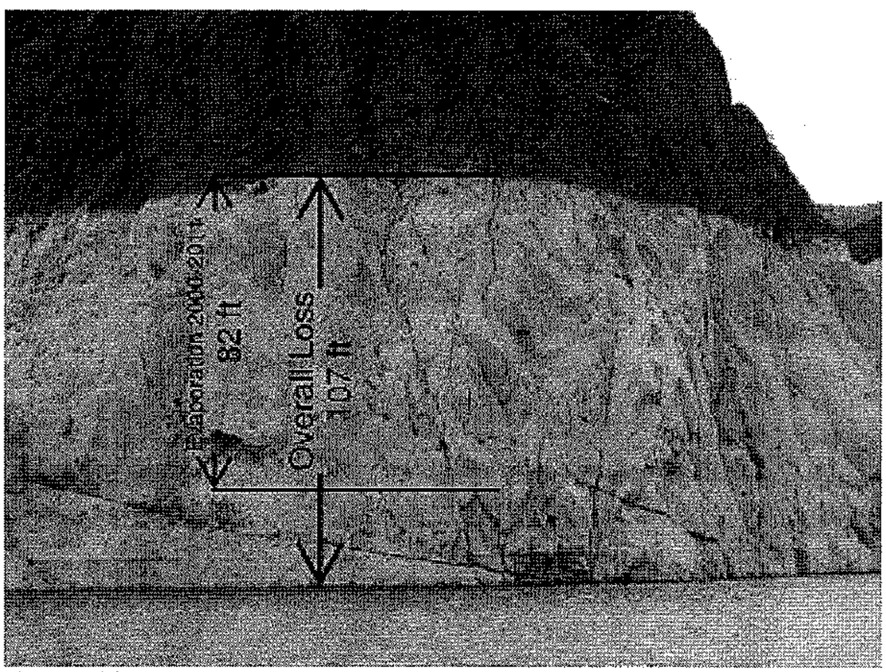

Photo: Cable Jones 2011

Aquatain is a liquid based on silicone that can be poured onto a body of water where it will form a very, very thin layer right across the top, hence retarding the ability of the sun, wind and weather to evaporate the water – reducing losses by 50%. The inventor, Graham Strachan, invented this anti-evaporation liquid to combat the

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droughts in Australia.

Evaporation is more complex than you might think: it's not just about the sun heating the water, but also the action of the wind along with several other factors. When molecules of water get energetic enough (because of sun or wind energy, or their ambient temperature in relation to the external temperature) and they're at the surface of the water body, then they can cross the liquid/gas threshold and literally escape into the atmosphere as a gas.

Reservoirs such as Lake Mead have a great depth to the water which actually decreases the amount of surface area available thus reducing evaporative losses. Evaporation can be retarded by building dams deeper to reduce the surface area in proportion to the total volume of the dam, and by building wind breaks to shade the reservoir from the action of wind. However, this isn't any good for an already established reservoir that's losing thousands of acre-feet of water into the air. What is the solution then?

Since the 1950s attempts have been made to use anti-evaporation liquids to stop water from evaporating, but all solutions to this time have needed almost daily re-application. At their best these anti-evaporation liquids have reduced evaporation by 30% or 40% and require special storage specifications.

Lake Havasu, a reservoir used for drinking water, uses its own anti-evaporation method shown below by trying to cover its lake surface by as many boats as possible. Using the anti-evaporation liquid, Aquatain is a solution that is much less resource-intensive than covering the lake surface with boats.

Photograph: Cable Jones 2011 of an aerial picture at Lake Havasu Water District Ofiice

Aquatain is the first anti-evaporation film that is based on silicone as a polydimethylsiloxane. The basic idea is that if you could create a film or monolayer (layers that are one molecule thick) over the surface of the water, the action of evaporation (water turning into water vapor) could be decreased.

Simple to apply, Aquatain will be poured onto the surface of Lake Mead to cut evaporation dramatically. Rain water falls straight through Aquatain into the reservoir and the Aquatain film re-forms above it.

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Location: Describe location(s) where option could be implemented and other areas that the option would affect, if applicable. Attach a map, if applicable.

The solution involves the entire surface area of Lake Mead, and, hopefully, in the future, every other reservoir surface in the Colorado River Basin saving over 853,000 acre-feet of water annually.

Quantity and Timing: Roughly quantify the range of the potential amount of water that the option could provide over the next 50 years and in what timeframe that amount could be available. If option could be implemented in phases, include quantity estimates associated with each phase. If known, specify any important seasonal (e.g., more water could be available in winter) and/or frequency (e.g., more water could likely be available during above-average hydrologic years) considerations. If known, describe any key assumptions made in order to quantify the potential amount.

This solution involves the entire surface area of Lake Mead and in the future every other reservoir surface in the Colorado River Basin. If all the reservoir surfaces in the Colorado River Basin were covered with Aquatain, a total of 42,675,000 acre-feet of water could be collected over 50 years and this amount would fill Lake Mead over 1.5 times. At Lake Mead alone, a total of 20,000,000 acre-feet of water over 50 years or 400,000 acre-feet per year could be saved starting from the first year of implementation. More water will be available during years when there is a larger surface area due to higher lake levels. Evaporation goes up in the summer, so the amount of water available during the peak times of water use would be greater and the effects of using anti-evaporation liquid can be more readily seen. Conservative numbers of 800,000 acre-feet loss from Lake Mead due to evaporation was used in calculations, although evaporation is more close to 937,500 acre-feet average for the last 50 years.

In 1998, the highest loss of evaporation was recorded at 2,283,000 acre-feet for the past 30 years in the entire Colorado River Basin. Taking half this amount times 50 years would equal 57,075,000 acre-feet close to the amount of the entire reservoirs' storage capacity (roughly four times the average natural inflow) in the Colorado River Basin.

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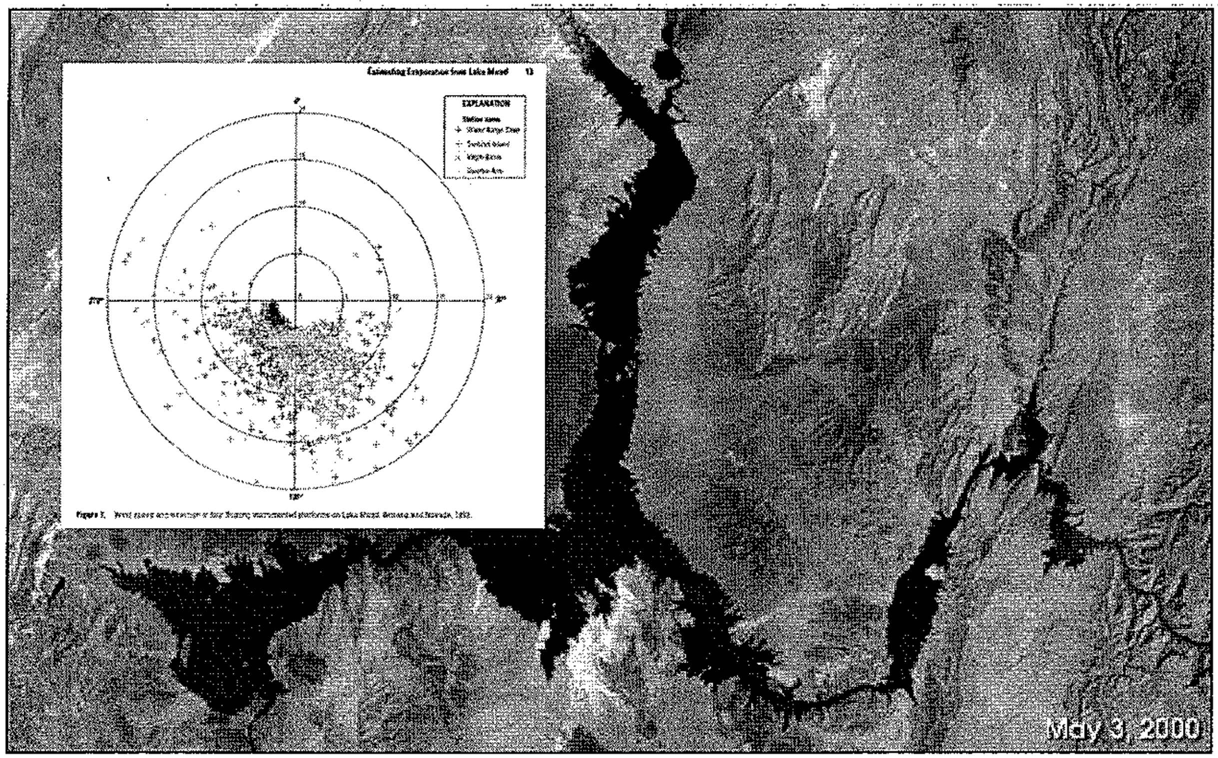
Additional Information

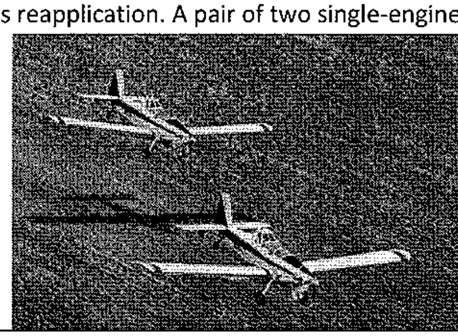
Technical Feasibility: Describe the maturity and feasibility of the concept/technology being proposed, and what research and/or technological development might first be needed.

Lake Mead is very large, averaging 125, 600 acres of surface area and will require aerial application to spread the anti-evaporation liquid, Aquatain, over the entire surface of the reservoir in a few hours. This anti-evaporation liquid, Aquatain, would be applied with a tail wind to increase spreading capability. The photograph below shows an aerial of Lake Mead with a diagram of wind direction and intensity superimposed on top. The diagram shows



the directions that the wind hits four research buoys and the intensity of the wind. The diagram was taken for a research project conducted by the USGS from 1997-1999 to better quantify actual evaporation losses from different areas of the lake. Much of the wind comes from the southwest with some from the southeast and reaches greatest intensity in the 5 to 10 mph range.

The anti-evaporation liquid would be applied at an application rate of 10,000 gallons every 10 days for the average surface area of 125,600 acres. The Aquatain anti-evaporation liquid spreads across the surface of the water easily. To cover the entire surface when the reservoir is completely full about 160,000 acres, 14,000 gallons would be needed. The liquid breaks down slowly over the ten days and requires reapplication. A pair of two single-engine aircraft flying parallel or one in front of the other (as shown in the photograph at the right) with about 600 feet between them is best for application.



Each plane would carry 800 gallons of Aquatain. It would take 7 to 9 roundtrips at the surface areas noted above to cover the entire reservoir surface with 10,000 to 14,000 gallons of Aquatain anti-evaporation liquid. The drop speed of these aircraft is 120 miles per hour and the entire length of the reservoir is 112 miles.

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They can travel for a total of 610 miles before needing to refuel, so the aircraft will circle the reservoir twice before refueling. The Boulder City Airport would probably be the airport where the aircraft would refuel and pick up more Aquatain anti-evaporation liquid. Lake Mead is four miles southeast of Boulder City making the refueling and pickup of more anti-evaporation liquid easier. A gravel strip could even be built where the aircraft would land to load more Aquatain anti-evaporation liquid.

Aquatain is insoluble in water, and degrades into carbon dioxide, Inorganic Silicate and water. Aquatain has been approved for drinking water use and is pending approval for mosquito abatement use across the nation. The technology has been developed and available commercially since 2003. Facilities currently using Aquatain in the United States are swimming pools, golf course ponds, community ponds and lagoons.

Costs: Provide cost and funding information, if available, including capital, operations, maintenance, repair, replacement, and any other costs and sources of funds (e.g., public, private, or both public and private). Identify what is and is not included in the provided cost numbers and provide references used for cost justification. Methodologies for calculating unit costs (e.g., $/acre-foot or $/million gallons) vary widely; therefore, do not provide unit costs without also providing the assumed capital and annual costs for the option, and the methodology used to calculate unit costs.

Quantifying costs do vary widely, so to give some sense of the affordability of this solution, other data is provided in the next two paragraphs that explain the amount spent on other projects with resulting acre-feet costs.

SNWA recently spent 115 million dollars on Brock reservoir to receive 400,000 acre-feet over 20 years; this would make the cost of water at $288 acre-foot. SNWA, being a wholesaler sells untreated water for $220 per acre-foot.

California wholesalers have paid $800 per acre-foot in past years. The proposed pipeline, SNWA is trying to put in to bring 200,000 acre-feet from Northern counties in Nevada is at the cost of$3.5 billion or $20,000 per acre-foot initially due to high capital costs and then ongoing for 50 years will equal about $350 an acre-foot.

The cost of applying anti-evaporation liquid, Aquatain to the surface of Lake Mead will cost approximately $91/AF plus aircraft, fuel, delivery fees, permits and maintenance fees. Factors including quantity and monitoring could affect price per year. In the table below, anticipated costs are shown:

50 year Costs					
#	Item	Capital	Operations	Repair	Replacement
2	AT-802A Aircraft	$3,600,000	$1,000,000	$1,000,000	$3,600,000
166,878	Gallons Gasoline	na	$951,205	na	na
18,250,000	Gallons Aquatain anti-evaporation liquid	$1,825,000,000	na	na	na
2	Pilots	na	$7,000,000	na	na
50	Monitoring and Reporting	na	$3,750,000	na	na
Total		$1,828,600,000	$12,701,205	$1,000,000	$3,600,000
Operations		$12,701,205			
Repair		$1,000,000			
Replacement		$3,600,000			
Overall Total		**$1,846,000,000**			

Lake Mead - 50 years total savings: **20,000,000 acre-feet of water.**

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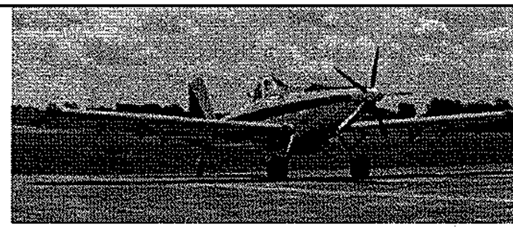
The AT-802/802A is the world's largest single engine aircraft, and its popularity reflects the industry's trend to larger, high-production turbine equipment. With a payload of 9,500 lbs, the AT-802A provides more working capacity than any other single-engine agriculture plane. Its power, speed and payload deliver large operation efficiencies.



The AT-802A aircraft will carry 800 US gallons of Aquatain along with 254 US gallons of gasoline. The lead time for buying this aircraft is 15 months. The AT-802A aircraft with all required equipment is 1.8 million dollars. The aircraft is designed to operate "loaded" from small community airports or remote gravel strips having a minimum runway length of 4,000 feet. Once it has dropped its initial load, aircraft can return for more Aquatain. Because of its speed, maneuverability and quick turn-around, the AT-802A aircraft are especially effective for this.

Permitting: List the permits and/or approvals required and status of any permits and/or approvals received.

None required

Legal / Public Policy Considerations: Describe legal/public policy considerations associated with the option. Describe any agreements necessary for implementation and any potential water rights issues, if known.

A new type of surplus called Intentionally Created Surplus (ICS) was recently instituted and the saved water by applying Aquatain anti-evaporation liquid could give SNWA or any other entity interested in creating ICS, a way of producing a quantity of water any year they want to apply it.

Aquatain does not affect water chemistry or prevent oxygenation. Aquatain is safe for human contact, even ingestion. Aquatain does not affect the environment or bio-accumulate and does not adversely affect potable water. Aquatain is Certified by NSF International/ANSI60 as safe for human contact and application to drinking water storages. There are 50 years of medical studies on PDMS (main ingredient) and examples where formulations of this substance are used would be in syringes (it coats the inside making it easier for the rubber washer to slide up and down), infant care such as baby bottle nipples and personal care like shampoos, lotions, sun screens, lipsticks, eye liner and are food additives.

Implementation Risk / Uncertainty: Describe any aspects of the option that involves risk or uncertainty related to implementing the option.

Water Rights to Evaporation Loss: Who has the authority to take control of this water? Anyone that puts up enough money?

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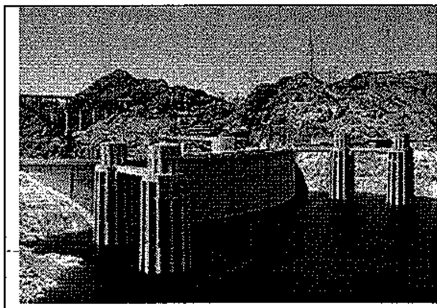
Reliability: Describe the anticipated reliability of the option and any known risks to supply or demand, such as: drought risk, water contamination risk, risk of infrastructure failure, etc.



The intakes to the Hoover Dam will need to be surrounded by a one foot depth barrier on the surface of the water to prevent the Aquatain from leaving the reservoir by being sucked into the intakes.

Photo: Hoover Dam Images

Water Quality: Identify key water quality implications (salinity and other constituents) associated with the option in all of the locations the option may affect.

Decreasing evaporation will decrease the salinity creation. Evaporation is the main culprit in leaving salt behind during the evaporation process. Adding anti-evaporation liquid is a solution to mitigate this problem.

Energy Needs: Describe, and quantify if known, the energy needs associated with the option. Include any energy required to obtain, treat, and deliver the water to the defined location at the defined quality.

Energy Required	Source(s) of Energy
Not applicable	

Hydroelectric Energy Generation: Describe, and quantify if known, any anticipated increases or decreases in hydroelectric energy generation as a result of the option.

Location of Generation	Impact to Generation
Hoover Dam	For every foot of surface elevation lost, 5.7 Megawatts of power generation is lost. Each year 3.75 feet of evaporation would be cut increasing the potential generation power of the Hoover Dam. The water intakes at the Hoover Dam provide a maximum hydraulic head (water pressure) of 590 feet as the water reaches a speed of about 85 mph. The total generation of the dam is 2080 MW. The full elevation of the lake is at 1,219 feet. The current level is 1,112 feet. The lowest recorded level happened in June 2010 at 1,082 feet. The level at which power cannot be generated any longer is 1,050 feet. The bottom of the dam is at elevation 506 feet. Hoover Dam is in the process of replacing their turbines with a new design that can work at surface elevation 1,000. The new turbine would only need 540 feet of hydraulic head.

Recreation: Describe any anticipated positive or negative effects on recreation.

Location(s)	Anticipate Benefits or Impacts

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Entire Lake Mead	No impacts on recreation.

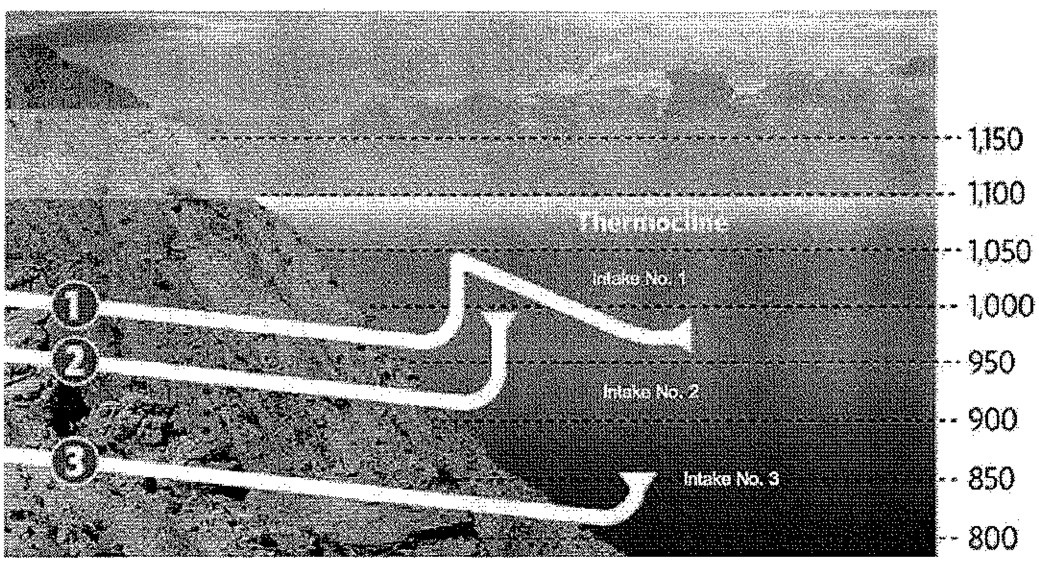
Environment: Describe any anticipated positive or negative effects on ecosystems within or outside of the Colorado River Basin.

Location(s)	Anticipated Benefits or Impacts
Entire Lake Mead Reservoir	Less evaporation means less heat loss from the surface of the water. Heat loss will be decreased by 15% to 20%. Before the dams were created, the water temperature ranged from over 80 degree F in the heat of the summer to just above 32 degrees F in the winter. Impounding water in reservoirs affects the water temperature of dam releases due to thermal stratification. During the summer, the surface layers of the reservoirs are typically warm as the result of inflows, ambient air temperature, and solar radiation. Conversely, lower reservoir layers remain cooler year-round. For these reasons, water temperatures downstream of reservoirs are influenced by reservoir water levels. Water temperature can affect the health of flow- and water-dependent species in the Basin.

Socioeconomics: Describe anticipated positive or negative socioeconomic (social and economic factors) effects.

The Metropolitan Water District of Southern California pumps water across the Colorado River Aqueduct to hydrate much of Southern California and without Hoover Dam's hydroelectric power, Metropolitan's costs to transport water will double or even triple.

Metropolitan and the Southern Nevada Water Authority are storing excess water from other sources in Lake Mead, and so when water leaves due to evaporation, that storage leaves with it. This solution is a win-win for all stakeholders on the Colorado River Basin.



Source: Southern Nevada Water Authority and Jean Reid Norman, "Water demand drop-off postpones intake work," *Las Vegas Sun*, Sunday, Sept. 13, 2009.

SNWA also has interest in creating additional storage in the lake and keeping the level of the lake higher than

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their first intake. At the cost per acre-foot much lower than current projects underway, many stakeholders will have interest in submitting money to have a portion of this water set aside for them.

Other Information: Provide other information as appropriate, including potential secondary benefits or considerations. Attach supporting documentation or references, if applicable.

Potential secondary benefits:

The solution is not permanent.

We Can't Make It Rain….
But We Can Help Ease The Pain!

A NEW GENERATION PRODUCT!




WaterGuard

Liquid blanket to save water

- **Easy to apply**
- **Cost-effective**

WaterGuard
Liquid blanket to save water

Introducing..... WaterGuard!

WaterGuard is a unique liquid which spreads over the surface of water to form a very thin film and reduce evaporation.

Many people are familiar with Aquatain, the first silicone based liquid for evaporation control. WaterGuard is a new, improved formulation manufactured by Aquatain Products Pty Ltd which is even more effective and more economical for reducing evaporation from farm dams, reservoirs and pools.

How Does It Work?

WaterGuard is produced from polymers which repel each other very strongly when they come in contact with the water. This results in a strong spreading action across the surface, forming a liquid ‘blanket’ to reduce evaporation.

Why Is It Important To Reduce Evaporation?

Water losses from evaporation are immense. A single square metre of water surface can easily lose up to 8 litres to evaporation every day in summer, and a one hectare dam can lose up to 80,000 litres. Water that is essential for animals and growing crops.

What Savings Can You Expect With WaterGuard?

Trials in the US have achieved evaporation savings of 50% and above.

Is WaterGuard Safe?

The components of WaterGuard are safe chemicals, and many of them are used in food and pharmaceutical applications.

An application for certification of WaterGuard for drinking water is currently underway.

Rain, Wave And Wind Action?

Once the film is in place, it is very resistant to disturbances. It will move around slowly over the surface, but will not build up at one end of the water body. In the event of rain, the blanket will not be affected as it will allow the rain to go through without disturbing the film.

Application Methods

WaterGuard can simply be poured on to the water directly from the drum, and it will spread rapidly across the surface. For larger applications, it can also be applied by air.

PATENTS PENDING WORLDWIDE

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