



Documentation for the Agricultural
Water Conservation Goals and
Recommended Methods to Track
Progress

Final Report

January 2019

Prepared for:
Coachella Valley Water District

Prepared by:
Stantec
In association with
David J. Ringel, Consulting Engineer
and
Davids Engineering

Table of Contents

LIST OF ABBREVIATIONS	I
EXECUTIVE SUMMARY	III
ES.1 HISTORICAL AGRICULTURAL WATER USE.....	III
ES.2 BASIS FOR 2010 CVWMP UPDATE AGRICULTURAL WATER CONSERVATION GOAL	IV
ES.3 PROJECTED AGRICULTURAL USE AND CONSERVATION	IV
ES.4 EVALUATING AGRICULTURAL WATER USE EFFICIENCY AND CONSERVATION IN THE COACHELLA VALLEY.....	V
ES.5 RECOMMENDATIONS	V
1.0 INTRODUCTION	1.1
2.0 HISTORICAL AGRICULTURAL WATER USE	2.1
2.1 FACTORS AFFECTING AGRICULTURAL WATER USE	2.1
2.2 WATER USE BY SOURCE	2.2
2.3 AGRICULTURAL ACRES.....	2.6
2.4 AVERAGE WATER USE PER IRRIGATED ACRE.....	2.9
2.5 AGRICULTURAL WATER USE BASELINE.....	2.10
2.6 HISTORICAL WATER USE REDUCTION COMPARED TO BASELINE	2.10
2.7 ADDITIONAL FACTORS FOR CONSIDERATION	2.13
3.0 BASIS FOR AGRICULTURAL WATER CONSERVATION TARGETS IN 2010 CVWMP UPDATE	3.1
3.1 2002 CVWMP TARGET	3.1
3.2 2010 CVWMP UPDATE TARGET	3.1
3.2.1 Water Advisory Committee.....	3.2
3.2.2 Water 2025 Report.....	3.2
3.2.3 Extraordinary Conservation Program	3.5
3.3 SUMMARY	3.5
4.0 PROJECTED AGRICULTURAL WATER USE AND CONSERVATION	4.1
4.1 AGRICULTURAL ACREAGE REDUCTION.....	4.1
4.2 PROJECTED AGRICULTURAL USE WITHOUT AND WITH CONSERVATION	4.2
4.3 REDUCTION IN AGRICULTURAL GROUNDWATER USE.....	4.7
4.4 OBSERVATIONS	4.8
5.0 EVALUATING AGRICULTURAL WATER USE EFFICIENCY AND CONSERVATION IN THE COACHELLA VALLEY	5.1
5.1 OVERVIEW	5.1
5.2 ON-FARM WATER BUDGET COMPONENTS.....	5.1
5.3 AGRONOMIC WATER USES	5.2
5.4 RECOVERABLE VS. IRRECOVERABLE LOSSES.....	5.3
5.5 METHODS TO QUANTIFY AGRICULTURAL WATER USE EFFICIENCY (WUE).....	5.4
5.5.1 Crop Consumptive Use Fraction	5.4
5.5.2 Agronomic Water Use Fraction	5.4

5.5.3	Total Water Use Fraction	5.5
5.5.4	Water Management Fraction	5.5
5.6	APPLICABILITY OF WUE METHODS TO CVWD	5.5
5.6.1	Coachella Valley Agriculture.....	5.6
5.6.2	Available Information to Support Quantification of Agricultural Water Use Efficiency	5.6
6.0	RECOMMENDATIONS	6.1
6.1	EVALUATION OF WATER USE EFFICIENCY	6.1
6.2	OUTREACH WITH THE AGRICULTURAL COMMUNITY	6.2
7.0	REFERENCES.....	7.1

LIST OF TABLES

Table 2-1	Five-Year History of Crops by Acreage	2.3
Table 2-2	Historical Agricultural Water Use by Source	2.4
Table 2-3	Historical Agricultural Acreage - Improvement District No. 1	2.7
Table 2-4	Estimated Irrigated Agricultural Acreage	2.9
Table 2-5	Estimated Agricultural Water Use Per Irrigated Acre	2.10
Table 2-6	Comparison of Agricultural Water Use Per Irrigated Acre with Baseline	2.11
Table 3-1	Total Savings by Conservation Technique - Water 2025 Report	3.3
Table 4-1	Projected Agricultural Water Demand - 2010 CVWMP Update.....	4.5
Table 4-2	Projected Agricultural Pumping from 2010 CVWMP Update	4.8
Table 5-1	Potential Agronomic Uses of Water in the Coachella Valley	5.3

LIST OF FIGURES

Figure 2-1	Historical Agricultural Water Usage (Figure 6-1, 2010 CVWMP Update).....	2.1
Figure 2-2	Comparison of Agricultural Water Use Per Irrigated Acre with Baseline	2.12
Figure 5-1	On-Farm Water Budget Components.....	5.2

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

List of Abbreviations

LIST OF ABBREVIATIONS

AF	Acre-Feet
AFY	Acre-Feet per Year
AQMD	South Coast Air Quality Management District
AW	Applied Irrigation Water
AWMP	Agricultural Water Management Plan
AWUF	Agronomic Water Use Fraction
CCUF	Crop Consumptive Use Fraction
CIMIS	California Irrigation Management Information System
CVWD	Coachella Valley Water District
CVWMP	Coachella Valley Water Management Plan
DP	Deep Percolation
DP _{aw}	Deep Percolation Derived from Applied Water
DP _{pr}	Deep Percolation Derived from Precipitation
DWR	California Department of Water Resources
ET	Evapotranspiration
ET _{aw}	ET Derived from Applied Water
ET _o	Reference Evapotranspiration
ET _{pr}	ET Derived from Precipitation
GIS	Geographical Information System
ID-1	Improvement District No. 1
IID	Imperial Irrigation District
IOPP	Inadvertent Overrun and Payback Policy
METRIC	Mapping Evapotranspiration at High Resolution with Internalized Calibration
NCEI	National Center for Environmental Information
NRCS	Natural Resources Conservation Service
PEIR	Program Environmental Impact Report
Pr	Precipitation
PRISM	Parameter-Elevation Regressions on Independent Slopes Model
QSA	Quantification Settlement Agreement
RAC	East Whitewater River Subbasin Area of Benefit Replenishment Assessment Charge
RO _{pr}	Runoff from Precipitation
SCAG	Southern California Association for Governments
SEBAL	Surface Energy Balance Algorithm for Land
SWP	State Water Project
TW	Tailwater of Runoff from Irrigation
TWUF	Total Water Use Fraction
USBR	United States Bureau of Reclamation
VSD	Valley Sanitary District
WAC	Water Advisory Committee
WMF	Water Management Fraction
WMP	Water Management Plan
WUE	Water Use Efficiency

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

List of Abbreviations

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Executive Summary

EXECUTIVE SUMMARY

The Coachella Valley Water District (CVWD) provides domestic water, wastewater, recycled water, irrigation/drainage, regional stormwater protection and groundwater management services throughout the Coachella Valley in Southern California. CVWD adopted the Coachella Valley Water Management Plan in 2002 (2002 CVWMP) to meet projected water needs and eliminate groundwater overdraft. The 2002 CVWMP was updated in 2010 and adopted by the CVWD Board of Directors in January 2012. The 2010 CVWMP Update serves as a roadmap for water resources planning and development for the Coachella Valley.

CVWD seeks to document the sources of data, assumptions, and calculations used to develop the agricultural water conservation goal of the 2010 CVWMP Update and develop methods to evaluate progress toward meeting the conservation goal. The scope of this report is to:

- Describe the data sources and methods used to estimate historical and future agricultural water use.
- Describe basis for agricultural water conservation targets in the 2010 WMP Update
- Evaluate alternative methods for estimating agricultural water conservation
- Recommend one or more methods to determine agricultural water conservation performance along with corresponding data needs

ES.1 HISTORICAL AGRICULTURAL WATER USE

CVWD requested information documenting the calculations of historical agricultural water use per irrigated acre. Water use per irrigated acre was used to estimate progress toward meeting the agricultural water conservation objective of the 2010 CVWMP Update. Multiple factors affect agricultural water use including crop type, crop-specific water and leaching requirements, acreage, other agronomic water uses such as evaporative chilling and frost protection, weather conditions, irrigation method, soil type and water source. Water use per irrigated acre was estimated for the 2010 CVWMP Update by compiling the annual water use for agriculture and dividing by the total acreage of irrigated crops.

Water delivery and irrigated acreage data prior to 2012 is not as reliable as data after 2012. While data is available for Canal water, fish farm effluent and recycled water deliveries, groundwater production data prior to 2005 was estimated from typical crop-specific water factors and acreages. From 2005 to 2011, groundwater production data is a combination of estimates and reported production; after 2012, all groundwater production is reported.

Irrigated acreage was based on crop survey data for Improvement District No. 1 (ID-1), the service area for Canal water. Acreage for agricultural land outside ID-1 was estimated prior to 2013. Beginning in 2014, CVWD digitizes its crop surveys in geographical information system (GIS) format, providing a significant accuracy improvement. For this report, historical data is reviewed and evaluated on a consistent basis to determine the acreage of irrigated crop land each year. Irrigated acreage decreased by about 13,000 acres from 2000 to 2009 due to urban development. Since the 2008-2009 recession, irrigated acreage increased by about 4,000 acres.

Estimated average water use per acre has ranged from 5.3 to 6.25 acre-feet per year per acre (AFY/acre) for the period 2000-2017. Water use per acre for the period 2000-2002 (before adoption of the 2002 CVWMP) averaged 6.11 AFY/acre; the 2010 CVWMP Update considered this as a “baseline” value. After adoption of the 2002 CVWMP, agricultural water use reduced by an average of 6.6 percent ranging from +4.9 percent to -13 percent.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Executive Summary

The potential inaccuracy of the irrigated acreage values prior to the use of GIS and the lack of reliable groundwater pumping data for the period 2000-2011 limit the accuracy of the water use per acre calculation as a metric for evaluating water conservation progress, especially for establishing a baseline to measure conservation performance. The variability of crop acreage, local weather conditions, and irrigation efficiency can play a significant role in the calculation of the average water use per acre. That said, the average agricultural water use per acre can still be a valuable planning metric for projecting future agricultural water demand in the Valley.

ES.2 BASIS FOR 2010 CVWMP UPDATE AGRICULTURAL WATER CONSERVATION GOAL

The 2002 CVWMP established an initial water conservation target for agricultural demand of 7 percent. This savings goal was based on increasing the average irrigation efficiency of Valley agriculture from 70 percent to 75 percent assuming no change in the overall crop mix. The 2010 CVWMP Update reviewed progress toward achieving the 7 percent goal and concluded that agricultural water use per acre had declined by an average of 9.9 percent for the 2003-2008 period. The 2010 CVWMP Update established a revised agricultural water conservation target of 14 percent. This target was based on information derived from three CVWD-led efforts: the Water Advisory Committee (WAC), the United States Bureau of Reclamation (USBR) Water 2025 Report, and the Extraordinary Water Conservation program, which are described in Section 3 of this report.

CVWD established the WAC in the 1990s to assist the District in analyzing past and current agricultural water use and water management within the Imperial Irrigation District (IID) and Improvement District No. 1 (ID-1) of the CVWD. The WAC report recommended methods for improving agricultural water use efficiency through scientific irrigation scheduling, improvements to irrigation systems, improved water, soil, and weather monitoring, and development of an irrigated land and water use database to provide field-specific to assist farmers.

The Water 2025 Report identified specific conservation savings of 47,600 AFY from a combination of flood to drip irrigation conversions, flood to sprinkler irrigation conversions, existing irrigation system overhauls, scientific irrigation management, and scientific soil salinity management. If these programs were implemented, a 14 percent reduction in agricultural water use could be achieved. CVWD also implemented a successful Extraordinary Conservation Program whereby CVWD farmers reduced agricultural water use during the period 2004 through 2009 by 73,200 AF and paid back the 2001-2002 overrun two years early.

The results of the Extraordinary Conservation Program and the Water 2025 Report represented the best data available supporting the 14 percent agricultural water conservation target at the time the 2010 CVWMP Update was prepared. Both programs required significant investments of CVWD funds to achieve the savings that were observed. The 14 percent conservation target may ultimately be attainable but would require substantial investment in the form of CVWD-furnished services, rebates, and other grower incentives.

ES.3 PROJECTED AGRICULTURAL USE AND CONSERVATION

The 2010 CVWMP Update projected agricultural water use to decline in response to urban development on agricultural land and water conservation. When the 2010 CVWMP Update was prepared, the population of the Eastern Coachella Valley was projected to increase from about 175,000 in 2005 to about 759,000 by 2045. This level of development was estimated to require about 45,600 acres of land, half of which was assumed to be agricultural and half raw (vacant) land. Demand on tribal land was expected to increase as growth occurred. Factoring in the loss of agricultural land and water

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Executive Summary

conservation, agricultural water demand was projected to decrease from about 328,000 AFY to 142,000 AFY in 2045. Water conservation was estimated to account for about 23,000 AFY of demand reduction by 2045.

The planning environment of the Valley has changed since the 2010 CVWMP Update was prepared. The growth anticipated in the Update has not materialized. Recent SCAG growth forecasts show about 40 percent lower growth than they projected when the 2010 CVWMP Update was prepared. Agricultural water use has been relatively stable for the past five years averaging about 297,000 AFY.

Agricultural use of groundwater was projected to decreased significantly due to a combination of water conservation, increased use of Canal water, and development of the Oasis Distribution System Project. This latter project would deliver Canal water to farms in the Oasis area where there is no Canal water distribution system. The Oasis distribution system has not yet been implemented. Development of this project could have a significant effect on meeting the groundwater pumping targets of the Update. The groundwater reduction targets in the 2010 CVWMP Update for agriculture have not materialized. In fact, agricultural use of groundwater has increased by about 7,000 AFY since 2012.

ES.4 EVALUATING AGRICULTURAL WATER USE EFFICIENCY AND CONSERVATION IN THE COACHELLA VALLEY

Alternative methods for documenting agricultural water conservation progress are considered in this report. Section 5 describes components of on-farm water use in the context of a water budget, reasonable and agronomic uses in the Coachella Valley, recoverable and irrecoverable losses of applied irrigation water. Agronomic water uses include, crop evapotranspiration, leaching, seedbed preparation, germination, hydrocooling, frost protection, market quality and dust control.

In 2012, the California Department of Water Resources (DWR), in consultation with the California Agricultural Water Management Council, academic experts, other irrigation experts, and other stakeholders prepared a report for the Legislature on proposed methods to determine agricultural water use efficiency. This report developed several metrics for evaluating agricultural water use efficiency including 1) Crop Consumptive Use Fraction (CCUF), 2) Agronomic Water Use Fraction (AWUF), 3) Total Water Use Fraction (TWUF), and 4) Water Management Fraction (WMF). These methods are described in Section 5. Of these methods, the AWUF appears to be most applicable to CVWD for evaluating agricultural water use efficiency as it recognizes all agronomic uses of water and can be applied at both the farm and the District scale

CVWD currently collects data on crop acreage, irrigation methods, and surface water and groundwater deliveries. These data can be supplemented with precipitation, crop evapotranspiration, leaching, and other agronomic uses to calculate the theoretical amount of water required for agriculture. The AWUF compares the theoretical amount of water required with the actual amount of water used. Changes to the agronomic water use fraction over time would provide an indication of progress in meeting water use efficiency goals.

ES.5 RECOMMENDATIONS

It is recommended that the CVWD utilize the AWUF outlined in the DWR 2012. This water use efficiency method can be applied at both the farm and District scale and characterizes agricultural water management and changes in applied surface water over time, considering cropping changes, weather variation, irrigation methods, and other factors.

It is further recommended that the CVWD:

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Executive Summary

- Evaluate the quality of existing data and develop and implement a plan to improve data quality over time;
- Implement the procedures developed by JMLord and described in the Water 2025 report to estimate surface water use at the farm scale. Combining this with information on well location from the groundwater replenishment assessment to estimate total water use at the farm scale.
- Refine existing estimates of agronomic water use through outreach with CVWD growers. This could be through a combination of surveys, direct interviews, and grower meetings. Information would be gathered on several aspects of farm water management.
- Evaluate the use of remote sensing data to determine crop evapotranspiration.
- Evaluate District-wide irrigation efficiency based on crop acreage and irrigation method using GIS data for the crop reports.
- Calculate average agricultural water use per acre as a general planning number and determine a reasonable range for this value for projecting future agricultural water demands.
- Reevaluate the assumptions for urban growth on agricultural land versus raw land using data from recent and proposed developments.
- Revisit the assumption of a stable future crop mix and its effects on water use per acre in future CVWMP updates.
- Continue to refine projected agricultural demands based on adopted growth forecasts as they become available.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Introduction

1.0 Introduction

The Coachella Valley Water District (CVWD) provides domestic water, wastewater, recycled water, irrigation/drainage, regional stormwater protection and groundwater management services to a population of 290,000 throughout the Coachella Valley in Southern California. CVWD operates and maintains 2,004 miles of domestic water piping, 1,129 miles of sanitary sewers, 485 miles of irrigation water piping, and 134 miles of stormwater channels. The system also includes 93 domestic water wells, 62 domestic reservoirs, five wastewater reclamation plants, and three groundwater recharge facilities. The mission of CVWD is to provide a reliable, safe water supply to the Coachella Valley.

CVWD adopted the Coachella Valley Water Management Plan in 2002 (2002 CVWMP) to meet projected water needs and eliminate groundwater overdraft. The 2002 CVWMP was updated in 2010 in response to changes in the water planning environment such as increased growth projections and reduced State Water Project (SWP) reliability. The 2010 Coachella Valley Water Management Plan Update (2010 CVWMP Update) was adopted by the CVWD Board of Directors in January 2012, following completion of a supplemental program environmental impact report (PEIR). The 2010 CVWMP Update has a 35-year planning horizon (to 2045) and serves as a roadmap for water resources planning and development for the Coachella Valley.

An integral portion of the original 2002 CVWMP and 2010 CVWMP Update is the implementation of water conservation programs to use the available water supplies as efficiently as possible. The 2002 CVWMP established water conservation goals for urban, golf, and agricultural uses. The original agricultural conservation goal was a seven percent savings. This goal was reviewed and revised in the 2010 CVWMP Update. The revised goal for agricultural water conservation was a 14 percent savings in water use by 2020 compared to historical use. The 2010 CVWMP Update used the period of 2000-2002 as the historical use baseline for agricultural water use as representing the most recent period before adoption of the 2002 CVWMP.

The 2002 CVWMP and the 2010 CVWMP Update were prepared by MWH and WaterConsult with input from JMLord, Inc. on agricultural planning and conservation. MWH was acquired by Stantec Consulting, Inc. in 2016. For purposes of this report, work performed prior to MWH's acquisition is attributed to MWH and work performed after is attributed to Stantec.

CVWD seeks to document the sources of data, assumptions, and calculations used to develop the agricultural water conservation goal of the 2010 CVWMP Update and develop methods to evaluate progress toward meeting the conservation goal. The scope of this report is to:

- Describe the data sources and methods used to estimate historical and future agricultural water use
- Describe basis for agricultural water conservation targets in the 2010 WMP Update
- Evaluate alternative methods for estimating agricultural water conservation
- Recommend one or more methods to determine agricultural water conservation performance along with corresponding data needs

This report consists of the following sections:

1. Introduction
2. Historical Agricultural Water Use
3. Basis for 2010 CVWMP Update Agricultural Water Conservation Goal
4. Projected Agricultural Use and Conservation

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Introduction

5. Evaluating Agricultural Water Use Efficiency and Conservation in The Coachella Valley
6. Recommendations
7. References

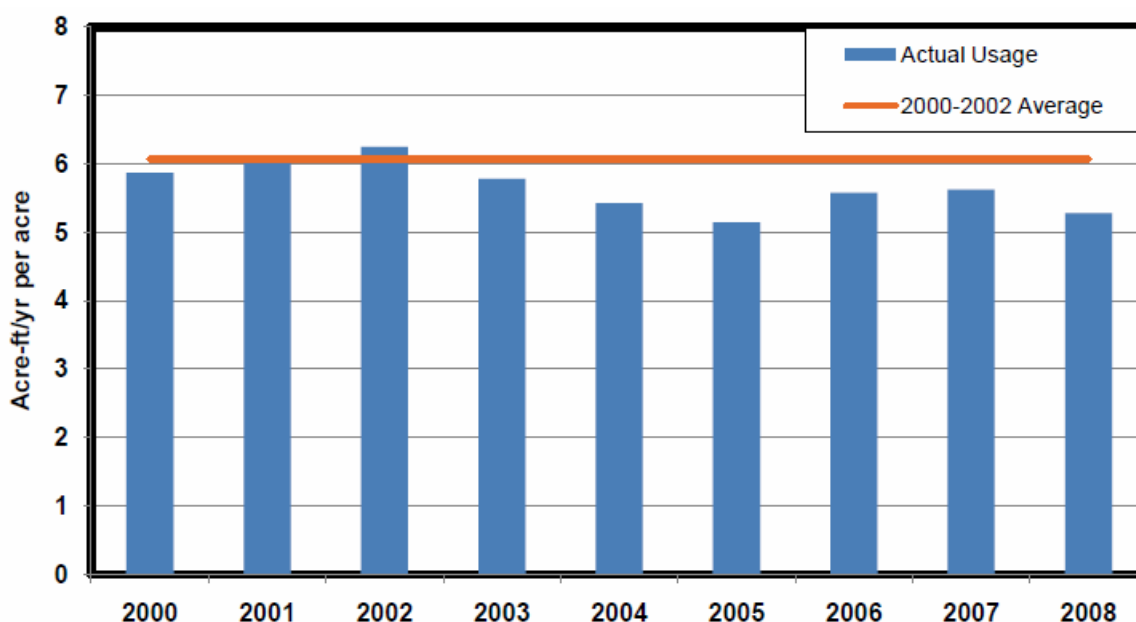
DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Historical Agricultural Water Use

2.0 Historical Agricultural Water Use

The purpose of this section is to describe the data sources, assumptions, and calculations used to estimate historical agricultural water use per acre in the 2010 CVWMP Update. Figure 6-1 of the 2010 CVWMP Update presented a comparison of average agricultural water use per irrigated acre for the period 2000 - 2008. This figure indicated agricultural water use per irrigated acre for the period 2003 - 2008 had declined by 9.9 percent compared to the period 2000-2002, which represented the period prior to the adoption and implementation of the 2002 CVWMP. Figure 6-1 of the 2010 CVWMP Update is replicated as Figure 2-1 here, as shown below.

Figure 2-1 Historical Agricultural Water Usage (Figure 6-1, 2010 CVWMP Update)



2.1 Factors Affecting Agricultural Water Use

The 2010 CVWMP Update projected the development of both agricultural and vacant land for urban land uses as the population in the Valley increased. In the absence of information on the locations and extent of future development, the 2010 CVWMP Update assumed that half of new development in the Eastern Coachella Valley would occur on raw or vacant land and half would occur on existing agricultural land. As agriculture land was converted to urban uses, the agricultural water demand was expected to decrease over time. The 2010 CVWMP Update considered the uncertainty associated with future water demand projections in Section 3.4 of that report and presented a range of possible future demands in Figure 3-4 of that report based on a sensitivity analysis. Total water demand without conservation was estimated to range from 793,600 to 971,500 AFY in 2045. Variations on the assumption regarding development of raw versus agricultural land was a primary reason for this range.

A method was needed to project the amount of water needed for agricultural purposes in the future. The 2010 CVWD Update planning staff determined that the average agricultural water use per irrigated acre, adjusted for future water conservation, would be applied to the projected agricultural acreage to estimate

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Historical Agricultural Water Use

future agricultural demand. The initial step was to estimate the amount of water historically used by agriculture prior to adoption of the 2002 CVWMP.

Numerous factors affect agricultural water use per acre, including:

- Crop type,
- Crop-specific water and leaching requirements,
- On-farm practices such as double-cropping or multi-cropping (growing multiple crops on the same acreage),
- Climate control such as evaporative chilling and frost protection,
- Potential evapotranspiration and micro-climates,
- Irrigation method (for example flood, sprinkler, drip, etc.) and distribution uniformity,
- Soil type, and
- Water source - Canal water, groundwater, or recycled water

At the time the 2010 CVWMP Update was being prepared, it was understood that agricultural crops grown in the CVWD service area were relatively consistent from year to year due to significant amounts of permanent crops, predominantly dates, citrus, and table grapes, and seasonal vegetable crops. In the absence of better data, the 2010 CVWMP Update assumed that the general mix of crops would remain essentially the same in the future and that the historical average water use per irrigated acre was a reasonable approximation of future agricultural water needs. Water use per irrigated acre was estimated by compiling the annual water use for agriculture and dividing by the total acreage of irrigated crops.

Table 2-1 shows a five-year history of the top ten crops grown in the Coachella Valley as presented in CVWD's 2016 Crop Report. This table shows the annual variability in acreage, which can affect the irrigation water requirements. Although the 2010 CVWMP Update assumed a stable crop mix in the future, these recent data show that crop acreages can vary significantly from year to year based on market conditions. Consequently, CVWD should revisit the assumption of a stable future crop mix and its effects on water use per acre in future CVWMP updates.

The following subsections describe the information used to determine water use per acre.

2.2 WATER USE BY SOURCE

Coachella Valley farmers obtain their water supply from two principal sources: Coachella Canal water and local groundwater. In previous years, certain farmers used fish farm effluent or recycled water, respectively, for irrigation when it was available and cost-effective. Table 2-2 presents the historical agricultural water use by source type for the period 2000-2017 in acre-feet per year (AFY). The following paragraphs describe the basis for the values in this table.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Historical Agricultural Water Use

Table 2-1 Five-Year History of Crops by Acreage

Crop Description	2012	2013	2014	2015	2016
Dates	7600	7600	7765	8211	7964
Grapes	7497	7992	7802	7592	7379
Golf Course	5775	5637	6007	6043	6043
Bell Peppers	4899	4558	4490	5044	5288
Carrots	2587	3141	3930	4572	4777
Lemon-Lime	3983	4014	3887	3902	3927
Lettuce	3999	3823	3234	2930	3217
Dates- N/B	1065	1343	1602	1878	2170
Sweet Corn	2795	1995	1259	1279	1883
Cauliflower	1195	1125	1008	1134	1417
Top Ten Crops	41395	41228	40984	42585	44065
Other Crops	23774	23176	23327	22063	22552
* All Crops Combined	65581	65745	66431	65729	66617

Reference: CVWD, 2016 Crop Report, page 13. Acreage includes double crops.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Historical Agricultural Water Use

Table 2-2 Historical Agricultural Water Use by Source

Year	Canal Water ¹ (AFY)	Estimated Groundwater Pumping ² (AFY)	Reported Groundwater Pumping ³ (AFY)	Fish Farm Effluent ⁴ (AFY)	Recycled Water (VSD) ⁴ (AFY)	Total Water (AFY)
2000	267,829	100,155	0	951	1,549	370,484
2001	258,204	104,145	0	1,226	1,627	365,202
2002	262,405	105,914	0	1,305	1,260	370,884
2003	233,404	94,931	0	1,191	715	330,241
2004	222,041	80,440	0	617	760	303,858
2005	205,974	51,297	24,119	1,252	712	283,354
2006	227,684	40,130	25,335	986	622	294,758
2007	241,115	23,796	29,561	865	532	295,870
2008	244,856	35,952	27,620	926	443	309,796
2009	248,620	40,000	24,851	0	353	313,824
2010	230,773	36,395	30,773	0	157	298,098
2011	242,487	28,649	31,986	0	212	303,334
2012	254,519	0	33,836	0	217	288,572
2013	251,506	0	33,539	0	142	285,187
2014	269,206	0	35,730	0	0	304,936
2015	254,915	0	39,578	0	0	294,493
2016	268,130	0	40,759	0	0	308,889
2017	251,476	0	40,096	0	0	291,572

Reference: CVWD Agricultural Water Production Records: 2000-2017.

Notes:

- 1 Canal water deliveries shown are exclusively for irrigated agriculture and exclude recreational uses (golf and lakes) and groundwater replenishment.
- 2 Groundwater production was estimated based on calculated crop water demand minus Canal water deliveries and reported groundwater production. Beginning in 2005, groundwater pumpers began reporting production. The values shown are estimated unreported production calculated by subtracting the reported production from the estimate total groundwater production (calculated from the crop water use minus Canal deliveries).
- 3 Groundwater production in this column is based solely on production meter records reported to CVWD. All agricultural were reporting their production beginning in 2012.
- 4 Kent Seatech provided fish farm effluent to several nearby farms until 2009 when the fish farm operation ceased. The 2010 CVWMP Update assumed half of the available fish farm effluent was used for agriculture and the remainder for one-site fish farm use.
- 5 Recycled water from Valley Sanitary District (VSD) was used to irrigate forage crops until 2013, after which irrigation was discontinued.

Coachella Canal water is the principal water supply for agriculture within Improvement District No. 1 (ID-1), the contractual service area for Colorado River water. Canal water deliveries to farms are metered and CVWD maintains historical records of deliveries classified by type of use. The data presented in Table 2-2 are summarized from CVWD billing records and represent water delivered strictly for agricultural irrigation. These values exclude recreational uses such as golf course irrigation and lakes, deliveries to fish farms and duck clubs (which can be relatively high per acre), and groundwater replenishment. A portion of the Canal water and groundwater delivered for agricultural uses may be used for packaging and processing uses that are not directly related to crop irrigation. It is unknown whether sufficient information exists to segregate these uses from agronomic uses. The second major source of agricultural water is local groundwater pumped from the Indio Subbasin. Groundwater is pumped by some farmers inside the ID-1 service area, but groundwater is the sole source of water for farms outside the ID-1

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Historical Agricultural Water Use

service area and areas inside ID-1 that do not have access to Canal water. Prior to the implementation of the East Whitewater River Subbasin Area of Benefit Replenishment Assessment Charge (RAC) in 2005, historical records of groundwater production were limited due to a lack of metering and production reporting to CVWD or to the State Water Resources Control Board.

In the early 1990s, CVWD retained JMLord, Inc. to evaluate historical groundwater production for use in developing and calibrating a groundwater model. JMLord estimated agricultural water use on a section-by-section basis for selected years (1958, 1968, 1975, 1980, 1987, 1992, and 1996) using digitized CVWD crop survey maps to obtain crop acreage by section, documented crop-specific water and leaching requirements, and estimated irrigation efficiency based on the typical irrigation methods practiced at those times. Total water use by section was calculated by multiplying the crop acreage by the crop-specific water and leaching requirements and dividing by the estimated irrigation efficiency and totaling the resulting demands, JMLord then estimated groundwater pumping in each section of land by subtracting the Canal water deliveries to that section from the calculated total water use. Total demand, Canal water deliveries, and estimated groundwater pumping were totaled for Canal water-served land inside ID-1, non-served land within ID-1, and land outside of ID-1.

The water use information developed by JMLord was subsequently applied to available crop acreage reports to estimate total agricultural water use and groundwater pumping for the period 2000-2008. Stantec does not have the data JMLord used for these calculations. MWH used crop acreages for 2009-2011 from CVWD's Annual Reviews and JMLord's crop water use to estimate agricultural demands and an irrigation efficiency of 72 percent for these years. Groundwater pumping was estimated by subtracting Canal water deliveries from the estimated total agricultural demand.

Following commencement of the RAC program, farmers were required by State law to report their production to CVWD. From 2005-2011, reported production tended to be lower than the estimated production calculated from crop acreage and water use factors minus other water sources. Consequently, CVWD continued to include estimated production for this period in the Engineer's reports. Beginning in 2012, CVWD staff determined that essentially all agricultural groundwater pumpers were reporting their production and estimates of groundwater use were no longer required. This change from estimated to reported pumping is shown in Table 2-2.

Fish farm effluent and recycled water were also used for crop irrigation in previous years. In accordance with a settlement agreement between Kent Seatech and CVWD, Kent implemented on-site and off-site recycling of a portion of its fish farm effluent to offset a portion of its groundwater pumping from 1996 through 2008. Due to a lack of specific data, CVWD and MWH assumed that one-half of the Kent effluent was used on-site and the balance was deliveries to nearby farms. In 2009, Kent ceased its fish farm operations and recycling program, but continued operation of an algae bioenergy facility. Kent resumed fish farm operations in 2015 but is not delivering effluent to local farmers at this time. Valley Sanitary District (VSD) delivered wastewater effluent for irrigation of nearby forage crop land until 2013, when it ceased deliveries.

In summary, review of the agricultural water source data indicates that Canal, fish farm, and recycled water data were based on available delivery records. The groundwater production values for 2000-2011 were based on estimates calculated from crop acreage and water use estimates minus the other water sources. The groundwater production values in this period are significantly higher than those after 2012 when CVWD staff determined all agricultural pumpers were reporting their production. However, there was no other more reliable water use data available for this period. Consequently, the total amount of water used for agriculture and the resulting water use per irrigated acre may be overstated for the 2000-2011 period.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Historical Agricultural Water Use

2.3 AGRICULTURAL ACRES

CVWD prepares an annual crop and water data report for submission to the United States Bureau of Reclamation (USBR) on Form 7-2045. These reports present crop acreage for land within CVWD's Improvement District No. 1 (ID-1), the service area for Coachella Canal water deliveries. Stantec compiled data presented in the crop reports which are summarized in Table 2-3 for this report. MWH had previously added the estimated irrigated acreage located outside ID-1 to determine the total acreage under irrigation each year for the period 2000-2008. This total agricultural acreage was used to estimate applied water per irrigated acre as presented in Figure 6-1 of the 2010 CVWMP Update.

There are several caveats regarding the historical crop acreage data:

1. The acreage reported on Form 7-2045 represents only the acreage within ID-1; irrigated acreage outside ID-1 is not included. Prior to 2012, irrigable land was reported to be 78,530 acres with 24,032 acres of non-irrigable land for a total acreage of 102,562 acres and excluded 34,854 acres. This latter acreage is presumed be urban and raw land and is included in the reports from 2013 to the present.
2. Over the years, the methods used to prepare the crop reports have changed. For the years prior to 2013, CVWD crop census data was entered on paper plat maps three times per year and the acreages were totaled. After 2014, the acreages were still compiled three times per year, but the data are entered directly in CVWD's geographical information system (GIS) in the field. The GIS data are believed to be substantially more accurate than the previous reports.
3. The crop reports include golf course, fish farm, duck club, and polo field acreages. For the analysis of agricultural water use, only polo fields are included in the irrigated agricultural acreage total. Canal water use data for polo fields has historically been classified as agricultural. This assumption may need to be revisited in the future as this use is primarily recreational and does not produce a harvested crop. Water deliveries and groundwater production for other uses are categorized separately.
4. The original irrigated agricultural acreage calculations for the 2010 CVWMP Update excluded non-bearing crop acreage, predominantly immature citrus, dates and table grapes. This resulted in slightly reduced irrigated acreage and higher water use per irrigated acre in the original calculations. Non-bearing crops typically use less water than mature producing crops (ranging from 20 percent of crop ET to 100 percent of crop ET at 70 percent canopy cover). At the time of the original calculations, the acreage of non-bearing crops was about one-third of that in the last five years. Some acreage is also irrigated for crops that are not-harvested commercially but used for soil building. Table 2-3 includes non-bearing and non-harvested crops in the total irrigated acreage.
5. Some data inconsistencies were observed in the USBR crop report for 2015. For example, the sum of acres by irrigation method (drip, flood, and sprinkler) should equal the sum of commercial acres, multi-cropped acres, and irrigated/not harvested acres. There appears a difference of about 500 acres in these numbers. The values shown in Table 2-3 are based on updated crop acreage data provided by CVWD.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Historical Agricultural Water Use

Table 2-3 Historical Agricultural Acreage - Improvement District No. 1

Year	Commercial Acreages ¹ (acres)	Double cropped Acreages ² (acres)	Irrigated - Not Harvested ³ (acres)	Total - Fish, Duck, Golf ⁴ (acres)	Total Irrigated Ag Land ⁵ (acres)	Not irrigated-Idle ⁶ (acres)	Not irrigated-Fallow ⁷ (acres)	Non-Commercial Acres ⁸ (acres)	Irrigable Land ⁹ (acres)	Urban and Raw Land ⁹ (acres)	Total ID-1 (acres)
2000	64,693	10,544	626	5,454	59,865	814		12,398	78,530	58,886	137,416
2001	62,116	10,219	1,908	6,557	57,467	2,005		12,501	78,530	58,886	137,416
2002	62,224	8,139	1,683	7,152	56,755	2,069		12,554	78,530	58,886	137,416
2003	60,246	8,588	1,806	7,308	54,744	2,926		13,552	78,530	58,886	137,416
2004	58,565	8,147	1,302	7,188	52,679	2,691		15,972	78,530	58,886	137,416
2005	57,500	8,017	307	6,614	51,193	1,068		19,655	78,530	58,886	137,416
2006	54,626	7,914	713	5,997	49,342	1,092		20,654	77,085	58,886	137,416
2007	53,855	8,175	704	5,491	49,068	1,361	1,450	21,160	78,530	58,886	137,416
2008	53,851	7,700	694	5,302	49,243	1,390	1,454	21,141	78,530	58,886	137,416
2009	51,265	7,971	1,254	5,227	47,292	2,800	1,794	21,417	78,530	58,886	137,416
2010	54,281	8,463	613	5,495	49,399	1,007	970	21,659	78,530	58,886	137,416
2011	53,075	8,232	1,602	5,517	49,160	1,739		22,114	78,530	58,886	137,416
2012	54,047	9,390	2,144	6,476	49,715	8,476	9,627	24,017	98,311	39,105	137,416
2013	55,277	7,968	2,500	6,551	51,226	7,344	8,950	1,073	75,144	62,272	137,416
2014	54,863	8,118	3,450	6,934	51,379	5,264	10,858	1,919	76,354	61,062	137,416
2015	54,655	7,769	3,760	6,983	51,432	5,396	10,680	1,966	76,457	60,959	137,416
2016	53,637	8,456	4,354	6,983	51,008	6,074	10,377	1,969	76,411	61,005	137,416
2017	54,179	7,354	3,840	7,084	50,935	6,508	9,899	2,002	76,428	60,987	137,416

Notes: Data from annual CVWD Crop and Water Reports to USBR. Agricultural acreage reporting methods changed in 2012. Values from 2013 to present are based on GIS.

1. Commercial Acres - land used for commercial crop production. Includes fish farms, duck clubs, polo fields, and golf courses.
2. Double-cropped Acres - portion of Commercial Acres where multiple crops are grown during the year.
3. Irrigated - Not Harvested - acreage of non-bearing crops, e.g. Dates, Grapes & various citrus varieties in their juvenile state as well as crops planted for soil building (not included in Commercial Acres).
4. Total - Fish, Duck, Golf - Portion of commercial acreage of fish farms, duck clubs, and golf courses.
5. Total irrigated Ag Land - sum of commercial acres and irrigated-not harvested acres minus fish farms, duck clubs, and golf courses but includes polo fields (turf).
6. Not irrigated-idle - irrigable land temporarily out of production for the year.
7. Not irrigated-fallow - irrigable land out of production for multiple years. Fallow land is included with idle land for 2000-2006 and 2011.
8. Non-commercial Acres - irrigable land where there are non-permanent structures, e.g. trailer, reservoir or fenced in maintenance yards. Before 2013, may have included a portion of urban or raw acreage.
9. Urban and raw land - land within ID-1 that is dedicated to permanent non-agricultural purposes or is undeveloped. Values prior to 2012 are estimated and may have included an unknown amount of idle or fallow land.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Historical Agricultural Water Use

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Historical Agricultural Water Use

6. Data for irrigated acreage outside ID-1 are not reported on the Form 7-2045 reports or CVWD's annual review reports. JMLord estimated the irrigated acreage outside ID-1 to be 4,315 acres for the period 2000-2008. This value was initially used for 2009-2013 as well. From 2014 to the present, CVWD GIS data includes acreages outside ID-1. Discrepancies appear to exist between the original outside ID-1 acreages used to estimate water use per acre for the 2010 CVWMP Update and the later GIS figures. Adjusted acreage estimates for outside ID-1 for 2000-2013 are presented in Table 2-4. The adjusted values assume the irrigated acres outside ID-1 are correlated to total irrigated acres inside ID-1. The ratio varies from 3.45 percent to 3.68 percent for 1996 and 2014. The ratio is interpolated from 1997 through 2014 to estimate irrigated acreage outside ID-1 for 2000-2013.

Table 2-4 Estimated Irrigated Agricultural Acreage

Year	Original ID-1 Irrigated Acreage ¹ (acres)	Original Outside ID-1 Irrigated Acreage ² (acres)	Original Total Irrigated Acreage (acres)	Adjusted ID-1 Irrigated Acreage ³ (acres)	Adjusted Outside ID-1 Irrigated Acreage ⁴ (acres)	Adjusted Total Irrigated Acreage (acres)
2000	58,722	4,315	63,037	59,865	2,659	62,523
2001	55,559	4,315	59,874	57,467	2,483	59,950
2002	55,072	4,315	59,387	56,755	2,543	59,298
2003	52,938	4,315	57,253	54,744	2,502	57,246
2004	51,713	4,315	56,028	52,679	2,391	55,070
2005	50,886	4,315	55,201	51,193	2,300	53,493
2006	48,629	4,315	52,944	49,342	2,197	51,539
2007	48,364	4,315	52,679	49,068	2,222	51,290
2008	50,947	4,315	55,262	49,243	2,063	51,306
2009	47,292	4,315	51,607	47,292	1,985	49,277
2010	49,399	4,315	53,714	49,399	2,222	51,621
2011	49,160	4,315	53,475	49,160	2,292	51,452
2012	49,715	4,315	54,030	49,715	2,397	52,112
2013	51,226	4,315	55,541	51,226	2,412	53,638
2014	51,379	2,445	53,824	51,379	2,445	53,824
2015	51,432	2,521	53,953	51,432	2,519	53,951
2016	51,008	2,788	53,796	51,008	2,788	53,796
2017	50,935	2,731	53,666	50,935	2,731	53,666

Notes:

- 1 Original ID-1 irrigated acreage was based on commercial acres minus golf and fish farm acreage. Irrigated/not harvested acreage was excluded.
- 2 Original acreage outside ID-1 was estimated by JMLord.
- 3 Adjusted ID-1 irrigated acreage equals commercial plus irrigated/not harvested acreage less golf, fish farms, and duck clubs.
- 4 Adjusted acreage outside ID-1 is based on the trended ratio of outside ID-1 acreage to total irrigated agricultural acreage (with double cropping) for 1996 and 2014. Values after 2014 are actual irrigated agricultural acreage.

2.4 AVERAGE WATER USE PER IRRIGATED ACRE

Table 2-5 presents the calculated average water use per irrigated acre using the original acreage estimates and the adjusted acreage estimates. No additional adjustments are made for annual variations in reference evapotranspiration or precipitation.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Historical Agricultural Water Use

Table 2-5 Estimated Agricultural Water Use Per Irrigated Acre

Year	Total Water Use (AFY)	Original Irrigated Acreages (acres)	Original Water Use Per Irrigated Acre (AFY/Acre)	Adjusted Irrigated Acreages (acres)	Adjusted Water Use Per Irrigated Acre (AFY/Acre)
2000	370,484	63,037	5.88	62,523	5.93
2001	365,202	59,874	6.10	59,950	6.09
2002	370,884	59,387	6.25	59,298	6.25
2003	330,241	57,253	5.77	57,246	5.77
2004	303,858	56,028	5.42	55,070	5.52
2005	283,354	55,201	5.13	53,493	5.30
2006	294,758	52,944	5.57	51,539	5.72
2007	295,870	52,679	5.62	51,290	5.77
2008	309,796	55,262	5.61	51,306	6.04
2009	313,824	51,607	6.08	49,277	6.37
2010	297,814	53,714	5.55	51,621	5.77
2011	303,043	53,475	5.67	51,452	5.90
2012	288,360	54,030	5.34	52,112	5.54
2013	285,402	55,541	5.13	53,638	5.32
2014	305,896	53,824	5.67	53,824	5.67
2015	295,331	53,953	5.46	53,953	5.46
2016	308,889	53,796	5.74	53,796	5.74
2017	291,572	53,666	5.43	53,666	5.43

2.5 AGRICULTURAL WATER USE BASELINE

The 2010 CVWMP Update used the average agricultural water use per acre for the period 2000-2002 as a baseline for assessing subsequent agricultural water use. This period represented the most recent time frame with available data before adoption of the 2002 WMP and implementation of the Extraordinary Water Conservation program for the inadvertent overrun payback. Using the original agricultural acreage values, the baseline average water use was 6.09 AFY/acre. Use of the adjusted acreage figures resulted in an average baseline water use of 6.11 AFY/acre.

2.6 HISTORICAL WATER USE REDUCTION COMPARED TO BASELINE

The 2010 CVWMP Update stated that “agricultural water usage was reduced by 15 percent on an AF/acre basis in 2005.” This statement is based on a comparison of the annual water use per irrigated acre to the average water use per irrigated acre in each subsequent year. Table 2-6 presents a comparison of water use per irrigated acre and the calculated reduction from the 2000-2002 baseline for the original irrigated acreage estimates and the adjusted acreage values. The estimated reduction in 2005 was 15.5 percent when using the original acreages and 13.0 percent when using the adjusted acreages.

Figure 2-2 presents a graphical comparison of the original and adjusted water usage per irrigated acre.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Historical Agricultural Water Use

Table 2-6 Comparison of Agricultural Water Use Per Irrigated Acre with Baseline

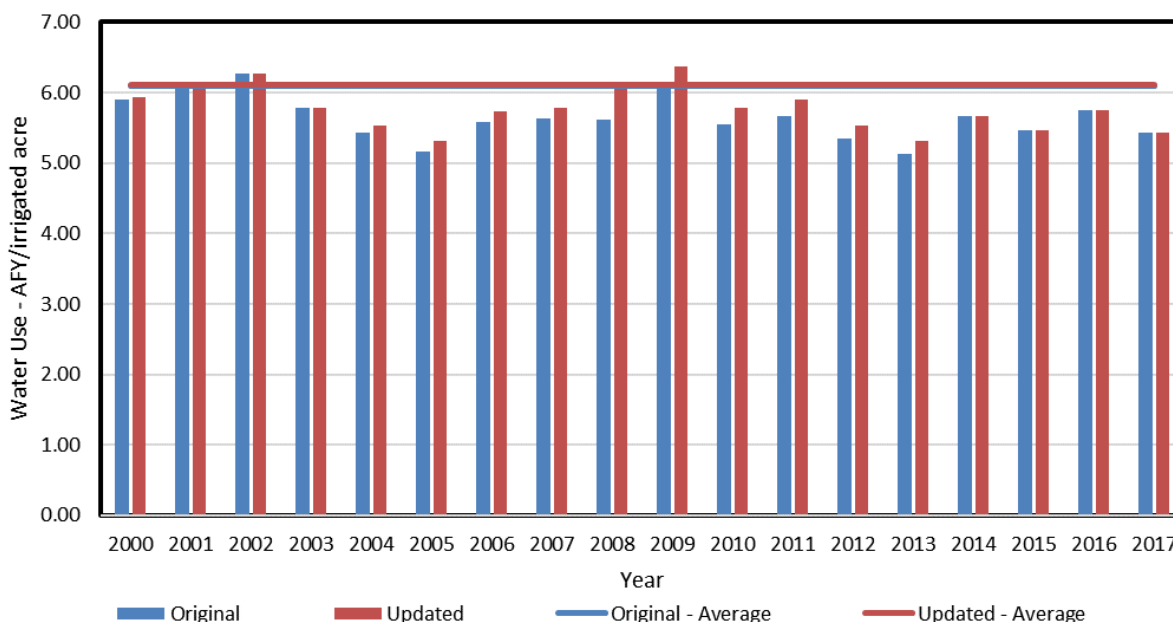
Year	Original Water Use Per Acre (AFY/Acre)	Water Use Reduction from Original Baseline (%)	Adjusted Water Use Per Acre (AFY/Acre)	Water Use Reduction from Adjusted Baseline (%)
2000	5.88		5.93	
2001	6.10		6.09	
2002	6.25		6.25	
2003	5.77	5.0	5.77	5.3
2004	5.42	10.7	5.52	9.4
2005	5.13	15.5	5.30	13.0
2006	5.57	8.3	5.72	6.0
2007	5.62	7.5	5.77	5.2
2008	5.60	7.7	6.04	0.9
2009	5.57	-0.4	6.39	-4.9
2010	5.55	8.6	5.77	5.2
2011	5.67	6.6	5.90	3.2
2012	5.34	12.1	5.54	9.1
2013	5.13	15.4	5.32	12.7
2014	5.67	6.7	5.67	7.0
2015	5.46	10.1	5.46	10.3
2016	5.74	5.3	5.75	5.6
2017	5.43	10.6	5.43	10.8

Note: Original baseline estimate was 6.07 AFY/acre; adjusted baseline estimate is 6.09 AFY/acre.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Historical Agricultural Water Use

Figure 2-2 Comparison of Agricultural Water Use Per Irrigated Acre with Baseline



The average use for the period 2003-2008 was 5.52 AFY/acre using the original acreages and 5.68 AFY/acre using the adjusted acreages. For the period 2009-2017, the average use was 5.56 AFY/acre using the original acreages and 5.69 AFY/acre using the adjusted acreages. Since 2009, average agricultural water use per acre (using the adjusted acreages) appears to have decreased by about 6.5 percent compared to the 2000-2002 values.

There are several reasons for the observed reduction in water demand per irrigated acre in the 2003-2008 period. CVWD was required to pay back by 2011 a 73,200 AF overrun of Colorado River diversions that occurred prior to the signing of the Quantification Settlement Agreement. About 75 percent of the payback occurred in 2004-2006. CVWD farmers implemented extraordinary water conservation measures that completed the pay back two years early. This program had a big effect on Canal water use from 2004-2009.

As described previously, groundwater use was estimated prior to 2012. Estimated groundwater production was much higher in 2000-2002 than in subsequent years, which may have skewed the baseline estimate. The reason for the higher estimates could not be determined for this report.

Also, during this period, agricultural land was being removed from production due to housing development. About 13,000 acres of agricultural land was removed from production between 2000 and 2009. If the converted acres were high water use crops, the average use per acre would decline. The housing market crashed during the 2008-2009 recession and some land went back into production. Agricultural acres have been relatively stable since 2013. During this latter period, CVWD also switched to a GIS-based crop survey system, with a significant improvement in data accuracy.

This report reflects adjustments to the crop acreages to correct the previous omission of non-bearing crop acreage and overestimates of acreage outside ID-1 as described in Item 4 of Section 2.3. These adjustments reduced the irrigated acreage prior to 2013 and increased the calculated water use per acre.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Historical Agricultural Water Use

Water consumption data prior to 2012 were based on crop acreage, irrigation water requirements, and assumed irrigation efficiencies. JMLord used an average irrigation efficiency of 70 percent to estimate groundwater pumping for 1996. It is assumed that similar values were used to estimate agricultural demand for 2000-2008. MWH assumed a 72 percent irrigation efficiency for 2009-2011. If these irrigation efficiencies were too low, the agricultural demand and the water use per acres would be overstated. CVWD's data indicates sprinkler-irrigated land increased from 10,512 acres in 2000 to 21,032 acres in 2017, and flood-irrigated acres decreased from 30,274 acres in 2000 to 9,036 acres in 2017. Drip-irrigated acreage declined 20 percent between 2000 and 2009, possibly due to land conversion; however, it has remained relatively stable since 2010. The switch from flood to sprinkler irrigation would be expected to increase the overall irrigation efficiency of the District.

2.7 ADDITIONAL FACTORS FOR CONSIDERATION

Several additional factors that may affect the amount of water use per irrigated acre are crop type and weather conditions. As mentioned previously, the 2010 CVWMP Update assumed the future mix of crops grown in the Coachella Valley would remain roughly the same as the recent historical data at that time. Market conditions dictate the crops grown, especially annual vegetables. However, changes in the mix of permanent crops would be expected to occur much more slowly due to the time required for those crops to mature sufficiently for full production. Data from CVWD's 2016 Crop Report shows increased acreage of carrots, dates, greens, and peppers, and decreasing acreage of citrus, corn, grapes, and lettuce since 2009. Citrus, date, and grape acreage is expected to increase in the future as recently planted land comes into production. More detailed analysis of cropping patterns should be performed to evaluate the effect of the crop mix on the average water use per acre. The crop water use for ET and leaching should be revisited and updated as needed to include water requirements for seedbed preparation, germination/establishment, frost protection, hydrocooling (for grapes), and dust control. The 2004 Water Advisory Committee report would be a useful source of information.

Weather conditions in the Coachella Valley vary from year to year resulting in variations in reference evapotranspiration (ET_o). In June 2017, MWH (now Stantec) and Formation Environmental prepared a report reviewing CVWD's ET_o map. That report presented estimated annual ET_o values for Thermal Airport for the period of 1980-2015. From 2001-2015, the ET_o averaged 72.2 inches per year and varied by about 3.4 percent. If the calculated water use per irrigated acre were adjusted to reflect ET_o variation, the reduction in 2005 from the baseline would have been 9.5 percent compared to 13.0 percent. Additional analysis of historical ET_o data may be useful in assessing the changes in agricultural water use from year to year.

The method of irrigation used can also have a significant effect on water use per acre. Previous analyses used a single irrigation efficiency factor. As the mix of drip, flood, and sprinkler irrigation changes in the future, the effect on irrigation efficiency should be evaluated. It is recommended that irrigation efficiency be evaluated based on crop acreage and irrigation method using GIS data for the crop reports.

The potential inaccuracy of the irrigated acreage values prior to the use of GIS and the lack of reliable groundwater pumping data for the period 2000-2011 limit the accuracy of the water use per irrigated acre as a metric for evaluating water conservation, especially for establishing a baseline to measure conservation performance. The variability of crop acreage, local weather conditions, and irrigation efficiency can play a significant role in the calculation of the average water use per acre. That said, the average agricultural water use per acre can still be a valuable planning metric for projecting future agricultural water demand in the Valley.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Historical Agricultural Water Use

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Basis for Agricultural Water Conservation Targets in 2010 CVWMP Update

3.0 Basis for Agricultural Water Conservation Targets in 2010 CVWMP Update

The purpose of this section is to describe the basis for the water conservation targets in Table ES-6 and Table 6-2 of the 2010 WMP Update.

3.1 2002 CVWMP TARGET

The 2002 CVWMP established an initial water conservation target for agricultural demand of 7 percent. This savings goal was based on increasing the average irrigation efficiency of Valley agriculture from 70 percent to 75 percent assuming no change in the overall crop mix. The 2002 CVWMP states:

This level of conservation is believed to be achievable based on recent farm water use evaluations performed for CVWD by J.M. Lord (1999). Agricultural conservation measures would consist of working with Valley growers to ensure that the most up-to-date irrigation practices are being employed. In addition to conversion from furrow irrigation to drip irrigation, there are also refinements that can be made in existing drip irrigation management and design to improve distribution uniformity. Improvements include the use of buried drip systems, installation of pressure compensating emitters, and including more emitters per line. Individual water use practices would be reviewed on a field-by-field basis, evaluating the unique characteristics of each field and crop type. Confidential reports would be provided to each grower indicating the general efficiency of each field and containing recommendations for improved efficiency. The goal would be to improve regional irrigation efficiency from 70 to 75 percent. The District, on an on-going basis, evaluates specific agricultural conservation measures considered for implementation.

The 2010 CVWMP Update reviewed progress toward achieving the 7 percent goal. Section 2.5 of this report stated:

In order to comply with the QSA and the U. S. Bureau of Reclamation's (Reclamation) Inadvertent Overrun and Payback Policy (IOPP), Coachella Valley farmers implemented a number of extraordinary water conservation measures. Based on a comparison with 2000-2002 average water use per acre, agricultural water usage has varied from 2003 to 2008, but has generally declined about 9.9 percent. While this estimate may be high due to weather variations, crop water needs, accuracy of reported groundwater production, and variation in cropping patterns, it does indicate a significant decrease in agricultural water use over the period. Implementation of these measures allowed CVWD to complete its IOPP 72,000 AF payback requirement two years early.

3.2 2010 CVWMP UPDATE TARGET

This subsection presents the information used to establish the agricultural water conservation target of the 2010 CVWMP Update. The target was based on information derived from three CVWD-led efforts; the Water Advisory Committee, the USBR Water 2025 report, and the Extraordinary Water Conservation program as described below.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Basis for Agricultural Water Conservation Targets in 2010 CVWMP Update

3.2.1 Water Advisory Committee

During preparation of the 2010 CVWMP Update, JMLord staff evaluated information developed by the CVWD Water Advisory Committee (WAC) and the “Water 2025 Report on Agricultural Conservation of Colorado River Water in the Coachella Valley, California.” CVWD established the WAC in the 1990s to assist the District in analyzing past and current agricultural water use and water management within the Imperial Irrigation District (IID) and Improvement District No. 1 (ID-1) of the CVWD. In addition, the WAC appraised opportunities for future improvements in agricultural water use and water management issues. The work performed by the WAC was prepared under attorney-client privilege in anticipation of potential water rights litigation.

Among other evaluations, the WAC report recommended methods for improving agricultural water use efficiency through scientific irrigation scheduling, improvements to irrigation systems, improved water, soil, and weather monitoring, and development of an irrigated land and water use database to provide field-specific information on water use by crop to assist farmers. Although the WAC report did not document specific savings, the report set the stage for additional evaluations in the Water 2025 investigation.

3.2.2 Water 2025 Report

In 2005, the USBR awarded funding to CVWD from its Water 2025 Challenge Grant Program for a demonstration project to show how state-of-the-art irrigation water management can save water in agriculture, and how those savings can be quantified. The Final Project Report for Cooperative Agreement No. 05FC340010-Agricultural Conservation of Colorado River Water in the Coachella Valley, California was submitted to USBR in January 2009. The Water 2025 investigation consisted of five tasks:

- Task 1 - Quantification of Current and Historic Applied Water using GIS
- Task 2 - Detailed Field Monitoring
- Task 3 - Implementation of Conservation Practices on Demonstration Fields
- Task 4 - Quantification of Water Savings from Conservation Practices
- Task 5 - Intrinsic Market

CVWD contracted with JMLord, Inc. to develop tools and analytical methods to evaluate agricultural water conservation practices in the Coachella Valley and to conduct field testing to demonstrate the water savings of these practices (JMLord, 2009). As shown in Table 3-1, the estimated agricultural water use savings through the implementation of specific water conservation measures totaled 47,598 AFY. Comparing this anticipated savings to the average agricultural water use for the period of 1998-2005 of 340,200 AFY resulted in a potential savings of 14 percent of total agricultural water use.

CVWD staff recently reviewed the Water 2025 Report and identified several concerns. These included:

- Accuracy of soil moisture readings to determine irrigation run times.
- Potential double counting of savings from drip irrigation conversion and overhaul of existing irrigation systems, especially for dates.
- Uncertain savings due to scientific irrigation and salinity scheduling

Based on these and other concerns, CVWD staff questions the validity of the data used to establish the 14 percent agricultural water conservation factor.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Basis for Agricultural Water Conservation Targets in 2010 CVWMP Update

Table 3-1 Total Savings by Conservation Technique - Water 2025 Report

Conservation Technique	Crop	Acreage (Acres)	Applicable Percentage of Acres (%)	Quantified Savings (AFY/Acre)	Total Savings (AFY)	Confidence Level
Conversion Flood to Drip	Dates	7,425	58.6	1.29	5,613	High
Conversion Flood to Drip	Citrus	8,511	6.2	2.68	1,414	High
Conversion Flood to Sprinkler	Lettuce	3,112	32.0	0.25	249	Poor
Conversion Flood to Sprinkler	Carrots	1,775	22.0	0.4	156	Poor
Overhaul Irrigation System	Dates	7,425	100.0	0.38	2,822	Good
Overhaul Irrigation System	Grapes	10,299	100.0	0.7	7,209	Good
Overhaul Irrigation System	Citrus	8,511	100.0	0.46	3,915	Good
Scientific Irrigation/Salinity Management*	Dates-Drip	3,713	41.4	0.41	630	Good
Scientific Irrigation/Salinity Management*	Dates-Drip	3,713	41.4	0.41	630	Good
Scientific Irrigation/Salinity Management*	Dates- Flood	3,713	58.6	2.04	4,438	High
Scientific Irrigation/Salinity Management*	Citrus- Drip	4,256	93.8	0.1	399	Fair
Scientific Irrigation/Salinity Management*	Grapes- Drip	5,150	100.0	2.33	11,998	High
Scientific Salinity Management Only*	Grapes- Drip	5,150	100.0	1.7	8,754	High
Total					47,598	

Reference: CVWD, 2009. Table 29, Final Project Report for Cooperative Agreement No. 05FC340010-Agricultural Conservation of Colorado River Water in the Coachella Valley, California.

* Applied to 50 percent of the Total Acres

Total savings equals acres times percentage of acres times quantified savings.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Basis for Agricultural Water Conservation Targets in 2010 CVWMP Update

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Basis for Agricultural Water Conservation Targets in 2010 CVWMP Update

3.2.3 Extraordinary Conservation Program

With the 2003 signing of the Quantification Settlement Agreement (QSA), the U. S. Bureau of Reclamation (Reclamation) adopted the Inadvertent Overrun and Payback Policy (IOPP). This policy defined procedures that account for contractor diversions of Colorado River water in excess of their respective allocation and the requirements for paying back those excess diversions. The QSA specified that CVWD, Imperial Irrigation District (IID) and Metropolitan Water District of Southern California (Metropolitan) had overrun their allocations in 2001 and 2002 by a combined total of 313,200 AF of which the CVWD share was 73,200 AF. The QSA required this water to be paid back within eight years (2004 through 2011).

The District's response to the IOPP requirements included the implementation of the CVWD Extraordinary Conservation program. This program was funded by the District, with grower participation in a number of agricultural conservation programs. Grower participation was entirely voluntary. Through the Extraordinary Conservation Program, the District was able to completely payback the IOPP overrun (73,200 AF) by 2009, two years early. Conservation program measures included:

- Scientific Irrigation Scheduling
- Salinity Management
- Salinity Field Mapping
- Conversion to Micro-Irrigation
- Distribution Uniformity Evaluations
- Grower Training and Meetings
- Engineering Evaluations

As described in the 2010 CVWMP Update and Section 2 of this report, CVWD farmers reduced agricultural water use during the period 2004 through 2009 by 73,200 AF and paid back the 2001-2002 overrun two years early. The field experience from the Extraordinary Conservation Program showed higher targets were achievable than those in adopted in the 2002 CVWMP. While conservation averaged about 5 percent during the payback period, peak conservation of about 13 percent was achieved in a single year (2005). It is noted that the extraordinary water savings calculations were prepared by CVWD and JMLord staff and were not available to MWH at the time of the 2010 CVWMP Update.

3.3 SUMMARY

The 2010 CVWMP Update adopted a goal of 14 percent reduction in agricultural water use based on the achievements of the Extraordinary Conservation Program and the demonstrated savings achieved by the Water 2025 investigation. The results of the Extraordinary Conservation Program and the Water 2025 report represented the best data available supporting the 14 percent agricultural water conservation target at the time the 2010 CVWMP Update was prepared. However, CVWD has concerns about the validity of the Water 2025 report and the data used establish the 14 percent agricultural water conservation factor set in the 2010 CVWMP Update, and recent analysis shows that the highest target met during the payback period was 13 percent (2005). Both the Extraordinary Conservation Program and the Water 2025 report required significant investments of CVWD funds to achieve the savings that were observed. While the 14 percent conservation target may ultimately be attainable, achieving this target would likely require substantial investment in the form of CVWD-furnished services, rebates, and other grower incentives. Any conservation target should also consider the various agronomic uses of water described in Section 5.3.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Basis for Agricultural Water Conservation Targets in 2010 CVWMP Update

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Projected Agricultural Water Use and Conservation

4.0 Projected Agricultural Water Use and Conservation

The purpose of this section is to describe the basis for future agricultural water use projections and conservation tracking used in the 2010 CVWMP Update.

4.1 AGRICULTURAL ACREAGE REDUCTION

This subsection documents the expected reduction in agricultural acreage due to urbanization and population growth used in the 2010 CVWMP Update. The following assumptions and calculations were made:

- The population of the Eastern Coachella Valley was projected to increase from 174,700 in 2005 to 758,600 in 2045 based on the Riverside County Planning Department's 2006 forecast (excluding CVWD's Imperial County service area) as shown in Table 3-1 of the 2010 CVWMP Update.
- Assumptions for urban growth acres - $3.2 \text{ people/dwelling unit (DU)} \times 4 \text{ DU/acre} = 12.8 \text{ people/acre}$, or $78.1 \text{ acres/1,000 people}$. The density assumption was based on review of proposed developments and represented the average of acres developed to dwelling units. Total acres required for urban development in Eastern Coachella Valley = $(758,600 - 174,700) \text{ people} / 12.8 \text{ people per acre} = 45,617 \text{ acres}$.
- Assumptions for new golf acreage - The average golf course is about 125 acres. The number of new courses by year 2045 was 76 based on the ratio of existing golf to population in the Eastern Coachella Valley. Total acreage of new golf is $125 \text{ acres/course} \times 76 \text{ courses} = 9,500 \text{ acres}$ by 2045.
- Total acreage required for development in the Eastern Coachella Valley was estimated to be 55,117 acres ($45,617 + 9,500$).
- Assumptions for development of agricultural land versus vacant land - 50 percent of urban and golf development on agricultural land and 50 percent on undeveloped (raw) land in Eastern Coachella Valley; all on undeveloped land in the Western Coachella Valley. Total acres of agricultural land developed = $55,117 \times 0.50 = 27,558 \text{ acres}$ by 2045.
- Agricultural acreage was projected to reduce by 27,558 from 52,168 acres in 2005 to 24,601 acres in 2045.

The projected agricultural acreage used in the 2010 CVWMP Update is shown in Table 4-1.

A number of changes have taken place in the Coachella Valley since the 2010 CVWMP Update was prepared that may impact agricultural acreage in the future. The 2008-2009 recession had a significant impact on land development in the Valley. As a result, projected population growth in the Valley has been reduced since the 2010 CVWMP Update. The most recent projection is 421,900 people in the East Valley by 2045 based on the adopted Southern California Association of Governments (SCAG) 2016 Regional Transportation Plan (RTP) forecast. This lower population growth would likely reduce the agricultural acreage lost to development and result in higher projected agricultural demands. Very few new golf courses have been planned or constructed. Recent development proposals show a trend away from golf course recreation with more compact development. Based on discussions with CVWD management, current demand forecasts are assuming only 15 new courses in the Coachella Valley.

The validity of the assumption of new development on a combination of agricultural and raw land is not known. Some development proposals utilize land removed from agricultural production years ago, while others are located on undeveloped land. It is recommended that CVWD evaluate the existing land use of

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Projected Agricultural Water Use and Conservation

proposed developments to assess the validity of this planning assumptions. This evaluation should be done prior to the next CVWMP Update.

In addition to urban development, the potential exists for new agricultural demand in the Valley. The recent California drought resulted in land acquisition for future agricultural use; however, no actual development has taken place. Construction of the Oasis source substitution project could make Canal water available for irrigation of currently fallow or vacant land in that area. There is also the potential for Canal water demand on undeveloped tribal land if the federal government funds construction of Canal water distribution facilities. A 2016 report prepared by MWH on strategies to maximize imported water use identified almost 59,000 AFY of potential new agricultural demand.

4.2 PROJECTED AGRICULTURAL USE WITHOUT AND WITH CONSERVATION

This subsection documents the data sources and calculations used for the statement on Page 6-12 of the 2010 CVWMP Update: “Assuming no change in cropping patterns and average ET conditions, agricultural water use is expected to decrease from 6.2 AFY per acre to about 5.33 AFY per acre. As agricultural land is removed from production in response to urban development, it is expected that the amount of water saved through agricultural conservation will decrease from almost 39,500 AFY in 2020 to 23,000 AFY in 2045.”

The following assumptions and calculations were made to determine agricultural water use and future conservation:

- The 2010 CVWMP Update used a “base” agricultural water use per acre in 2005 to project future agricultural demand. The year 2005 was abnormal for several reasons - 1) agricultural groundwater use was not being reported so it had to be estimated; 2) Canal water deliveries were reduced due to extraordinary water conservation measures implemented to pay back previous Canal diversion overruns; and 3) 2004-2005 was an “El Niño” year with above normal rainfall and below normal ET. Consequently, adjustments were required to determine the “base” agricultural water use from the actual values.
- Agricultural water use in 2005 was calculated using the actual Canal water (205,633 AF), estimated groundwater (75,416 AF), recycled water (712 AF), and fish farm (1,252 AF) deliveries plus the 2005 extraordinary conservation (18,491 AF) and divided by 92 percent to account for the 8 percent below average ETo and higher rainfall occurring in 2005. (Note: Stantec could not determine the basis for the ETo being 8 percent below average in 2005.) The “base” agricultural water use in 2005 was estimated to be 327,754 AFY $[(205,633 + 75,416 + 712 + 1,252 + 18,491) / 0.92 = 327,722 \text{ AFY}]$.
- The irrigated agricultural acreage in 2005 was originally estimated to be 52,168 acres. The source of this value cannot readily be determined. However, it is noted that the adjusted irrigated acreage for 2005 was 53,493 acres as shown in Table 2-4.
- “Base” agricultural water use per acre in 2005 was estimated to be 6.28 AFY/acre. This value equals the adjusted agricultural water demand (327,722 AFY) divided by 52,168 irrigated acres. This value appears to be slightly high in light the water use factors developed in Section 2 of this report.
- The projected irrigated agricultural acreage in 2045 was 24,601 acres as shown in Table 4-1. This value was calculated by subtracting 27,558 acres of urban development on agricultural land (see Section 4.1) from the 2005 acreage of 52,168 acres.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Projected Agricultural Water Use and Conservation

- Future agricultural water use without conservation was calculated using the projected agricultural acreage times average use (6.28 AFY/acre). In 2045, the estimated agricultural water demand was calculated to be 24,601 acres x 6.28 AFY/acre = 154,500 AFY.
- Information on tribal water use in the East Valley was not available for use in the 2010 CVWMP Update. Consequently, tribal water use in 2005 was assumed to be 24,200 AFY based on an average water use factor of 5.5 AFY/acre and 4,400 acres of tribal land (from CVWD's GIS database). Tribal water use was assumed to be primarily agricultural with some urban use and the 24,200 AFY was assumed to be included in the existing Canal water and groundwater use amounts. Tribal water use was assumed to increase at the same rate as municipal water use. Tribal water demand was projected to reach 35,200 AFY by 2045. The 2010 CVWMP Update did not track tribal demand separately, therefore, the increase in tribal water demand of 11,000 AFY was added to the calculated agricultural demand. The total agricultural demand was estimated to be 165,500 AFY in 2045 as shown in Table 4-1. The total agricultural (and tribal) water demand in 2045 was listed as 166,100 AFY in Table 3-2 of the 2010 CVWMP Update. This higher value included a 600 AFY adjustment made for consistency with previous draft demand projections.
- Future agricultural water conservation was based on a 14 percent reduction from baseline use per acre as described in Section 3 of the CVWMP. This level of savings was assumed to commence in 2010 and reach full implementation by 2020. This savings corresponds to an increase in the average irrigation efficiency from 70 percent (before CVWMP adoption) to 81 percent with no change in crop ET and leaching requirements (avg 4.34 AFY/acre).
- Calculated agricultural water use with expected conservation was calculated by multiplying the projected agricultural water demand without conservation by one minus the expected conservation savings in each year. For 2045, the agricultural water demand with conservation was 165,500 AFY x (1-0.14) = 142,300 AFY and the savings due to conservation efforts was 23,200 AFY.

Table 4-1 presents the projected agricultural acreage, water demands, increased tribal demand and total demand with and without conservation in 5 yr increments between 2010 and 2045.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Projected Agricultural Water Use and Conservation

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Projected Agricultural Water Use and Conservation

Table 4-1 Projected Agricultural Water Demand - 2010 CVWMP Update

Year	Projected Agricultural Acreage ¹ (acre)	Water Use Factor w/o Conservation (AFY/Acre)	Baseline Agricultural Water Demand ² (AFY)	Additional Tribal Demand (AFY)	Total Agricultural Demand without Conservation (AFY)	Agricultural Conservation Percentage ³ (%)	Projected Agricultural and Tribal Water Demand (AFY)	Agricultural Water Conservation Savings (AFY)
2005	52,168	6.28	327,800	0	327,800	0.0	327,800	0
2010	50,377	6.28	316,500	900	317,400	1.3	313,400	4,000
2015	47,912	6.28	301,000	1,900	302,900	7.6	279,700	23,100
2020	44,415	6.28	279,100	3,200	282,300	14.0	242,700	39,500
2025	40,383	6.28	253,700	4,800	258,500	14.0	222,300	36,200
2030	36,925	6.28	232,000	6,100	238,100	14.0	204,700	33,300
2035	32,818	6.28	206,200	7,700	213,900	14.0	183,900	29,900
2040	28,709	6.28	180,400	9,300	189,700	14.0	163,100	26,600
2045	24,601	6.28	154,500	11,000	165,500	14.0	142,300	23,200

Notes:

- 1 Agricultural acreage projections used 2005 irrigated acreage as a base value. Future agricultural acreage was reduced in proportion to the projected population growth assuming 39.1 acres of agricultural land lost per 1,000 population growth. The source for the 52,168 acres in 2005 cannot be determined from the report background calculations. Actual acreage in 2005 is estimated to be 53,493 acres per Table 2-4.
- 2 The baseline agricultural demand in 2005 of 327,800 AFY was calculated by totaling the actual Canal water (205,633 AFY), estimated groundwater (75,416 AFY), recycled water (712 AFY), and fish farm (1,252 AFY) deliveries plus the 2005 extraordinary Canal water conservation (18,491 AFY) and divided by 92 percent to account for the 8 percent below average ETo and higher rainfall occurring in 2005.
- 3 The agricultural conservation factor was applied only to the baseline agricultural water demand.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Projected Agricultural Water Use and Conservation

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Projected Agricultural Water Use and Conservation

4.3 REDUCTION IN AGRICULTURAL GROUNDWATER USE

This subsection documents the data sources and rationale for the statement on Page 6-28 of the 2010 CVWMP Update: “For the 2010 WMP Update, agricultural use of groundwater is assumed to decrease from about 66,000 AFY in 2009 to about 7,000 AFY by 2045, a decrease of 59,000 AFY or 89 percent.”

When the 2010 CVWMP Update was prepared the amount of groundwater pumping for agriculture was not fully documented. Stantec estimated the agricultural water demand in 2009 using CVWD’s annual crop report acreages, and crop consumptive water use, leaching requirements, and irrigation efficiencies from JMLord. The total agricultural demand was estimated to be about 315,000 AFY. The amount of agricultural groundwater use in 2009 was estimated to be 65,600 AFY by subtracting the Canal, fish farm and recycled water deliveries to agriculture from the total agricultural water demand. The estimated agricultural groundwater pumping was about 21 percent of agricultural demand.

The anticipated conversion of agricultural land to urban uses was expected to remove about 27,600 acres from production, leaving a projected demand of 165,500 AFY in 2045 as shown in Table 4-1. Assuming no other management actions, groundwater pumping would reduce to 34,500 AFY, with the remaining demand met from other sources. As described previously in Section 3, implementation of water conservation measures was expected to reduce agricultural water use per acre by 14 percent from 2020 onward. The conservation savings in 2045 was estimated to be 23,200 AFY as shown in Table 4-1. With no other changes in water management beside conservation, agricultural groundwater pumping was expected to decrease from 34,500 AFY to 29,700 AFY due to water conservation in 2045.

A key objective of the 2010 CVWMP Update was to reduce groundwater pumping by all use sectors to help eliminate projected overdraft. The CVWMP Team believed some agricultural groundwater pumping would be needed to meet demands in areas that could not be served with alternative supplies. The Team set an agricultural groundwater pumping goal of 5 percent of agricultural demand after conservation. The 2045 target for agricultural groundwater pumping with conservation was 7,100 AFY.

Source substitution was proposed to further reduce agricultural groundwater pumping by delivering Canal water, recycled water, and desalinated drain water to farmers. To meet the agricultural pumping target, CVWD would need to implement at least 22,600 AFY of source substitution projects by 2045. the 2010 CVWMP assumed that a significant increase in agricultural source substitution would be required between 2010 and 2026 (the year of maximum QSA allocation) to fully use the Canal water supply made available through the QSA. The lead time for implementing major projects such as Oasis are such that intermediate source substitution projects are needed.

The largest agricultural source substitution project proposed was the Oasis Distribution System Project that would extend the Canal water distribution system to farmers on the Oasis slope that do not have access to Canal water. In addition, farmers located outside the ID-1 boundary in the Oasis area could also be served. In the 2010 CVWMP Update, the Oasis project was expected to deliver about 27,000 AFY of Canal water with a like reduction in groundwater pumping. This project would be sufficient to meet the planned reduction in groundwater pumping.

The 2014 Preliminary Design Report for the Oasis Area Irrigation System Expansion Project determined that 7,101 acres of land could be served by the project. The projected water demand of the Oasis area is 32,000 AFY, of which 18,600 AFY is existing demand (4,133 acres) and 13,400 AFY is the demand of vacant land that could be farmed in the future (2,968 acres). The 2014 Oasis Report used a water demand factor of 4.5 AFY/acre for the Oasis area to reflect the lower demand of the predominant crops - citrus, grapes, and vegetables.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Projected Agricultural Water Use and Conservation

Table 4-2 shows the projected agricultural water demand, water conservation savings, the groundwater pumping target and the source substitution required to meet the pumping target. Additional source substitution is required to meet the pumping target if the Oasis Project were implemented within the time frame shown.

Table 4-2 Projected Agricultural Pumping from 2010 CVWMP Update

Year	Agricultural Demand ¹ (AFY)	Water Conservation ¹ (AFY)	Groundwater with Conservation Only ² (AFY)	Groundwater Pumping Target ³ (AFY)	Required Source Substitution ⁴ (AFY)	Oasis Project ⁵ (AFY)	Additional Source Substitution ⁶ (AFY)
2010	317,400	4,000	65,500	55,800	9,700	0	9,700
2015	302,900	23,100	58,500	28,000	30,500	0	30,500
2020	282,300	39,500	50,700	12,100	38,600	13,500	25,100
2025	258,500	36,200	46,500	11,100	35,400	27,000	8,400
2030	238,100	33,300	42,800	10,200	32,600	27,000	5,600
2035	213,900	29,900	38,500	9,200	29,300	27,000	2,300
2040	189,700	26,600	34,100	8,200	25,900	25,900	0
2045	165,500	23,200	29,700	7,100	22,600	22,600	0

Notes:

- 1 Agricultural demand and water conservation from Table 4-1.
- 2 Groundwater pumping with conservation assumes the ratio of pumping to total demand remains constant during the planning period.
- 3 The groundwater pumping target was based on 5 percent of agricultural demand with conservation after 2020.
- 4 Required source substitution is the amount of pumping reduction needed to achieve the pumping target.
- 5 Oasis project deliveries assumed initial operations by 2018 and full operation by 2025.
- 6 Additional source substitution is the amount of agricultural pumping reduction outside of the Oasis Area needed to meet the pumping target.

4.4 OBSERVATIONS

The planning environment of the Valley has changed since the 2010 CVWMP Update was prepared. The growth anticipated in the Update has not materialized. An evaluation of population in the Valley for the 2015/2016 urban water management plans estimated the population to be 457,000 in 2015 compared to a projection of 511,000. Recent SCAG growth forecasts show significantly lower growth than they projected when the 2010 CVWMP Update was prepared. SCAG's 2016 Regional Transportation Plan (RTP) now forecasts a Valley population of 631,000 by 2040 compared to the population of 1,030,000 projected in its 2008 RTP, which was used for the Update.

Agricultural acreage has been relatively stable for the past five years; this period also coincides with CVWD's use of GIS technology for crop mapping. This recent trend may indicate relatively little land use conversion or the resumption of farming on previously vacant land, offsetting acreage lost to urban development. There is insufficient data available to determine if the land use conversion assumptions of the 2010 CVWMP Update remain valid. A detailed analysis of recent and proposed developments would be required to determine whether development is occurring on agricultural or vacant land, and whether agriculture is resuming on previously idle or fallow land.

The groundwater reduction targets in the 2010 CVWMP Update for agriculture have not materialized. Agricultural groundwater pumping has increased by about 7,000 AFY since 2012 or about 20 percent while Canal water use has ranged from 251,000 to 269,000 AFY in the same period. The reason for these changes are not known based on currently available information. The Oasis distribution system has not

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Projected Agricultural Water Use and Conservation

yet been implemented. Development of this project could have a significant effect on meeting the groundwater pumping targets of the Update.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Projected Agricultural Water Use and Conservation

5.0 Evaluating Agricultural Water Use Efficiency and Conservation in the Coachella Valley

5.1 OVERVIEW

In order to provide recommendations to support the CVWD in tracking agricultural water use and water use efficiency under current conditions and into the future, this section describes components of on-farm water use in the context of a water budget, reasonable and agronomic uses in the Coachella Valley, recoverable and irrecoverable losses of applied irrigation water, methods to quantify agricultural water use efficiency, and applicability of these methods to the CVWD. Finally, recommendations are provided to support evaluation and improvement of agricultural water management in the CVWD.

5.2 ON-FARM WATER BUDGET COMPONENTS

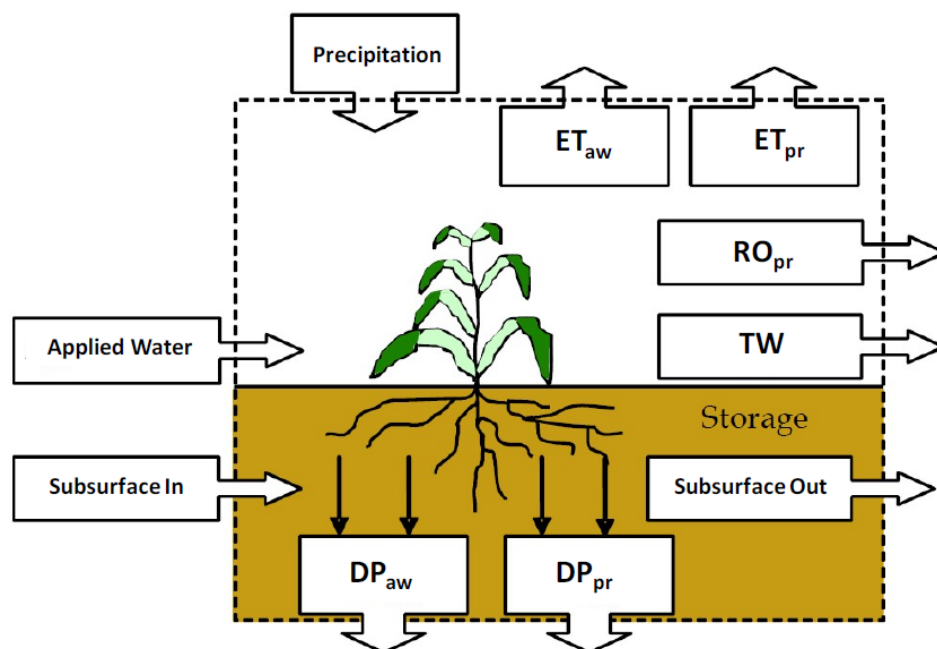
A water budget or water balance is a means of accounting for the use of water over time for a defined area of interest. In agricultural settings, water budgets can be prepared at scales ranging from individual fields to entire basins. In the context of Agricultural Water Management Plans (AWMPs), water budgets often provide the foundation for planning and implementing physical and operational improvements at scales ranging from entire water districts to individual growers. Water budgets also allow for the estimation of performance measures or efficiencies that can be used to evaluate water management over time considering variation in cropping, weather, and other factors that influence water use on a year to year basis. Burt et al. (1997) provides a seminal discussion on the development of water budgets for irrigated land and application of irrigation performance measures.

A schematic of a typical water budget structure for an irrigated field is shown in Figure 5-1. As shown, potential inflows include precipitation (Pr), applied irrigation water (AW), and subsurface inflows in some cases. Outflows include evapotranspiration (ET), runoff from precipitation (RO_{pr}), runoff from irrigation (TW or tailwater), deep percolation (DP), and lateral subsurface outflows in some cases. Often, ET is partitioned into ET derived from applied water (ET_{aw}) and ET derived from precipitation. Deep percolation is often similarly partitioned into applied water and precipitation components (DP_{aw} and DP_{pr}). In addition to inflows and outflows, the amount of water stored as moisture in the crop root zone varies over time. The fundamental concept of the water budget is that for any given time period of interest, the inflows minus the outflows is equal to the change in storage.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Evaluating Agricultural Water Use Efficiency and Conservation in the Coachella Valley

Figure 5-1 On-Farm Water Budget Components



5.3 AGRONOMIC WATER USES

In addition to ET_{aw} , which commonly represents more than 70 percent of the amount of AW for a given field, there are several other agronomic water uses that may occur in the Coachella Valley to support crop production. Table 5-1 summarizes potential agronomic uses of water in the CVWD service area. Several of these uses were identified and estimated in the WAC report described previously. Other uses could potentially be identified through consultation with local agronomists, growers, or other experts.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Evaluating Agricultural Water Use Efficiency and Conservation in the Coachella Valley

Table 5-1 Potential Agronomic Uses of Water in the Coachella Valley

Agronomic Water Use	Description
ET _{aw}	Consumptive use of applied irrigation water in the production of the crop. Consists primarily of transpiration of water to the atmosphere through the crop's tissue. Applies to all crops.
Leaching	Application of water to remove salt from the crop root zone. Water requirements vary depending on the salinity of the irrigation water and the crop type. All crops in the Coachella Valley require leaching to some degree, with most crops being sensitive to moderately sensitive to salinity.
Seedbed Preparation	Application of water prior to planting to provide sufficient soil moisture to construct beds. Additional water may be applied immediately prior to planting to support seed germination or transplant establishment. Applies to vegetable crops.
Germination	Application of water following planting to further aid seed germination and root establishment for transplants. Applies to vegetable crops.
Hydrocooling	Overhead sprinkling of table grape vineyards in the fall to promote earlier, more uniform grape development in the following season.
Frost Protection	Application of water during periods of freezing temperatures to prevent damage to crop tissue. Applies to vegetables and citrus.
Market Quality	Application of water to overcome irrigation system non-uniformity to ensure quality and uniformity in color, size, and shape. Applies to all crops.
Dust Control	Water applied to unpaved roads and fields to prevent dust emissions to comply with South Coast Air Quality Management District (AQMD) regulations.
Irrigation System Maintenance	Use of water to flush microirrigation (drip or microspray) irrigation systems to remove accumulated silt from the use of Colorado River water. This prevents clogging of drip emitters and microsprayers to maintain the uniformity of applied irrigation water. Applies to all crops.

5.4 RECOVERABLE VS. IRRECOVERABLE LOSSES

Water that is applied and “lost” to deep percolation or tailwater at the farm scale may be recoverable for use by other water users in a basin. In CVWD, tailwater production is negligible, and most water lost at the farm or field scale percolates below the root zone and is conveyed to the Salton Sea via tile drains or enters the upper saline semi-perched aquifer or lower fresh water aquifer. While water entering the Salton Sea or semi-perched aquifer is irrecoverable, deep percolation of surface water to the lower aquifer is a source of groundwater recharge (albeit with elevated salinity) that should be considered when evaluating water use efficiency at the District scale.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Evaluating Agricultural Water Use Efficiency and Conservation in the Coachella Valley

5.5 METHODS TO QUANTIFY AGRICULTURAL WATER USE EFFICIENCY (WUE)

In response to the Water Conservation Act of 2009 (Senate Bill x7-7), the California Department of Water Resources (DWR), in consultation with the California Agricultural Water Management Council, academic experts, other irrigation experts, and other stakeholders prepared a report for the Legislature on proposed methods to determine agricultural water use efficiency (DWR 2012). The methods developed build upon Burt et al. (1997) and have since been incorporated into the California Water Code as a required component of AWMPs under AB1668. Although CVWD is not required to prepare an AWMP during the life of the Quantification Settlement Agreement, CVWD may wish to consider applying one or more proposed methods to evaluate current and future agricultural water management in the context of the CVWMP.

5.5.1 Crop Consumptive Use Fraction

The Crop Consumptive Use Fraction (CCUF) is a method to quantify WUE based on the ratio of ET_{aw} to AW (Equation 1):

$$CCUF = ET_{aw} / AW \quad [1]$$

Although CCUF considers the consumptive use of applied water, it does not consider other agronomically beneficial uses of water. CCUF can be applied for individual fields, ranches, or for the District as a whole and is consistent with the Irrigation Consumptive Use Coefficient as described by Burt et al. (1997).

As part of the WAC report, estimated values of CCUR (referred to as the Irrigation Crop Consumptive Use Ratio or ICCUR in the Report) within ID1 from 1972 to 2002 ranged from approximately 0.45 in the 1970s to around 0.6 in the 1990s and early 2000s.

5.5.2 Agronomic Water Use Fraction

The Agronomic Water Use Fraction (AWUF) expands upon the CCUF by incorporating other agronomic uses (Equation 2):

$$AWUF = (ET_{aw} + \text{Other Agronomic Water Uses}) / AW \quad [2]$$

The AWUF is consistent with the “classical” definition of Irrigation Efficiency described by Burt et al. (1997) by considering all agronomic water needs. AWUF is more difficult to estimate than CCUF due to uncertainties in many of the agronomic uses but provides a more complete indicator of irrigation performance. AWUF can be applied for individual fields, ranches, or for the District as a whole.

Similar to the CCUF, the WAC included estimates of AWUF for ID1 from 1972 to 2002 in their report (described as Beneficial Use Ratio or BUR). To calculate AWUF, potential agronomic uses other than ET_{aw} were considered. The estimates were developed based on outreach with local growers by JMLord and supporting calculations. In applying the calculations, the WAC attempted to avoid double counting of agronomic uses by recognizing that many uses provided both leaching and additional agronomic benefits. A summary of estimated agronomic uses of water above and beyond ET_{aw} follows:

- Leaching - Calculated based on crop-specific salinity tolerance and estimated salinity of applied irrigation water and ranged from 1.3 inches for spinach to 16.2 inches for carrots.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Evaluating Agricultural Water Use Efficiency and Conservation in the Coachella Valley

- Seedbed Preparation - Calculated based on estimated water requirement to fill soil to field capacity prior to planting and ranged from 1.8 inches for lettuce and spinach to 5.2 inches for melons.
- Germination - Calculated based on average sprinkler application rates and run times reported by three growers and ranged from 1.4 inches for artichokes, bell peppers, and melons to 2.6 inches for broccoli, carrots, lettuce, spinach, and sweet corn.
- Hydrocooling - Calculated based on monitoring of four vineyards in Fall 2002 as 20.4 inches.
- Frost Protection - Calculated based on monitoring of four fields in Fall 2002 as 1.5 inches.
- Market Quality - Calculated based on amount of water required to overcome estimated distribution uniformity of properly designed and maintained irrigation systems considering ET_{aw} and leaching requirements and ranged from 3.0 inches for spinach to 24.6 inches for dates.
- Dust Control - Calculated based on information provided by two growers as 0.8 inches across all crops.

The WAC did not include an estimate of water requirements for irrigation system maintenance to periodically flush accumulated silt from microirrigation systems, though this could be considered as part of future efforts to evaluate agricultural WUE.

Based on the WAC analysis, the AWUF increased from approximately 0.72 in the 1970s to about 0.88 in the late 1990s to early 2000s.

5.5.3 Total Water Use Fraction

The Total Water Use Fraction (TWUF) further expands upon the CCUF by incorporating environmental uses of applied water (Equation 3):

$$TWUF = (ET_{aw} + \text{Other Agronomic Water Uses} + \text{Environmental Uses}) / AW \quad [3]$$

The TWUF would likely not be applicable to CVWD, as irrigation return flows do not support environmental uses within the District.

5.5.4 Water Management Fraction

The final methodology proposed by DWR is the Water Management Fraction (Equation 4):

$$WMF = (ET_{aw} + \text{Recoverable Return Flows}) / AW \quad [4]$$

The WMF can be applied at the supplier or basin scale to provide an indicator to the amount of applied irrigation water contributing to crop consumptive use or available for reuse. In the Coachella Valley, as described previously, recoverable return flows from irrigation include deep percolation of applied irrigation water that provides a source of recharge for the lower aquifer.

5.6 APPLICABILITY OF WUE METHODS TO CVWD

Application of one or more methods to quantify water use efficiency for CVWD requires information describing agricultural water use. This section provides an overview of available information that could be used by the District. It is recommended that the AWUF be applied as the primary method of quantifying WUE. Despite uncertainties in individual components of the AWUF, which could be reduced over time, the AWUF is considered superior to simply monitoring applied water demands, as it directly and indirectly considers a range of factors including changes in land use, weather, irrigation management and technology, etc. Through improved data collection and outreach with the agricultural community, these

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Evaluating Agricultural Water Use Efficiency and Conservation in the Coachella Valley

uncertainties can be further decreased over time. Available data from approximately 2012 to present has substantially improved to support development of a baseline describing agricultural WUE that can be relied upon moving forward.

5.6.1 Coachella Valley Agriculture

The Coachella Valley is a unique and diverse agricultural region containing a wide variety of crops, soils, and irrigation methods. Primary perennial crops include dates, grapes, and citrus, while primary annual crops include bell peppers, carrots, and lettuce, along with a wide range of additional high value crops. Soils are commonly stratified, consisting of layered sands, silts, and loams. Irrigation methods include a combination of microirrigation (drip and microspray), sprinkle, and gravity (furrow, basin, and border strip) techniques. A hallmark of the Coachella Valley has been the early and continued adoption of microirrigation systems and associated increase in distribution uniformity and potential WUE.

5.6.2 Available Information to Support Quantification of Agricultural Water Use Efficiency

The following section describes the data available to CVWD to support the quantification of agricultural water use efficiency.

5.6.2.1 Land Use and Irrigation Methods

CVWD has a designated zanjero to survey cropping and irrigation methods. The zanjero conducts surveys to create maps showing crops and irrigation methods three times annually. In recent years (i.e. 2014 to present), these maps have been digitized in a GIS format. The maps and associated data can be used to track land use now and in the future at scales from individual fields or ranches to the District as a whole. This system has greatly improved over historical practices, where records were recorded on paper plat maps representing individual one square mile sections, efficiently transferring field observations to digital GIS data. This information would be used to support quantification of several components of the AWUF moving forward, including crop ET and other, non-consumptive agronomic uses.

5.6.2.2 Precipitation

Sources of precipitation data include ground-based measurements and gridded estimates derived from a combination of ground-based measurements and information describing topography within the valley (i.e. elevation, slope, and aspect). Ground-based data include information from four active California Irrigation Management Information System (CIMIS) stations and several airport and fire station precipitation gages available through NOAA's National Center for Environmental Information (NCEI). Gridded data are available as part of the Parameter-elevation Regressions on Independent Slopes Model (PRISM) developed at Oregon State University. The use of gridded data could be used to track precipitation at the field/ranch scale, as well as for the District as a whole. This information would be used to support quantification of the amount of crop consumptive use derived from precipitation, as compared to applied irrigation water, as part of estimating the AWUF.

5.6.2.3 Surface Water Deliveries

The District maintains records of parcels receiving surface water deliveries and the meters which serve them. These records, historically referred to as "yellow cards" are maintained on an annual basis. There are instances where one meter serves many parcels as well instances where many meters serve one parcel, complicating the ability to quantify surface water use on individual fields. It is however possible to

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Evaluating Agricultural Water Use Efficiency and Conservation in the Coachella Valley

quantify the smallest unit of land served by a group of meters. These areas typically correspond to collections of fields commonly referred to as ranches.

In addition to tracking parcels served by individual meters, CVWD zanjeros record delivery volumes for each active meter on a daily basis using propeller meters at each turnout. Delivery volumes are transmitted to the District office in real time. Propeller meters are maintained as part of an established, systematic maintenance program to ensure reasonable accuracy.

This information would be used to support estimation of the AWUF at scales from the District to individual ranches by quantifying the amount of surface water delivered and applied.

5.6.2.4 Groundwater Pumping

Historically, groundwater pumping in the Lower Valley was estimated by difference between total estimated irrigation demands and measured surface water deliveries. Since implementation of the groundwater replenishment assessment for the East Whitewater River Subbasin Management Area in 2004, irrigation pumping has become increasingly reported on a monthly basis for individual wells. Since 2012, annual pumping has been based directly on reported pumping volumes. In addition to information on surface water deliveries described previously, reported pumping from 2012 onward would be utilized to support estimation of the AWUF at scales from the District to individual ranches by quantifying the amount of groundwater pumped and applied.

5.6.2.5 Crop Evapotranspiration

Crop evapotranspiration (ET) can be estimated via different approaches. Traditionally, a crop coefficient approach has been the standard, whereby crop ET is estimated over time based on the product of the ET for a reference crop (e.g. grass) and the relative ET of the crop of interest based on the growth stage of the crop of interest at that time (Allen, 1998). Challenges associated with this approach include uncertainties crop acreages over time, including double cropping; uncertainties in the timing of crop development within a season and across years, and uncertainties in effects of water stress, fertility, pests, disease, crop age (for perennial crops), or other factors that may influence actual crop ET. Existing, published estimates of crop coefficients are available from several sources, though these tend to assume ideal growing conditions and may overestimate actual ET.

More recently (i.e. in the last 10 to 15 years) actual ET is commonly estimated via remote sensing. The primary satellite used to estimate actual ET for agricultural fields is the Landsat satellite system, which currently includes the Landsat 7 and Landsat 8 satellites. Several methodologies exist, including energy balance approaches such as Surface Energy Balance Algorithm for Land (SEBAL) and Mapping Evapotranspiration at High Resolution with Internalized Calibration (METRIC) and more simplified vegetation index-based methods (Batiaanssen, 2005) (Allen, 2007) (Clark, 2013). Energy balance approaches overcome uncertainties in the traditional crop coefficient approach by utilizing actual information from the satellite for each pixel to quantify ET for a field. For Landsat, each pixel is approximately one quarter acre in size. This allows for estimation of ET for agricultural fields, which are almost always much more than an acre in size and allows for evaluation of the uniformity of ET within the fields. Additional information about the variability of ET within fields may be of value to growers in evaluating management of fields, including irrigation practices and system performance. The simplified vegetation index approaches are also able to overcome many of the limitations of the crop coefficient approach, though are limited in their ability to detect acute water stress compared to the energy balance methods. This may be an important limitation to application in the Coachella Valley due to crop water stress, particularly for vineyards and potentially citrus in summer months as demonstrated by Clark et al. (2007) using SEBAL.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Evaluating Agricultural Water Use Efficiency and Conservation in the Coachella Valley

Once ET estimates are developed, ET_{aw} and ET_{pr} is estimated based on precipitation timing and amount. These methods include empirical approaches developed by the NRCS, University of California, or others, as well as methods that rely on simulation of the root zone water budget on a daily or monthly basis for individual crops and soil types.

This information would be used to quantify the primary destination of applied water, ET_{aw} , as part of estimating AWUF. An inter-comparison of techniques to estimate crop ET for the neighboring Imperial Valley can be found in Thoreson et al. (2009) and provides a comparison to valley-wide estimates of ET from crop coefficients and SEBAL to an independent water balance analysis.

5.6.2.6 Leaching

As described previously, leaching requirements can be estimated based on crop-specific salinity tolerance and estimated salinity of applied irrigation water. Specifically, the leaching requirement (LR) is calculated according to the following equation (USSL 1954):

$$LR = \frac{EC_{iw}}{5a - EC_{iw}} \quad [5]$$

where EC_{iw} is the electroconductivity of the irrigation water and a is the crop threshold soil salinity at which yield reduction begins. Threshold salinity values are available in Agricultural Salinity Assessment and Management, published by the American Society of Civil Engineers (ASCE 2012).

LR is converted to a depth of required leaching application based on the following equation:

$$LR_d = ET_{aw} \frac{LR}{1 - LR} \quad [6]$$

where LR_d is the leaching requirement expressed as a depth, and ET_{aw} is amount of crop evapotranspiration derived from applied irrigation water.

5.6.2.7 Other Agronomic Uses

Primary agronomic uses of water in the Coachella Valley are crop ET and leaching. Other agronomic uses are important, if not critical to crop production, but may in many cases also contribute to crop ET and the leaching requirement. If these uses are determined to substantially contribute to crop ET and/or leaching, they should not be included as part of the AWUF. The following is a summary of potential opportunities to update prior estimates of other agronomic uses described previously.

Seedbed Preparation. As described in the 2005 WAC report, seedbed preparation applies to non-permanent crops grown on beds and was calculated based on the estimated amount of water to fill the crop root zone to field capacity¹ prior to planting. Based on grower interviews conducted by JMLord, seedbed preparation was determined to generally consist of two steps. First, the soil is wetted to a depth of three feet and soil moisture content is increased from approximately 20 percent of field capacity to 70 percent to support construction of the beds. Then, assuming the soil has dried to 60 percent of field

¹ Field capacity represents the soil water content at which gravitational drainage has ceased and water is retained via capillary action.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Evaluating Agricultural Water Use Efficiency and Conservation in the Coachella Valley

capacity during and following bed formation, the soil is wetted from 60 percent to 100 percent of field capacity to apply soil fumigants.

Due to changing growing practices over time, the assumptions used to estimate water requirements for seedbed preparation previously may require revision to reflect current conditions. This could be accomplished through consultation with U.C. Cooperative Extension, academic researchers, growers, or others. It is likely that water applied for seedbed preparation contributes substantially to crop ET and, in cases where plastic mulch is not used to cover the beds prior to fumigation, the leaching requirement.

Germination. Water requirements for crop germination were estimated by the WAC based on consultation with local growers and ranged from 1.4 to 2.6 inches. Similar to seedbed preparation, grower practices may have changed over time and these estimates could be updated through consultation with U.C. Cooperative Extension, academic researchers, growers, or others. It is likely that water applied for germination contributes substantially to crop ET and potentially leaching in cases where the beds are not covered with plastic mulch.

Hydrocooling. Water used to induce dormancy in Coachella Valley vineyards, referred to by the WAC as hydrocooling was estimated based on monitoring of several vineyards. These estimates could be updated through tracking the number of vineyards applying water through overhead sprinklers during the fall or through consultation with vineyard producers; however, hydrocooling contributes substantially to the leaching requirement.

Frost Protection. The WAC estimated water requirements for frost protection based on a combination of field monitoring and guidelines for initiation of frost protection provided by the Rainbird Corporation. Based on monitoring and consultation with growers, it was estimated that when nighttime temperatures are expected to drop close to or below freezing, growers typically run their irrigation systems from 6 p.m. until the following morning when temperatures have risen such that the risk of frost protection is reduced.

Additional information describing irrigation requirements for frost protection is available from the United Nations Food and Agriculture Organization (FAO 2005). Based on these guidelines, frost protection requirements could be estimated based on observed temperature over time.

Although frost protection may contribute somewhat to crop ET and the leaching requirement, it is a required practice to prevent crop damage and thus could be required an additional agronomic use.

Market Quality. Due to market quality requirements for many high value crops grown in the Coachella Valley, the WAC calculated water requirements based on estimated distribution uniformities for properly designed and maintained irrigation systems using the following equation:

$$MQ = \frac{ET_{aw} - LR_d}{DU} \quad [7]$$

where MQ is the water requirement to maintain market quality, ET_{aw} is amount of crop evapotranspiration derived from applied irrigation water, LR_d is the crop leaching requirement expressed as a depth, and DU is the distribution uniformity for a properly designed and maintained irrigation system.

Due to advances in irrigation technology and management over time, the amount of water required to maintain market quality may have decreased since the WAC report. Estimates of water requirements for market quality could be updated through consultation with irrigation designers and suppliers, U.C. Cooperative Extension, academic researchers, growers, or others. Due to the need to maintain uniform crop ET and soil salinity, MQ could be consider an independent water requirement above crop ET and leaching.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Evaluating Agricultural Water Use Efficiency and Conservation in the Coachella Valley

Dust Control. Water requirements to maintain dust control were estimated by the WAC to be relatively low (0.8 inches per year), but do represent a required use of water to meet air quality regulatory requirements. Water applied for dust control to unpaved farm roads does not contribute substantially to crop ET or the leaching requirement. Prior estimates could be updated through additional consultation with local growers.

Recommendations

6.0 Recommendations

6.1 EVALUATION OF WATER USE EFFICIENCY

Based on review of past evaluations of agricultural water use in CVWD, including the CVWMP, WAC report, and Water 2025 report; evaluation of accepted, peer-review approaches to evaluate irrigation performance and WUE; and review of available information describing agricultural water management in CVWD, the following recommendations are provided to develop a baseline for evaluating current and future agricultural water use to support implementation of the CVWMP:

- Utilize one or more DWR WUE methods to characterize agricultural water management and changes in applied water over time, considering cropping changes, weather variation, irrigation methods, and other factors. The most appropriate method is the AWUF, as it recognizes all agronomic uses of water and can be applied at both the farm and District scale.
- Refine existing estimates of agronomic use through outreach with CVWD growers. This could be through a combination of surveys, direct interviews, and grower meetings. Information would be gathered on several aspects of farm water management, including but not necessarily limited to the following:
 - o Crops grown and acreage farmed (by grower)
 - o Reliance on surface water vs. groundwater and factors affecting decision to use either source
 - o Factors affecting decisions of when and how much water to apply
 - o Use of water for ET, leaching, seedbed preparation, germination, hydrocooling, frost protection, market quality, dust protection, irrigation system maintenance, and other purposes
 - o Changes in irrigation practices over time
- As part of implementing the quantification of WUE using the AWUF, evaluate the quality of existing data and develop and implement a plan to improve data quality over time.
- Implement the procedures developed by JMLord and described in the Water 2025 report to estimate surface water use at the farm scale using recent surface water delivery data (e.g. 2012 to present). Combine this with information on well location from the groundwater replenishment assessment to estimate total water use at the farm scale. This would allow for quantification of the AWUF at the farm scale to provide a basis for evaluating water management for individual growers to support targeted outreach to support water conservation while also further improving CVWD data on water usage. Although there are uncertainties in where surface water delivered to customers is ultimately applied, CVWD has a system in place to track the destination of surface water deliveries at the farm scale. These uncertainties could be reduced through consultation with individual growers, which would require voluntary grower participation. Also, the uncertainties can be decreased by aggregating spatially to operator areas and temporally to annual values. It is noted that this recommendation relies upon farmers providing information and data to CVWD. It is not clear whether farmers would be willing to share this information with CVWD and, as such, other methods of quantification should continue to be pursued.
- The calculation of average agricultural water use per acre has value as a general planning number for projecting future agricultural water demands. However, its application to the evaluation of WUE is limited due to the variation in weather, crop types, and irrigation practices over time. Future CVWMP updates should revisit this calculation to determine a reasonable range of values for use in demand projections. In addition, the assumptions for urban growth on agricultural land versus raw land should be revisited using data from recent and proposed developments.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

Recommendations

- CVWD should regularly review and perform quality assurance on new and historical data available to them. The most reliable data sources should be identified and prioritized for use in calculating WUE moving forward, and the data discrepancies identified in this report should be noted when making future calculations.

6.2 OUTREACH WITH THE AGRICULTURAL COMMUNITY

In addition to conducting outreach to improve understanding of agronomic uses of water for agriculture, it is recommended that outreach with the agricultural community be conducted to build consensus regarding agricultural water use efficiency and to understand preferences and opportunities for actions the District could undertake to encourage farm water conservation, such as incentives or services to implement improved irrigation technology and management practices. It is anticipated that this outreach would begin with a discussion of the conservation strategy and targets developed as part of the CVWMP but would also be an open exchange allowing growers to provide direct input from their perspectives. Specific outreach could include the development of materials for inclusion on the CVWD website, conducting grower meetings, conducting surveys, and direct interviews of willing growers. Provisions to maintain the confidentiality of grower response should be implemented.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

References

7.0 References

- Allen, R. G., Tasumi, M., and Trezza, R. 2007. Satellite-based energy balance for mapping evapotranspiration with internalized calibration_METRIC—Model. *J. Irrig. Drain. Eng.*, 133.4, 380-394.
- Allen, R. G., L. S. Pereira, D. Raes, and M. Smith. 1998. Crop evapotranspiration: Guidelines for computing crop water requirements. *FAO Irrigation and Drainage Paper N° 56*. Rome, Italy. 290
- Bastiaanssen, W. G. M., Noordman, E. J. M., Pelgrum, H., Davids, G., Thoreson, B. P., and Allen, R. G. 2005. SEBAL model with remotely sensed data to improve water-resources management under actual field conditions. *J. Irrig. Drain. Eng.*, 131.1, 85-93.
- Burt, C.M., Clemmens, A.J., Strelkoff, T.S., Solomon, K.H., Bliesner, R.D., Hardy, L.A., Howell, T.A. and Eisenhauer, D.E. 1997. Irrigation performance measures: efficiency and uniformity. *J. Irrig. Drain. Engrg.* 123, 423-442.
- Clark, B., L. Hall, L. Dotson, and G. Davids. 2013. Remote Sensing of Evapotranspiration and Root Zone Water Balance Modeling to Estimate Groundwater Extraction in the Kaweah River Delta of California. Using 21st Century Technology to Better Manage Irrigation Water Supplies. U.S. Committee on Irrigation and Drainage. Seventh International Conference on Irrigation and Drainage. Phoenix, Arizona. April 16-19, 2013.
- Clark, B., Soppe, R., Lal, D., Thoreson, B., Bastiaanssen, W., and Davids, G. 2007. Variability in Crop Coefficients in Space and Time - Examples from California. The Role of Irrigation and Drainage in a Sustainable Future. U.S. Committee on Irrigation and Drainage. Fourth International Conference on Irrigation and Drainage. Sacramento, California. October 3-6, 2007.
- Coachella Valley Water District, Coachella Valley Water Management Plan, prepared by MWH (now a part of Stantec) and WaterConsult, September 2002.
- Coachella Valley Water District, Final Program Environmental Impact Report for the Coachella Valley Water Management Plan and State Water Project Entitlement Transfer, prepared by MWH (now a part of Stantec), 2002.
- Coachella Valley Water District, 2010 Coachella Valley Water Management Plan Update, prepared by MWH (now a part of Stantec) and WaterConsult, January 2012.
- Coachella Valley Water District, 2016 Crop Report.
- Coachella Valley Water District, Agricultural Water Production Records. 2000-2017.
- Coachella Valley Water District, Annual Crop and Water Data Reports to United States Bureau of Reclamation (Form 7-2045), 2000-2017.
- Coachella Valley Water District, Annual Review and Water Quality Reports, 2000-2017.

DOCUMENTATION FOR THE AGRICULTURAL WATER CONSERVATION GOALS AND RECOMMENDED METHODS TO TRACK PROGRESS

References

Coachella Valley Water District, Crop Summary Data from GIS, 2014-2017.

Coachella Valley Water District, Final Project Report for Cooperative Agreement No. 05FC340010-Agricultural Conservation of Colorado River Water in the Coachella Valley, California (Water 2025 Report), January 5, 2009.

Dahl Consultants, Preliminary Design Report for the Oasis Area Irrigation System Expansion Project, prepared for Coachella Valley Water District, 2014.

DWR. 2012. Proposed Methodology for Quantifying the Efficiency of Agricultural Water Use. California Department of Water Resources Division of Statewide Integrated Water Management. Water Use Efficiency Branch. May 2012. 105 pp.

JMLord, Inc. Unpublished estimates of irrigated acreage outside Improvement District No. 1, 2009.

MWH (now a part of Stantec) and Formation Environmental, Review of Coachella Valley Reference Evapotranspiration Map, prepared for Coachella Valley Water District, June 2017.

MWH (now a part of Stantec), Unpublished data files documenting population projections and water demand forecasts for the 2010 Coachella Valley Water Management Plan Update.

Prism Climate Group. <http://prism.oregonstate.edu>. 2018 Northwest Alliance for Computational Science & Engineering (NACSE), based at Oregon State University

Thoreson, B., Clark, B, Soppe, R., Keller, A. Bastiaanssen, W., J. Eckhardt. 2009. Comparison of Evapotranspiration Estimates from Remote Sensing (SEBAL), Water Balance, and Crop Coefficient Approaches. ASCE EWRI World Environmental and Water Resources Congress 2009: Great Rivers. Kansas City, Missouri. May 17-21, 2009.

United States Bureau of Reclamation, Letter to Coachella Valley Water District, Colorado River Water Delivery Agreement, Exhibit C Payback for 2005. December 15, 2006.

United States Salinity Laboratory (USSL). 1954. Diagnosis and Improvement of Saline and Alkali Soils. USDA Handbook No. 60, L.A. Richards, Editor, Washington, DC, 160 pages.

Water Advisory Committee for the Coachella Valley Water District, Water Management within Improvement District No. 1 of the Coachella Valley Water District, August 25, 2004.