STEPHANIE OSLER HASTINGS, Bar No. 186716
MACKENZIE W. CARLSON, Bar No. 323850
BROWNSTEIN HYATT FARBER SCHRECK, LLP
1021 Anacapa Street, 2nd Floor
Santa Barbara, California 93101
Telephone: 805.963.7000
Email: SHastings@bhfs.com; Mcarlson@bhfs.com

Attorneys for Plaintiff
GOLDEN STATE WATER COMPANY

SUPERIOR COURT OF THE STATE OF CALIFORNIA

COUNTY OF RIVERSIDE

Coordination Proceeding Special Title (Cal. Rules of Court, rule 3.550) MOJAVE BASIN AREA WATER CASES	JCCP NO.: 5265 Lead Case No. CIV 208568 Assigned for All Purposes to the Honorable Harold W. Hopp, Dept. 1 Honorable Craig G. Reimer, Judge Presiding by assignment of the Chief Justice
CITY OF BARSTOW, et al., Plaintiff, v. CITY OF ADELANTO, et al., Defendant.	**GOLDEN STATE WATER COMPANY'S EVIDENCE IN SUPPORT OF MOTION TO ENFORCE JUDGMENT – VOLUME 1 (Pages GSWC 0001 to GSWC 0292)** Date: October 2, 2024 Time: 8:30 am Dept.: 1 Judge: Hon. Craig G. Reimer **Reservation ID: 562595011427**

INDEX OF EXHIBITS

EXHIBIT	DESCRIPTION	PAGE(S)
1.	aquilogic, Inc., Expert Report of Anthony Brown, Hydrologic Conditions and Water Flow Between the Alto Subarea and the Centro Subarea of the Mojave Basin, San Bernardino County, California (Sep. 5, 2024)	GSWC 0001 – GSWC 0161
	Court Orders	
2.	Order (1) Discharging Order to Show Cause Why the FPA of Alto Should Not Be Reduced by Another 4.5% of BAP, (2) Reducing the FPA in Alto by Another 0.1 % of BAP, and (3) Directing the Watermaster to Re-Evaluate PSY for the Entire Basin, *City of Barstow v. City of Adelanto*, Riverside Sup. Ct. Case No. CIV208568 (Sep. 16, 2022)	GSWC 0162 – GSWC 0171
3.	Ruling on the Watermaster's Annual Motion to Adjust Free Production Allowance for Water Year 2024–2025, *City of Barstow v. City of Adelanto*, Riverside Sup. Ct. Case No. CIV208568 (Jul. 3, 2024)	GSWC 0172 – GSWC 0184
	Watermaster Reports, Studies, and Presentations	
4.	Wagner & Bonsignore, Consulting Civil Engineers, Production Safe Yield & Consumptive Use Update (Feb. 28, 2024).	GSWC 0185 - GSWC 0292
5.	Watermaster, Thirtieth Annual Report of the Mojave Basin Area Watermaster, Water Year 2022–23 (May 1, 2024) https://www.mojavewater.org/wp-content/uploads/2024/04/30AR2223.pdf.	GSWC 0293 - GSWC 0484
6.	Watermaster, Thirtieth Annual Report of The Mojave Basin Area Watermaster Water Year 2022–23, Appendix L (May 1, 2024) https://www.mojavewater.org/wp-content/uploads/2024/04/30AppL2223.pdf.	GSWC 0485 - GSWC 0837
	General Hydrologic Resources	
7.	Cha, M., Li, M., Wang, X. (2020). Estimation of Seasonal Evapotranspiration for Crops in Arid Regions Using Multisource Remote Sensing Images. July 21. https://doi.org/10.3390/rs12152398.	GSWC 0838 - GSWC 0859
8.	Gleason, C.J. and Durand, M.T., Remote Sensing of River Discharge: A Review and a Framing for the Discipline, Remote Sensing Vol. 12, No. 1107 (Mar. 31, 2020) https://doi.org/10.3390/rs12071107.	GSWC 0860 – GSWC 0888
9.	Masafu, C., Williams, R., and Hurst, M.D., Satellite Video Remote Sensing for Estimation of River Discharge, Geophysical Research Letters, 50, e2023GL105839 (Mar. 31, 2020) https://doi.org/10.1029/2023GL105839.	GSWC 0889 - GSWC 0900

10.	Conaway, J., Eggleston, J., Legleiter, C.J., Jones, J.W., Kinzel, P.J., Fulton, J.W., Remote Sensing of Streamflow in Alaska Rivers—New Technology to Improve Safety and Expand Coverage of USGS Streamgaging, U.S. Geological Survey Fact Sheet 2019–3024. (Apr. 2019) https://doi.org/10.3133/fs20193024.	GSWC 0901 – GSWC 0905
11.	Holmes, T.R.H. (2019). Chapter 5 – Remote sensing techniques for estimating evapotranspiration. In: Extreme Hydroclimatic Events and Multivariate Hazards in a Changing Environment. June 6. https://ntrs.nasa.gov/api/citations/20210011848/downloads/26861.pdf	GSWC 0906 - GSWC 0921
12.	Kustas, W.P., Norman, J.M. (2009). Use of remote sensing for evapotranspiration monitoring over land surfaces. December 24. https://doi.org/10.1080/02626669609491522	GSWC 0922 - GSWC 0945
	Correspondence	
13.	Brownstein Hyatt Farber Schreck, LLP corresp. To Watermaster, Agenda Item 7 - Comments on Watermaster's Production Safe Yield Update (REVISED) (Feb. 28, 2024).	GSWC 0946 – GSWC 0965
14.	Brownstein Hyatt Farber Schreck, LLP corresp. to Watermaster, Agenda Items 7 & 9 - Comments on Watermaster's Production Safe Yield Update (February 2024), proposed recommendation for Free Production Allowance for Water Year 2024–25, Watermaster Annual Report for Water Year 2022-23 (Mar. 27, 2024).	GSWC 0966 – GSWC 0968
15.	Wagner & Bonsignore, Consulting Civil Engineers memo to Mojave Basin Area Watermaster Attorney, Response to comments on Transition Zone Water Balance memorandum, dated February 28, 2024 (Apr. 12, 2024).	GSWC 0969 - GSWC 0985
	Data	
16.	Golden State Water Company Centro Well Data, available at https://bhfs.sharefile.com/share/view/sc4bbae97dcb44d288d59e7da82922368	GSWC 0986 - GSWC 0987

Dated: September 5, 2024

BROWNSTEIN HYATT FARBER SCHRECK, LLP

By: ______________________
Stephanie Osler Hastings
Mackenzie W. Carlson

Attorneys for Plaintiff
GOLDEN STATE WATER COMPANY

30883973.2

EXHIBIT 1

aquilogic, Inc.
environment • water • strategy

245 Fischer Avenue, Suite D-2
Costa Mesa, CA 92626
Tel. +1.714.770.8040
Web: www.aquilogic.com

EXPERT REPORT OF ANTHONY BROWN

HYDROLOGIC CONDITIONS AND WATER FLOW BETWEEN THE ALTO SUBAREA AND THE CENTRO SUBAREA OF THE MOJAVE BASIN SAN BERNADINO COUNTY, CALIFORNIA

MOJAVE GROUNDWATER BASIN ADJUDICATION - CITY OF BARSTOW, ET AL. VS. CITY OF ADELANTO, ET AL. (CASE NO. CIV208568)

Signed: ____________________

Prepared for:

Brownstein, Farber, Hyatt, Schreck, LLP
1021 Anacapa St 2nd Floor
Santa Barbara, CA 93101

Project No.: 018-10

September 2024

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ACRONYMS AND ABBREVIATIONS

<	less than
>	greater than
≥	greater than or equal to
%	percent
AF	Acre-Feet
AFY	Acre-Feet per Year
Alto	Alto Subarea
aquilogic	Aquilogic, Inc.
BAP	Base Annual Production
Basin	Mojave Basin Area
BMP	Best Management Practice
Brownstein	Brownstein, Farber, Hyatt, Schreck, LLP
Centro	Centro Subarea
CV	Curriculum Vitae
DWR	California Department of Water Resources
EM	Electromagnetic EM
ET	Evapotranspiration
Expert Report	Expert Report of Hydrologic Conditions and Water Flow Between the Alto Subarea and the Centro Subarea of the Mojave Basin, San Bernadino County, California
FCGMA	Fox Canyon Groundwater Management Agency
FPA	Free Production Allowance
Golden State	Golden State Water Company
IWVGA	Indian Wells Valley Groundwater Authority
IWVWD	Indian Wells Valley Water District
Judgment	Stipulated Judgment
M&I	Municipal and Industrial
MK	Mann-Kendall
MWA	Mojave Water Agency
p-value	statistical confidence
PRISM	Parameter-elevation Regressions on Independent Slopes Model
PSY	Production Safe Yield
Q_{in}	Water going in (recharge = income)
Q_{out}	Water leaving (discharge = expenses)
r	traditional linear correlation coefficient
R-Cubed	Regional Rechange and Recovery Project

ΔS	Change in storage (increase/decrease = increase/decrease in savings)
SGMA	Sustainable Groundwater Management Act
SWRCB	State Water Resource Control Board Division of Drinking Water
Sy	Specific yield
τ	Kendall's tau- measure of the strength of the correlation between an independent variable and a dependent variable
TAC	Technical Advisory Committee
TLRD	Tulare Lake Reclamation District
TZ	The Transition Zone
UMRB	Upper Mojave River Basin
USGS	United States Geological Survey
VVWRA	Victor Valley Wastewater Reclamation Authority
WY	Water Year - October 1st the previous calendar year to September 30th, e.g., October 1, 2021, to September 30, 2022, is water year 2022
Watermaster	Mojave Water Agency
Watermaster Engineer	Wagner & Bonsignore

1.0 INTRODUCTION

Aquilogic, Inc. (**aquilogic**) has prepared this Expert Report of Hydrologic Conditions and Water Flow Between the Alto Subarea (Alto) and the Centro Subarea (Centro) of the Mojave Basin, San Bernadino County, California (Expert Report) for Brownstein, Farber, Hyatt, Schreck, LLP (Brownstein) special counsel to Golden State Water Company (Golden State). The report provides an analysis of hydrologic conditions in the Mojave Basin Area (Basin) relevant to inflow to Centro from the Transition Zone (TZ) of Alto (**Figure 1-1**). This analysis stems from Golden State's concerns about management of the Basin under the Stipulated Judgment (Judgment)[1] because many of Golden State's production wells in Centro have experienced chronically declining water levels, resulting in increased pumping and treatment costs.

In simple terms, declining groundwater levels (i.e., loss of storage) result from excess discharge (e.g., over-pumping) and/or insufficient recharge (e.g., stream bed seepage) in a hydrologic system. Current data and analyses presented herein demonstrate that the declining water levels do not correlate with increased pumping at Golden State's production wells in Centro. Therefore, it is likely that decreases in inflow to Centro have contributed to the declining water levels. Given this, the declining water levels call into question whether Watermaster's calculations are accurate and thus whether groundwater Producers in Alto are meeting their obligation to deliver defined volumes of annual recharge to Centro as specified in the Judgment.

At present, there is insufficient information to confirm if Centro receives the inflow specified in the Judgment because Watermaster's simplified water budget is not adequately detailed and does not employ current approaches used throughout California in other basins (see recommendation in **Section 6.0**). Specifically, there are no measurements of surface water inflow to Centro.

A detailed water budget with reduced reliance on estimated values is needed. Therefore, Watermaster should reevaluate the water budgets for Alto, TZ, and Centro using more current approaches. A more robust, revised water budget can then be used to evaluate whether groundwater Producers in Alto are satisfying their obligation to deliver the volumes of recharge to Centro specified in the Judgment. If the revised water budget indicates that the obligation is being met, then further analyses should be done to determine why water levels continue to fall in Centro.

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[1] Riverside (1996). Judgment after Trial, Mojave Basin Area Adjudication. City of Barstow et al. v. City of Adelanto et al. Riverside County Superior Court Case No. 208568. January 10.

1.1 Assignment

Aquilogic was retained by Brownstein on behalf of Golden State to investigate the causes of chronically declining water levels in Golden State's production wells in Centro. The investigation initially led to an examination of stream discharge and stream recharge in Alto, TZ, and Centro, which suggested that surface water inflow to the Centro may be overestimated by Watermaster (**Appendix A**).

Subsequently, **aquilogic** assessed the adequacy of the Watermaster water budgets for Alto, TZ, and Centro (**Section 4.0**), as described in the Watermaster's Annual Reports and in the Watermaster Engineer's most recent (2024) Production Safe Yield Update report.[2,3] Additionally, in response to Watermaster's Engineer's analysis of Golden State's concerns, **aquilogic** conducted a direct statistical analysis of water levels in Centro, described in this Expert Report, which assessed whether Golden State's groundwater production in Centro is the primary cause of the chronically declining water levels observed in Golden State's production wells (**Section 5.0**).

1.2 Structure of this Report

After this introduction section, this Expert Report summarizes our opinions in **Section 2.0**. The Expert Report presents the background physical setting of the Basin in terms of the geology, hydrology, land use, and climate in **Appendix B**. This allows a reader familiar with the Basin to more quickly get to the analyses performed by **aquilogic** (**Sections 4.0 and 5.0**). The Expert Report then briefly discusses key features of the Judgment (**Section 3.0**) to provide context for the analyses performed. An analysis of the water budgets prepared by Watermaster's Engineer is provided in **Section 4.0**. Analyses of water levels in Golden State's Centro production wells are presented in **Section 5.0** to show that water levels are primarily dependent on overall hydrologic conditions (e.g., inflow from Alto and TZ into Centro), rather than groundwater production. Finally, the Expert Report concludes with a set of recommended actions that Watermaster should undertake to improve the accuracy of all components of the water budgets for Alto (and TZ) and Centro, and thus the Production Safe Yield (PSY) for Alto and Centro (**Section 6.0**). If implemented by Watermaster, these recommendations should facilitate a deeper understanding of Basin hydrology and facilitate implementation the Judgment's physical solution.

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[2] Watermaster (2024). Thirtieth Annual Report of the Mojave Basin Area Watermaster, Water Year 2022-23, May 1, 2024.

[3] Watermaster (2024). Production Safe Yield & Consumptive Use Update. Prepared by Wagner and Bonsignore, Consulting Civil Engineers. February 28, 2024.

1.3 Qualifications

Aquilogic is currently providing, or has recently provided, consulting and expert support in the water rights matters below. This work includes support for all phases of a dispute or adjudication (e.g., basin boundaries, safe yield, allocation, physical solution) and during the implementation of a court-approved physical solution.

1. Steinbeck Vineyards No.1 LLC vs. County of San Luis Obispo et al. (Salina Valley - Paso Robles Area [California Department of Water Resources [DWR] Basin No. 3-04.06])
2. Santa Maria Valley Water Conservation District vs. City of Santa Maria et al. (Santa Maria Basin [No. 3-12])
3. San Luis Obispo Coastkeeper et al. vs. Santa Maria Valley Water Conservation District (Santa Maria Basin [No. 3-12])
4. Bolthouse Land Company LLC et al. vs. All Persons Claiming a Right to Extract or Store Groundwater in the Cuyama Valley Groundwater Basin (No. 3-13)
5. King's River Water Association (KRWA) et al. vs. Tulare Lake Reclamation District (TLRD) et al (Tulare Lake Basin [No. 5-22.12])
6. Indian Wells Valley Groundwater Authority (IWVGA) vs. Mojave Pistachios LLC (Indian Wells Valley Basin [No. 6-54]) and two related cases: Mojave Pistachios LLC vs. IWVGA; and Indian Wells Valley Water District (IWVWD) vs. All Persons Claiming a Right to Extract or Store Groundwater in the Cuyama Valley Groundwater Basin
7. Goleta Water District vs. Slippery Rock Ranch LLC (Goleta Basin [No. 3-16])
8. Santa Barbara Channelkeeper vs. State Water Resources Control Board (SWRCB) and related City of San Buenaventura vs. Duncan Abbott et al. (Ventura River Valley – Upper [No. 4-03.01], Lower (No. 4-03.02], Ojai [No. 4-01], Upper Ojai [No. 4-01])
9. Las Posas Valley Water Rights Coalition vs. Fox Canyon Groundwater Management Agency (FCGMA) (Las Posas Valley Basin [No. 4-08])
10. OPV Coalition et al vs. FCGMA et al (Santa Clara River Valley – Oxnard [No. 4-04.02], Pleasant Valley [No. 4-06])
11. Friends of Eel River vs. County of Humboldt et al (Eel River Valley [Basin No. 1-10])
12. Glenn C. Rice et al. vs. Okell Holdings LLC (Napa Vally [No. 2-02.01])

We are also providing consulting support related to the 2014 California Sustainable Groundwater Management Act (SGMA) and/or SWRCB permitting in the following groundwater basins (see **Figure 1-2**):

- Eel River Valley (No. 1-10)
- Santa Rosa Valley – Santa Rosa Plain (No. 1-55.01)
- Napa Sonoma Valley – Sonoma Valley (No. 2.02.02)
- Napa Sonoma Valley – Napa Valley (No. 2.02.01)

- Sand Point Area (2-27)
- Pajaro Valley (No. 3-02)
- Salinas Valley – 180/400 Foot Aquifer (No. 3-04.01)
- Salinas Valley – Langley Area (No. 3-04.09)
- Salinas Valley – East Side Aquifer (No. 3-04.02)
- Salinas Valley – Forebay Aquifer (No. 3-04.04)
- Salinas Valley – Upper Valley Aquifer (No. 3-04.05)
- Salinas Valley – Paso Robles Area (No. 3-04.06)
- Santa Maria Valley (No. 3-12)
- Santa Ynez River valley (No. 3-15)
- Cuyama Valley (No. 3-13)
- Goleta (No. 3-16)
- Ventura River Valley – Upper Ventura River (No. 4-03.01)
- Ventura River Valley – Lower Ventura River (No. 4-03.02)
- Ojai Valley (No. 4-02)
- Upper Ojai Valley (No. 4-01)
- Santa Clara River Valley – Mound (No. 4-04.03)
- Santa Clara River Valley – Oxnard (No. 4-04.02)
- LPVB (No. 4-08)
- Pleasant Valley (No. 4-06)
- Sacramento Valley – South American (No. 5-21.65)
- San Joaquin Valley – Madera (No. 5-22.06)
- San Joaquin Valley – Kings (No. 5-22.08)
- San Joaquin Valley – Kaweah (No. 5-22.11)
- San Joaquin Valley – Tulare Lake (No. 5-22.12)
- San Joaquin Valley – Tule (No. 5-22.13)
- San Joaquin Valley – Kern (No. 5-22.14)
- Cummings Valley (No. 5-27)
- Indian Wells Valley (No. 6-54)
- Borrego Valley (No. 7-24)
- San Juan Valley (No. 9-01)

1.3.1 Anthony Brown

Anthony holds a Bachelor of Arts Degree with Honors in Geography (1985) from King's College London, a Master of Sciences in Engineering Hydrology (1988) from Imperial College London, and a Diploma of Imperial College in Civil Engineering (1989).

He has over 30 years of experience as an environmental and water resources consultant. During this period, he has conducted and managed groundwater resources projects that have included: water resources evaluation, development, and management; water balance, storage capacity and safe yield analysis; and water rights disputes and adjudications.

Anthony's Curriculum Vitae (CV), including a list of publications and cases in which he has served as an expert, is provided in **Appendix C**.

1.3.2 Robert Abrams

Robert (Bob) holds a Bachelor of Science in Geology (1991) from San Francisco State University, a Master of Science in Hydrogeology (1996) from Stanford University, and a Doctor of Philosophy in Hydrogeology (1999) from Stanford University.

He has over 25 years of professional experience in groundwater resource development, groundwater sustainability, groundwater banking, groundwater quality, and model design and evaluation. Bob currently serves on seven Technical Advisory Committees (TACs) in four DWR Bulletin 118 groundwater basins/subbasins.

Bob's Curriculum Vitae (CV), including a list of publications, is provided in **Appendix D**.

2.0 Summary of Opinions

The key opinions listed below have been reached after careful review and analysis of available and pertinent information regarding the Basin. Certain other statements contained within this report and accompanying appendices may also be considered opinions. All opinions are (a) more likely than not true, (b) are supported by analysis and evidence to allow a finder of fact to understand the reasons for that opinion, and (c) have been reached with a reasonable degree of scientific certainty. Accepted methodologies and analyses widely used by professionals practicing in the fields of hydrology and water resources management have been employed to develop the opinions.

Based on our review, analysis, and findings, we have reached the following key opinions:

1. Production wells operated by Golden State in Centro are experiencing chronic water level declines. In simple terms, considering a conservation of mass, groundwater level declines (i.e., loss of storage) result from excessive discharge (e.g., over-pumping) and/or insufficient recharge (e.g., river seepage).
2. Based on currently available data and analyses performed by **aquilogic**, the observed chronic water level declines at Golden State's production wells in Centro do not result from over-pumping at the wells.
3. Thus, it is more likely that recharge to Centro from Alto has decreased and contributed to the observed chronic water level declines.
4. There is currently a deficit in the volume of water producers in Alto are obligated under the Judgment to deliver as recharge to Centro.
5. The Watermaster for the adjudicated Basin should take actions to better quantify recharge to Centro, notably stream flows in the Mojave River and subsurface flow.
6. The Watermaster should also address recommendations presented in **Section 6.0** of this Expert Report to ensure more effective management of groundwater in the Basin.

3.0 The Judgment

The first Stipulated Judgment was entered on September 22, 1993. Subsequently, there was a second trial to address the claims of the non-stipulating parties. The Final Judgment After Trial, Mojave Basin Area Adjudication (the Judgment) was entered on January 10, 1996.[4]

3.1 Production Safe Yield

Base Annual Production (BAP), PSY, and Free Production Allowance (FPA) are key values defined in the Judgment that govern the amount of groundwater that can be pumped for beneficial use by groundwater Producers in the Basin (see **Appendix E** for definitions of capitalized terms).

Initially, the Judgment specified that 1990 conditions of water use and disposal were representative of the then existing cultural conditions in the Basin, which informed the PSY. Watermaster later determined that Water Year (WY) 1997 was an appropriate baseline year to update the Subarea water budgets and calculate the current-year PSY.[5] Estimated consumptive use was first updated in 2000,[6] and again in 2019.[7] In 2022, the Court ordered Watermaster to update consumptive use and PSY, which was completed in 2024 (**Section 3.4**).[8,9]

The 2024 consumptive use update was used to update the elements of the current-year PSY, which was reported and used in the WY 2023 Watermaster Annual Report.[10,11] The current FPA and estimated PSY for each Subarea are summarized in **Table 3-1**. Watermaster continues to use a simplified water budget to determine current-year PSY for all Subareas. Also in WY 2023,

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[4] Riverside (1996). Judgment after Trial, Mojave Basin Area Adjudication. City of Barstow et al. v. City of Adelanto et al. Riverside County Superior Court Case No. 208568. January 10.

[5] Watermaster (2000). Sixth Annual Report of the Mojave Basin Area Watermaster, Water Year 1998-99, April 1, 2000. (Page 25)

[6] Webb (2000). Consumptive Water Use Study and Update of Production Safe Yield, Calculations for the Mojave Basin Area. Prepared by Albert A. Webb Associates for the Mojave Basin Areas Watermaster. February 16.

[7] Wagner & Bonsignore (2019). Consumptive Water Use Study and Update of Production Safe Yield, 2017-18 Water Year. Prepared by Wagner & Bonsignore Consulting Civil Engineers for the Mojave Basin Areas Watermaster. May 1.

[8] Riverside (2022). Order (1) Discharging Order to Show Cause Why the FPA of Alto Should Not Be Reduced by Another 4.5% of BAP, (2) Reducing the FPA in Alto by Another 0.1 % of BAP, and (3) Directing the Watermaster to Re-Evaluate PSY for the Entire Basin. City of Barstow v. City of Adelanto, Case No. CIV208568. Superior Court of the State of California, County of Riverside. September 16.

[9] Wagner & Bonsignore (2024). Consumptive Water Use Study and Update of Production Safe Yield. Prepared by Wagner & Bonsignore Consulting Civil Engineers for the Mojave Basin Areas Watermaster. February 28.

[10] Watermaster (2024). Thirtieth Annual Report of the Mojave Basin Area Watermaster, Water Year 2022-23, May 1, 2024.

[11] Watermaster (2024). Production Safe Yield & Consumptive Use Update. Prepared by Wagner and Bonsignore, Consulting Civil Engineers. February 28, 2024.

Watermaster began to employ a groundwater model to compute some factors/components of the water budget and some portions of the PSY calculation.

Surface water inflow is a significant component of several of the Subareas' water budgets and current-year PSYs. For Centro, surface water inflow has not been measured directly because there is no Mojave River stream gage at the upstream boundary of Centro. Instead, surface water inflow to Centro has been estimated by adjusting the Mojave River discharge at the Lower Narrows gage by a simplified TZ water budget. The Lower Narrows gage is located at the upstream boundary of the Alto TZ (**Figure 1-1**).

3.2 Subarea Obligations

Historically, some Subareas were found to have received at least a portion of their natural water supply from water flowing to them from upstream Subareas, either on the surface or as Subsurface Flow. It has been shown that upstream pumping negatively impacts downstream Subareas (see **Appendix B**, p. 10-11). To maintain that historical relationship, the average annual obligation of any Subarea to another is set in the Judgment equal to the estimated average annual natural flow (excluding Storm Flow) between the Subareas over the 60-year period WY 1931 through WY 1990. If the Subarea obligation is not met, Producers of water that bear a Replacement Water obligation in the upstream Subarea must provide Makeup Water. When flow is more or less than the average Subarea Obligation, the upstream area will be given "credit" or "debit" for offsetting future deficiencies or surpluses.

The Judgment stipulates that groundwater Producers in Alto have an obligation to deliver at least 23,000 Acre-Feet per Year (AFY) of Subsurface Flow and Base Flow to the TZ. Watermaster considers Alto Producers' Subarea Obligation to the TZ to satisfy the Subarea's obligation to Centro. For example, the first annual report notes, "[s]*uch discharge records are used in the calculations of compliance by Alto Subarea Producers with their obligation to the Centro Subarea*."[12] Subsequent annual reports contain similar statements.

3.3 Changes in BAP, PSY and FPA

The Judgment assigned BAP rights to each Producer that pumped 10 AFY or more, based on historical production during the period 1986 to 1990. Parties to the Judgment are assigned a variable FPA, which is a uniform percentage of BAP recommended by the Watermaster for each Subarea each year. In any given year, Watermaster may choose to recommend no change to the FPA for one or more Subareas. This percentage changes over time, with the goal of setting a

[12] Watermaster (1995). First Annual Report of the Mojave Basin Area Watermaster, 1993-1994, City of Barstow et al. v. City of Adelanto et al. Riverside County Superior Court Case No. 208568, Riverside County. February 28.

total FPA that is in balance with PSY. The changes in BAP, PSY, and FPA for Alto and Centro from WY 2005 through WY 2023 are shown on **Figures 3-1** and **3-2**, respectively. The general trend for the Alto and Centro Subareas is downward for all three quantities. Watermaster's recommended FPA and estimated PSY for WY 2025 for each Subarea are shown in **Table 3-1**.

Between WY 2005 and WY 2023, the Alto BAP was decreased once, for WY 2006, from 122,365 AF to 116,412 Acre-Feet (AF) (**Figure 3-1**). The Alto FPA has decreased several times, most recently to 59,771 AF for WY 2024.[13] A July 2024 Court Ruling established that the Alto FPA for WY 2025 would be the same as for WY 2024, 50.4% of BAP, or 58,672 AF.[14] The Alto PSY has been adjusted several times and is 62,005 AF for WY 2024.[15]

Between WY 2005 and WY 2023, the Centro BAP was decreased twice, once for WY 2006 to 56,269 AF and again for WY 2012 to 51,030 AF (**Figure 3-2**). The Centro FPA has decreased several times, most recently to 28,793 AF for WY 2024.[16] The July 2024 Court Ruling established that the Centro FPA WY 2025 would increase slightly to 56% of BAP, or 28,577 AF.[17] The Centro PSY has been adjusted several times and is 31,420 AF for WY 2024, per the Court's July 2024 Ruling.

[13] Watermaster (2024). Thirtieth Annual Report of the Mojave Basin Area Watermaster, Water Year 2022-23, May 1, 2024. Page 38.

[14] Riverside (2024). Ruling on the Watermaster's Annual Motion to Adjust Free Production Allowance for Water Year 2024-2025. City of Barstow v. City of Adelanto, Case No. CIV208568. Superior Court of the State of California, County of Riverside. July 3. (page 6)

[15] Watermaster (2024). Thirtieth Annual Report of the Mojave Basin Area Watermaster, Water Year 2022-23, May 1, 2024. Page 38.

[16] Watermaster (2024). Thirtieth Annual Report of the Mojave Basin Area Watermaster, Water Year 2022-23, May 1, 2024. Page 38.

[17] Watermaster (2024). Production Safe Yield & Consumptive Use Update. Prepared by Wagner and Bonsignore, Consulting Civil Engineers. February 28, 2024.

4.0 Watermaster's Water Budget and 2024 PSY Update

DWR is responsible for the management and regulation of the State of California's groundwater resources. DWR's Best Management Practices (BMPs) for water budgets summarizes the fundamental function of a water budget in a hydrologic evaluation as follows:[18]

> "*A water budget takes into account the storage and movement of water between the four physical systems of the hydrologic cycle, the atmospheric system, the land surface system, the river and stream system, and the groundwater system. A water budget is a foundational tool used to compile water inflows (supplies) and outflows (demands). It is an accounting of the total groundwater and surface water entering and leaving a basin or user-defined area. The difference between inflows and outflows is a change in the amount of water stored…In principle, a water budget is a simple concept that provides the accounting framework to measure and evaluate all inflows and outflows from all parts of the hydrologic cycle – atmospheric, land surface, surface water, and groundwater systems.*"

Although simple in concept, developing an accurate water budget for specific hydrologic systems can be challenging. Data uncertainty and the difficulty of acquiring data for certain components of a water budget (e.g., ungaged surface water flow, groundwater underflow) often require that estimated values are used. But, as the hydrologic sciences become more sophisticated with time, the "error bars" associated with estimated values can often be reduced.

DWR's water budget BMP further states that:[19]

> "*In many basins, stream depletion due to groundwater extraction will continue for decades prior to reaching a new equilibrium (Barlow, P.M. and Leake, S.A., 2012). Because of this transitional process, a water budget based on "average conditions" will not reflect this slow and progressive change*."

In the Judgment, the use of long-term averages is specified for various components of the water budget (see **Table 4-3** [summary of Watermaster's water budget chart]). However, the Judgement also requires Watermaster to use the "best available" data and "sound scientific and

[18] DWR (2016). Water Budget BMP – Best Management Practices for the Sustainable Management of Groundwater. California Department of Water Resources Sustainable Groundwater Management Program. December. (Pages, 2-3.)

[19] DWR (2016). Water Budget BMP – Best Management Practices for the Sustainable Management of Groundwater. California Department of Water Resources Sustainable Groundwater Management Program. December. (Page 6.)

engineering estimates" to evaluate the impacts of inflows and outflows that estimated values and long-term averages cannot (see **Section 6**).

An explanation of water budget concepts is presented below in **Section 4.1**, followed in **Section 4.2** by analysis of Watermaster's water budgets for Alto, TZ, and Centro.

4.1 Groundwater Budget

Water budgets are simple in concept but detailed in practice. The complexities of preparing a water budget are discussed below. A water budget is the numerical calculation accounting for the inputs to, outputs from, and changes in the volume of water in the various components (e.g., reservoir, river, aquifer) of the hydrological cycle, within a specified hydrological unit (e.g., a river catchment or groundwater basin) and during a specified time unit, occurring both naturally and as a result of human-induced water additions and removals. **Figure 4-1** shows a graphical representation of a water budget and its components.

The following are the basic components of a water budget:

1. Inflows, such as recharge of aquifers through infiltration and percolation of precipitation, percolation of stream flows, percolation of imported water, water injected into aquifers, and subsurface flow from adjacent basins or bedrock areas ("underflow").
2. Outflows, such as extraction through pumping, the loss of subsurface water through underflow to other surrounding basins, and evapotranspiration (ET).
3. Change in storage, which is the change in the volume of water within a groundwater basin as a result of inflows and outflows over time. Change in storage can theoretically be calculated from measured or modeled water surface elevations (i.e., groundwater levels) within aquifer systems.

In analytical terms, a water budget is an accounting of water entering a given hydrologic system (i.e., income), collectively referred to as recharge, and all water leaving the system (i.e., expenses), including groundwater production, collectively referred to as discharge. The accounting results in either water being added to storage (i.e., increased savings) in the system when inflows are greater than outflows or removed from storage when outflows are greater than inflows (i.e., decreased savings). This accounting is usually done on a WY (i.e., annual) basis. The accounting can also be done over an extended period (e.g., the baseline hydrologic period) to determine a long-term average water budget.

The water budget is based on the equation of hydraulic continuity, derived from the Law of Conservation of Mass described by Antoine Lavoisier, where:

$$Q_{in} = Q_{out} +/- \Delta S$$

- Q_{in} = Water going in (recharge = income)
- Q_{out} = Water leaving (discharge = expenses)
- ΔS = Change in storage (increase/decrease = increase/decrease in savings)

The inputs into this equation in the Basin are discussed in the following sections.

4.1.1 Recharge

The following are the four potential types of recharge to the aquifers in the Basin:

- Because Basin development means that deeper aquifer units (e.g., the Regional Aquifer/Older Alluvium) outcrop at surface at the basin edges, rainfall falling at the edge of the watershed in the mountain ranges can run off and recharge the deeper aquifer units (i.e., where they are exposed) directly from the surface at the basin periphery. This is often called "mountain-front recharge."
- Some of the rainfall that falls on the mountain ranges infiltrates and percolates into the underlying bedrock. Some small portion of this percolating water will flow into the Basin as bedrock underflow. That is, it enters the basin below the ground surface where the bedrock contacts unconsolidated sediments.
- Rainfall falling on the Basin floor can directly recharge the unconsolidated alluvial strata. This water eventually makes its way into the deeper formations that also serve as part of the Basin's aquifer system. Areas of direct recharge and potential recharge lie primarily within the central and low-lying areas of the Mojave River valley. Agricultural and open space lands are also considered areas of potential recharge.
- Bed seepage from stream flows recharge the Floodplain Aquifer and Regional Aquifers and other sediments near the surface. This is the largest component of recharge in the Basin. In many streams that rise in the adjacent mountains, this bed seepage is ephemeral and occurs coincident with precipitation events—for instance, a large local storm creates more flows, providing recharge at higher rates. In the Mojave River, bed seepage is ephemeral except for limited reaches, notably in upstream areas and downstream of wastewater treatment facilities.

Mountain front recharge and bedrock underflow is difficult to calculate without real world data on surface percolation rates and bedrock hydraulic properties. However, they can be estimated using groundwater flow models.

Direct recharge is possible to calculate analytically because rainfall data are available for the Basin, although the rainfall monitoring network is not extensive and rainfall in the mountains must be estimated. Evapotranspiration (ET) rates are available for crop types and natural vegetation identified in land-use surveys. Equally, groundwater flow models can use the same data.

Bed seepage from stream flows is difficult to calculate analytically without streamflow gages along reaches within the Mojave River. When streamflow gages are unavailable or infeasible, it can be estimated remote sensing techniques (see **Section 6.0**) and/or using groundwater flow models.

4.1.2 Pumping and Outflows

Metering of pumped wells means data are available for the majority of groundwater production within the Basin. Pumping is generally for agricultural, domestic, and Municipal and Industrial (M&I) water use.

Because the Basin is "closed," there are no outflows from the Basin. However, there are outflows from Subareas and concomitant inflows into neighboring Subareas. Thus, outflows are a component of each Subarea water budget.

4.1.3 Production Safe Yield

California courts have consistently applied a defined "safe yield" for purposes of managing a basin pursuant to a physical solution. In general, safe yield seeks to maximize the amount of groundwater usage within a basin while avoiding adverse effects.

The definition of PSY in the Judgment, which is consistent with the concept of safe yield, is presented and explained in **Appendix B** herein.

4.1.4 Baseline Hydrologic Period

The baseline hydrologic period over which long-term, average safe yield is calculated should be representative of historical and recent climatic (precipitation) and other hydrologic conditions, have sufficient data to characterize hydrologic conditions, and be long enough to calculate average values of key hydrologic parameters (e.g., average safe yield) representative of historical and recent conditions.

4.1.5 Methods to Quantify Safe Yield

The average safe yield of a given hydrologic system, such as a groundwater basin, can be calculated in a variety of ways. These include, but are not limited to, the following:

1. **Analytical Water Budget Method**: Quantification of each element in a water budget using field data, on a year-by-year basis, to calculate annual recharge.

2. **Numerical Model Budget Method**: Estimation of water budget components using a numerical groundwater flow model.
3. **Hill (or Conkling) Pumping Regression Method**:[20] Estimation using a linear regression analysis of groundwater level declines versus annual pumping.
4. **Storage Loss (or Specific Yield) Method**: Quantification of storage loss using changes in groundwater potentiometric surfaces[21] from year-to-year and subtraction of the annual loss from, or addition of annual gain to, annual pumping.

The storage loss method provides an accurate quantification of average total safe yield because pumping at known rates causes a direct, measurable change in the groundwater levels. The actual, measured change in groundwater levels correspond to a change in storage; that is, falling groundwater levels across a basin indicate a loss of storage. In any water year, a loss of storage would occur when pumping exceeds the recharge to the basin, such that pumping minus the loss of storage equals the safe yield for that year. This contrasts with the estimates of safe yield derived from groundwater flow models that are facsimiles of the real world.

The following data are needed for the storage loss method:

- Groundwater level data that characterize the spatial extent of the aquifer, available over an extended period (e.g., the baseline hydrologic period)
- Aquifer storativity/specific yield (Sy) values
- Groundwater production data and reasonable estimates of other water outflows from the defined hydrologic system (e.g., aquifer or groundwater basin).

In many basins, there are sufficient analytical data to use the storage loss method to determine the safe yield of the Basin and the current rate of storage loss in each of the Subareas. Review of all available water level data in the Basin would facilitate the feasibility of using this method in the Basin. Alternatively, groundwater flow models can be used to estimate storage loss and safe yield.

4.1.6 Groundwater Budget Summary

The equation of continuity implies that to maintain a water balance, if inputs are greater than outputs, then storage must increase. Conversely, if inputs are less than outputs, then storage must decrease. There are many basins where outputs, notably from groundwater pumping,

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[20] Conkling, H. (1946). Utilization of ground-water storage in stream system development. Transactions, American Society of Civil Engineers 3, 275-305.

[21] A potentiometric surface is a hypothetical surface representing the water table in an unconfined aquifer (the height water rises in a well) or the level to which groundwater would rise if not trapped in a confined aquifer.

exceed inputs and dramatic reductions in storage result. This "harvesting" of groundwater is not sustainable in the long-term (i.e., decades) and eventually the resource will be depleted and take many decades, if not centuries, to recover. Like a financial budget, when inflows are less than outflows (i.e., income is less than expenses), water can be withdrawn from storage (i.e., savings) to cover outflows (i.e., expenses). However, if this "overdraft" continues for an extended period (usually decades), the storage (savings) will eventually be depleted. In addition, the overdraft can cause other adverse results that cannot be mitigated (e.g., significant and unreasonable degradation of water quality, inelastic subsidence, etc.).

Water inflows to a defined hydrologic system, such as a groundwater basin, may include the following:

- Infiltration of direct precipitation and subsequent percolation to groundwater
- Infiltration of applied irrigation water not taken up by the crop (i.e., return flows)
- Streambed losses from surface water flows
- Mountain front recharge as overland flow and infiltration at the basin margins or bedrock underflow which recharges the aquifers at depth
- Subsurface underflow from adjacent basins
- Artificial recharge at spreading basins, injection wells, etc.

Water outflows from a defined hydrologic system, such as a groundwater basin, may include the following:

- Discharge to springs or "gaining" streams that eventually flow beyond the basin
- Direct evaporation of rainfall or rivers
- ET from vegetation that draws from groundwater
- Subsurface underflow to adjacent basins
- Groundwater production at wells

The water budget can be analytical (i.e., spreadsheet based on field data) or numerical (i.e., from a groundwater model).

In an analytical water budget, actual field data are used to calculate values for the various water budget elements. For example, this may include measurements from the following:

- Weather stations for precipitation data across the basin
- Stream gages to monitor surface water flow across the basin and calculate stream flow loss or gain
- Infiltration gauges and percolation tests across the basin

- Monitoring wells to calculate groundwater fluxes across boundaries or at basin margins based on groundwater levels and hydraulic properties
- Tensiometers and soil moisture content data to calculate water fluxes in the vadose zone (that is, the unsaturated area underground above the aquifers)
- Evaporimeters for direct evaporation and leaf/stomata transpirometers for transpiration
- Multi-spectral imaging from satellites to estimate ET
- Remote sensing of stream discharge
- Meters on groundwater production wells

Table 4-1 shows that data limitations and uncertainty in estimates of water-budget component subsequently cause uncertainty in average annual total safe yield calculations.

4.2 Watermaster's Water Budget

This section explains the components of Watermaster's water budget for Alto, TZ and Centro and outlines the concerns with the water budgets. In short, the water budgets presented in Watermaster Annual Reports do not provide enough information to determine if Centro receives sufficient inflow because: (1) Watermaster's simplified water budget is not adequately detailed and does not employ current approaches used throughout California; and most notably (2) there are no measurements of surface water inflow to Centro. A detailed water budget with reduced reliance on estimated values is needed.

The TZ is supplied by surface water inflow from Alto, Victor Valley Wastewater Reclamation Authority (VVWRA), estimated contributions from urban development, long-term subsurface flow, and return flow from production. The return flows are calculated from the verified production and data maintained by the Watermaster for estimating Consumptive Use. Water use in the TZ is primarily through urban and agricultural extraction (production) and Consumptive Use by native phreatophyte vegetation.

The following outlines a few examples of flaws in the Watermaster's current water budgets.

Inflow Assumptions Likely Do Not Reflect Declining Water Levels in Centro

Watermaster calculates the surface water outflow from the TZ into Centro using a simplified, estimated water budget and the assumption that the change in storage in the TZ is zero, based on TZ water levels being historically stable.[22] Watermaster uses an estimated surface water outflow for the TZ water budget (**Table 4-3** and the entries marked "Assumed"). However, this

[22] Watermaster (2024). Thirtieth Annual Report of the Mojave Basin Area Watermaster, Water Year 2022-23, May 1, 2024. (Page 25)

assumption may obscure complex groundwater flow dynamics in the TZ that cannot be captured by the simplified water budget (**Appendix A**).

These estimates are reported in Watermaster Annual Reports. The estimates typically range from 30,000 AFY to 35,000 AFY. Compared to average annual production of 5,570 AFY from Golden State's Centro wells over the last ten years and total average annual verified production for the Centro of 17,773 AFY (**Figure 4-3**; **Table 4-2**), these surface water inflows should be sufficient to satisfy verified production and prevent the observed chronic water-level declines observed in these production wells. However, chronic water-level declines are evident at Golden State's Centro wells (**Section 5.0**), as well as several other wells in the Centro (e.g., 09N02W03E01-03, 09N01W12N04-07); although not all Centro wells show declining water levels during their respective periods of record.

Crop and Phreatophyte Use Estimates Have Not Been Updated

The TZ water budget also relies on assumptions and estimates for the amount of Consumptive Use by agriculture and phreatophytes based on outdated studies and techniques. For example, Watermaster's estimation of agricultural Consumptive Use employs techniques that have largely been supplanted by the use remote sensing (i.e., satellite) data, which can provide refined estimates of ET and estimates of stream flows (see **Section 6.2 and 6.3**). Satellite remote sensing data is the current standard for estimating ET from various sources (see **Section 6.3**).

Assumed Replacement Water Deliveries to the TZ May Not Result the Assumed Inflows Into Centro

In its Annual Reports, Watermaster concludes that the obligation of Producers in Alto to deliver recharge to the TZ appears to have been met every year that the Judgment has been in effect, within the allowances set by the Judgment. However, there has always been a cumulative deficit for this obligation, which has been as high as 22,839 AF[23] (WY 2009) and is currently 15,731 AF.[24] Thus, it is not clear if water delivered to the TZ results in Centro receiving its full obligation from Alto (via the TZ). Monitoring equipment and techniques and a detailed water budget with reduced reliance on estimated values is needed to resolve this issue.

[23] Watermaster (2010). Sixteenth Annual Report of the Mojave Basin Area Watermaster, Water Year2008-09, May 1, 2010. (Tab. 4-3, p. 30)
[24] Watermaster (2024). Thirtieth Annual Report of the Mojave Basin Area Watermaster, Water Year 2022-23, May 1, 2024. (Tab. 4-3, p. 36)

4.3 Watermaster Model

The Upper Mojave River Basin (UMRB) model was originally developed for the Mojave Water Agency (MWA) as a predictive tool for the Regional Recharge and Recovery Project (R-Cubed) project. The current UMRB model is an expanded and updated version that extends the spatial boundaries of the original UMRB model to include the upper basin (the watersheds of Deep Creek and West Fork) and is a fully integrated groundwater/surface-water numerical model. The calibration period covers water years from 1951 to water year 2020.[25]

The updated UMRB model domain and active area is shown in **Figure 4-4**. The United States Geological Survey (USGS) finite difference code MODFLOW-NWT[26] was used to design the UMRB model. The model has six layers, 900 rows, and 1600 columns. The cell size is 200 feet by 200 feet. The layering is based on the hydraulic behavior from existing production wells where available and hydro-stratigraphic markers otherwise. Hydraulic parameters (hydraulic conductivity and storativity) are distributed by zones based on the earlier USGS model.[27] Aquifer production estimates prior to 1995 are derived from the USGS model. The surface water model component of the UMRB model is derived from the California Basin Characterization Model (BCM).[28]

The water budget extracted from the UMRB model was restricted to the actual UMRB area, excluding the upper basin (Deep Creek and West Fork watersheds). The water budget was further divided into subareas. It should be noted that only a portion of the TZ is covered by the UMRB model, i.e., the southern portion of the TZ. The remainder of the TZ, Centro, and Baja are not included in this version of the model but should be.

Until WY 2023, Watermaster's Annual Reports did not rely on a groundwater model in any significant way. For WY 2023, Watermaster published a proposed change in the determination of current-year PSY for Alto in the Annual Report, which utilized the updated UMRB model. The water budget table in the WY 2023 Annual Report also for the first time explicitly included the TZ, although a separate PSY for the TZ was not estimated (**Figure 4-2**).

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[25] MWA (2024). Mojave Basin Area Watermaster Appendix G Upper Mojave River Basin Groundwater Model Prepared by: Mojave Water Agency Water Resources. February 28, 2024. (page 1)

[26] Niswonger, R.G., S. Panday, and M. Ibaraki (2011). MODFLOW-NWT, a Newton Formulation of MODFLOW 2005: U.S. Geological Survey Techniques and Methods 6-A37

[27] Stamos, C.L., Martin, P., Nishikawa, T., and Cox, B.F. (2001). Simulation of Ground-Water Flow in the Mojave River Basin, California. Water-Resources Investigations Report 01-4002 Version 3, US Geological Survey, Sacramento, CA. (Page 45)

[28] Flint, L.E., Flint, A.L., and Stern, M.A. (2021). The basin characterization model—A regional water balance software package: U.S. Geological Survey Techniques and Methods 6–H1, 85 p.

Overall, the model estimates that Alto experienced an average change in storage of 15,000 AFY for the past seventy (70) years and 17,500 AFY for the past 20 years. The cumulative change of storage shows a continuous decline in storage for the past 70 years.

The updated model could be a potentially useful tool. However, the model in its current form is incapable of accurately simulating groundwater in the TZ or calculating the TZ water budget. The current UMRB model is too limited in spatial extent to be useful for simulations in the TZ. Furthermore, the model cannot yet simulate the potentially complex groundwater flow dynamics between the TZ and Centro, because Centro is not included in the model.

5.0 Groundwater Level Correlations and Trends

Golden State's observation of chronic water-level declines in their Centro (Barstow area) productions wells indicate an ongoing issue. **Aquilogic** has hypothesized that declining water levels in Centro indicate that the Subarea does not receive sufficient inflow under the Judgment.

Watermaster has proffered an alternate hypothesis that the chronically declining water levels are caused by concentrated pumping in small, segmented aquifers (i.e., segmented by faults or flow barriers[29]) along the river are depleted faster than they can be recharged through long dry periods.[30] Watermaster's alternate hypothesis implies that water levels in Golden State's Centro production wells are positively correlated to groundwater extractions. That is, the static depth to water in a given well increases as average pumping increases. However, Watermaster has not made available drawdown or other analyses to support this hypothesis.

Groundwater levels recorded in Golden State's production wells in the Barstow area have been chronically declining despite consistent average annual production from Golden State's production wells of 5,570 AF over the last ten years and total average annual verified production for Centro of 17,773 AFY (**Figure 4-3**). These production volumes are significantly less than Watermaster's estimate of 30,000 AFY to 35,000 AFY of inflow to Centro.

This section of the Expert Report describes qualitative and quantitative analyses conducted for each of Golden State's active production wells in Centro (Barstow area) for the WY 2005 through June 2024 period. The average monthly static depths to water (i.e., the non-pumping depth to water) were statistically evaluated using Mann-Kendall (MK) tests, which test correlations between an independent and dependent variable.

MK tests measure the strength of a correlation/trend and are often conducted when a normal distribution cannot be assumed or demonstrated for a given dataset (i.e., it is a non-parametric test). MK tests are hypotheses tests. For the analyses presented in this Expert Report, the null hypotheses are: (1) there is no correlation or trend of water levels with time, and (2) there is no correlation or trend of water levels with pumping magnitude. That is, depth to water does not change with time or magnitude of pumping. The alternate hypotheses are that the depth to water either increases or decreases with time or pumping magnitude.

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[29] Two of the six "Faults or Flow Barriers" mapped by Watermaster are not confirmed by the USGS (https://www.usgs.gov/programs/earthquake-hazards/faults) (see Figure 5-1 herein for some of the locations mapped by Watermaster).

[30] Watermaster (2024). Thirtieth Annual Report of the Mojave Basin Area Watermaster, Water Year 2022-23, May 1, 2024. (Page 39) .

The decision to reject or not reject the null hypothesis is subjective. However, most investigations use the 95% confidence level to inform the decision, which is obtained from the p-value derived from the MK calculations (i.e., confidence level = 1-[p-value]). The p-value represents the statistical confidence with which the null hypothesis can be rejected or not rejected. A p-value of 0.05 or less indicates that the null hypothesis can be rejected at the 95% or greater confidence level (i.e., there are correlations/trends in the data).

Tests were performed separately for water levels versus time and water levels versus total pumping for each month in each of Golden State's Centro wells for the WY 2005 to June 2024 period. In addition, average monthly static depth to water for these production wells was evaluated qualitatively versus average monthly Mojave River discharge, measured at the Lower Narrows stream gage.

Groundwater elevation and pumping data for 17 active Golden State production wells were provided by Golden State. The locations of these wells and several other production wells of various status (e.g., inactive, destroyed) are shown on **Figure 5-1**. **Aquilogic** conducted MK correlation/trend tests for the active wells for: (1) depth to water versus time and (2) depth to water versus monthly pumping (**Figures 5-2** through **5-18**; **Table 5-1**).

Kendall's *tau* (τ) is a measure of the strength of the correlation between an independent variable (e.g., time, pumping) and a dependent variable (e.g., depth to water). Positive values of *tau* indicate that the dependent variable increases as the independent variable increases. Negative values of *tau* indicate that the dependent variable decreases as the independent variable increases. *Tau* will generally be lower than values of the traditional linear correlation coefficient (r). "Strong" linear correlations of 0.9 or above correspond to *tau* values of about 0.7 or above. The lower values do not mean that *tau* is less sensitive than r, but just that the correlation is measured on a different scale of correlation.[31] For the analyses herein, we define the strength of correlation as follows:

- Strong: $Tau \geq 0.6$
- Moderate: $0.6 < Tau \geq 0.3$
- Weak: $Tau < 0.3$

Irrespective of the value of *tau*, correlations with $p > 0.05$ are not considered significant (i.e., no correlation).

[31] Helsel, D.R. and Hirsch, R.M. (2002). Statistical Methods in Water Resources. Chapter A3, Techniques of Water-Resources Investigations of the United States Geological Survey, Book 4, Hydrologic Analysis and Interpretation. September.

5.1 Depth to Water Versus Mojave River Discharge

A qualitative evaluation of depth to water versus Mojave River discharge was conducted. Daily average stream discharge data for the Lower Narrows stream gage were obtained from the USGS.[32] These daily averages were aggregated into monthly values and plotted along with monthly pumping and depth to water measurements. These plots are shown on **Figures 5-2** through **5-18** (upper panels). On these plots, all the available depth to water measurements are shown (i.e., no averaging).

For Agate Wells No. 4 and 5 hydrographs (**Figures 5-2** and **5-3**), depth to water generally decreases as Mojave River discharge increases (i.e., groundwater levels rise when Mojave River flows are higher). Most of the other hydrographs show visually that depth to water decreases sharply during and following large discharge events (i.e., storms) (**Figures 5-4** through **5-15**; **Figures 5-17** and **5-18**). Crooks Well No. 1 (**Figure 5-16**) appears to lack sufficient data for these sharp depth-to-water decreases to be visually apparent.

5.2 Mann-Kendall Test Analyses

MK tests were conducted to provide a quantitative analysis of the causative factors behind the variable depth to water observations at Golden State's active production wells.

5.2.1 Depth to Water versus Time

For MK tests in which time is the independent variable, review of **Table 5-1** reveals that correlations for WY 2005 through June 2024 are as follows:

- Weakly negative (i.e., depth to water decreases weakly with time) for:
  - Agate Well No. 4 (**Figure 5-2**)
  - Agate Well No. 5 (**Figure 5-3**)
- Moderately positive (i.e., depth to water increases moderately with time) for:
  - Bradshaw Well No. 2 (**Figure 5-6**)
  - Bradshaw Well No. 4 (**Figure 5-7**)
  - Bradshaw Well No. 5 (**Figure 5-8**)
  - Bradshaw Well No. 11 (**Figure 5-12**)
  - Bradshaw Well No. 12 (**Figure 5-13**)
  - Bradshaw Well No. 14 (**Figure 5-15**)
  - Glen Road Well No. 1 (**Figure 5-17**)
  - Glen Road Well No. 2 (**Figure 5-18**)

[32] USGS, National Water Information System: Web Interface, USGS 10261500 MOJAVE R A LO NARROWS NR VICTORVILLE CA https://waterdata.usgs.gov/nwis/uv?site_no=10261500&legacy=1

- Strongly positive (i.e., depth to water increases strongly with time) for:
  - Arrowhead Well No. 2 (**Figure 5-4**)
  - Bradshaw Well No. 1 (**Figure 5-5**)
  - Bradshaw Well No. 6 (**Figure 5-9**)
  - Bradshaw Well No. 7 (**Figure 5-10**)
  - Bradshaw Well No. 10 (**Figure 5-11**)
  - Bradshaw Well No. 13 (**Figure 5-14**)
  - Crooks Well No. 1 (**Figure 5-16**)

Therefore, the observed depth to water increases with time for 15 of the 17 wells (88%). The other two wells (Agate Well No. 4 and Agate Well No. 5) show a weak decreasing trend of observed depth to water with time. For the 17 active Golden State production wells, the null hypothesis of no change in depth to water with time can be rejected at greater than the 95% confidence level for the WY 2005 through June 2024 period. These MK tests confirm Golden State's observations that, in general, their Barstow-area production wells are experiencing chronic water level declines.[33] Further, the results indicate that the procedure used herein to conduct MK tests on Golden State's production data is robust.

5.2.2 Depth to Water versus Pumping

For MK tests in which pumping is the independent variable, review of **Table 5-1** reveals that correlations for the WY 2005 through June 2024 are:

- No correlations or trends (i.e., depth to water does not vary relative to pumping magnitude) for:
  - Agate Well No. 4 (**Figure 5-2**)
  - Arrowhead Well No. 2 (**Figure 5-4**)
  - Bradshaw Well No. 7 (**Figure 5-10**)
  - Bradshaw Well No. 12 (**Figure 5-13**)
  - Bradshaw Well No. 13 (**Figure 5-14**)
  - Crooks Well No. 1 (**Figure 5-16**)
- Weakly negative (i.e., depth to water decreases weakly as pumping increases) for:
  - Bradshaw Well No. 1 (**Figure 5-5**)
  - Bradshaw Well No. 4 (**Figure 5-7**)
  - Bradshaw Well No. 5 (**Figure 5-8**)
  - Bradshaw Well No. 14 (**Figure 5-15**)

[33] It should be noted that for Crooks Well No. 1, 74 of the 82 (90%) observed depths to water during the period noted above were measured during months in which there had been no pumping. Thus, for Crooks Well No. 1, the MK test utilized only the eight observations that occurred during a month in which there had been pumping.

  - Glen Road Well No. 2 (**Figure 5-18**)
- Weakly positive (i.e., depth to water increases weakly as pumping increases) for:
  - Bradshaw Well No. 2 (**Figure 5-6**)
  - Bradshaw Well No. 6 (**Figure 5-9**)
  - Bradshaw Well No. 11 (**Figure 5-12**)
  - Glen Road Well No. 1 (**Figure 5-17**)
- Moderately positive (i.e., depth to water increases moderately as pumping increases) for:
  - Agate Well No. 5 (**Figure 5-3**)
- Strongly positive (i.e., depth to water increases strongly as pumping increases) for:
  - Bradshaw Well No. 10 (**Figure 5-11**)

Therefore, for eleven of the 17 wells (65%), depth to water either decreases or does not significantly change as the magnitude of pumping increases. For six of these wells, the null hypothesis of no correlation or trend cannot be rejected for the 2005 through June 2024 period (i.e., p-values much greater than 0.05). Five of the wells in this group have statistically significant correlations/trends that indicate depth to water *decreases* as pumping magnitude increases.

5.3 Summary of Water-Level Analysis

Aquilogic has conducted quantitative MK analyses to support our hypothesis. These analyses indicate that only one of the 17 Golden State production wells assessed has depth to water observations that strongly increase as pumping magnitude increases. These results indicate that most of the depth-to-water data measured at Golden State production wells do not show a direct correlation or trend relative to groundwater production magnitude. For the wells listed above that do show weakly or moderately positive results, the most likely explanation is that groundwater production magnitude is a minor component of the observed increases in depth to water. Other factors, such as insufficient water supply (i.e., low/decreased inflows from Alto/TZ), appear to play a major role in the observed increases in depth to water over time.

In simple terms, declining groundwater levels (i.e., loss of storage) result from excess discharge (e.g., over pumping) and/or insufficient recharge (e.g., stream bed seepage) in a hydrologic system. Current data and analyses presented herein demonstrate that the declining water levels do not correlate with increased pumping at Golden State's production wells in Centro. Therefore, it is likely that decreases in inflow to Centro have contributed to the declining water levels. Given this, the declining water levels call into question whether groundwater Producers in Alto are meeting their obligation to deliver defined volumes of annual recharge to Centro as specified in the Judgment.

At present, there is insufficient information to confirm if Centro receives the inflow specified in the Judgment because Watermaster's simplified water budget is not adequately detailed and does not employ current approaches used throughout California (as recommended in **Section 6.0**). Specifically, there are no measurements of surface water inflow to Centro.

A detailed water budget with reduced reliance on estimated values is needed. Therefore, Watermaster should reevaluate the water budgets for Alto, TZ, and Centro using more current approaches. A more robust, revised water budget can then be used to evaluate whether groundwater Producers in Alto are satisfying their obligation to deliver the volumes of recharge to Centro specified in the Judgment. If the revised water budget indicates that the obligation is being met, then further analyses should be done to determine why water levels continue to fall in Centro.

6.0 Recommended Actions

Watermaster was directed by the Court in 2022 to re-evaluate the PSY for each Subarea. **Aquilogic** believes a rigorous reevaluation must include a detailed redetermination of the Basin and Subarea water budgets, especially for the TZ. Furthermore, the MK analyses conducted for this Expert Report demonstrate the utility of these hypothesis tests for identifying potential causes of water level declines. Additional MK tests (or other statistical hypotheses tests) would likely provide further insight into potential causes of water level declines.

In summary, Watermaster should address the following recommendations:

1. Watermaster should re-evaluate the water budgets for Alto, the TZ, and Centro. This should include improved quantification of the following:
   - Consumptive Use by agriculture and phreatophytes
   - Storage losses in the TZ
   - Subsurface flow between Alto and the TZ and thence to Centro
   - Surface water flows between the TZ and Centro
2. Watermaster should update the current UMRB model to include the entire adjudicated area subject to the Judgment, and then use the updated (and calibrated) model to reevaluate water budgets.
3. Watermaster should perform statistical analyses to correlate groundwater levels in Alto, the TZ, and Centro (three areas) with: (i) time; (ii) with combined surface and subsurface inflows; and with (iii) groundwater production (three variables). These analyses should consider the following three periods of time: (i) prior to the Judgment (pre-1994); (ii) during the period of production ramp-down (1994-2004); and (iii) the period after the ramp-downs (2005-2024).
4. Based on results from the above, Watermaster should determine whether Producers in Alto have met, are currently meeting, and will meet in the future their obligation to deliver defined volumes of water to Centro as specified in the Judgment.
5. If Watermaster determines the obligation has not been, is not being, and will not be met, Watermaster should develop a plan to ensure they are met in the future and then implement such a plan, and develop an approach to address past shortfalls in water delivery.
6. If Watermaster determines the obligation has been, is being, and will be met, Watermaster should recommend and implement additional analyses that would evaluate why chronic water levels declines are being observed at Golden State's production wells in Centro.

Further discussion of these recommendations is provided in this Expert Report and below.

6.1 Additional Statistical Analyses

Hydrological cause and effect can be difficult to determine based simply on observations. Hydrologic modeling can provide insight into the hydrologic response that results from changes in various components of the water budget. For such a model to be successful, it must be well-calibrated. Using a hydrologic model in a "what if," or hypothesis testing, mode facilitates understanding of hydrological causes and effects. Even in cases in which robust modeling has provided insight, observed data, such as water levels and measured stream discharge, still need to be analyzed to verify that model results and predictions have been "ground truthed."

The analyses described in this Expert Report show that groundwater production in the Centro, particularly for Golden State's production wells, is unlikely to be the cause of the observed chronic water-level declines in Golden State's production wells. Additional statistical analyses on other aspects of Alto, TZ, and Centro hydrology would provide supporting evidence for this conclusion.

The MK analyses presented in this Expert Report focused on water-level correlations with time and pumping for the period WY 2005 through June 2024, after which much of the production ramp-downs had already occurred and productions fairly stable. Additional analyses could be performed for the period prior to WY 1994 and for WY 1994 through WY 2004 – the period which includes much of the production ramp-down specified in the Judgment. Furthermore, potential quantitative correlations of water levels with stream discharge could also be undertaken, or a qualitative assessment as was conducted for this Expert Report. These analyses could be completed in Centro as needed and then extended to Alto and TZ.

6.2 Improved Measurement of Surface Water Flow into Centro

DWR recently initiated the California Stream Gage Improvement Program.[34] This is a "*new program will work with local partners to measure and plan for how much water is flowing in California rivers and streams, in turn providing a better snapshot of California's water supplies.*" This program provides grant funding to public agencies for to perform various activities,

[34] https://water.ca.gov/-/media/DWR%20Website/Web%20Pages/Work%20With%20Us/Technical%20Assistance/Stream%20Gage%20Improvement%20Program/Files/CalSIP%20Public%20Agency%20Guidelines_FINAL_08-14-24.pdf?utm_medium=email&utm_source=govdelivery.

including identifying current and historic stream gage sites that should be prioritized for upgrades or reactivation.[35]

Aquilogic recommends that Watermaster investigate this new program to determine the requirements for installing a new stream gage near the Helendale Fault, for example at or near the location of the decommissioned Wild Crossing gage. If it is determined that a new gage near the Helendale Fault is infeasible, remote sensing of stream discharge is now a common tool for hydrologic analyses. Remote sensing has become an invaluable alternative to stream gages for collecting hydrologic data. Its benefits include the ability to collect data in areas that impose physical, financial, or political limitations. Although collected stream gage data is commonly referred to as a measurement of discharge, it is an approximation of discharge. Like stream gages, remote sensing approximates discharge, without the limitations of the gage's single point location, or the costly and sometime hazardous repeated field visitations to gages.[36,37,38]

Remote sensing uses the detection of reflected electromagnetic (EM) radiation. This primary data is then processed into the signal of interest to the hydrologist. The raw signals include recorded reflectance, range and interferometric phase observations, and emittances.[39,40] High resolution commercial satellite video sensors can capture river dynamics with optical flow measurement algorithms by tracking movements of features between frames.[41] In recent remote sensing studies of gaged streams, the discharges calculated from remote sensing data were within 15% of the discharges approximated from the gaging data.[42] Stream discharge in the Mojave River can and should be approximated using remote sensing, and approximations

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[35] State Water Resources Control Board, California Stream Gaging Prioritization Plan 2022 https://www.waterboards.ca.gov/waterrights/water_issues/programs/stream_gaging_plan/docs/sb19-report.pdf (accessed on 3 September 2024)

[36] Conaway, J., Eggleston, J., Legleiter, C.J., Jones, J.W., Kinzel, P.J., Fulton, J.W. (2019). Remote Sensing of Streamflow in Alaska Rivers—New Technology to Improve Safety and Expand Coverage of USGS Streamgaging. U.S. Geological Survey Fact Sheet 2019–3024. April. https://pubs.usgs.gov/fs/2019/3024/fs20193024.pdf (pages 2-3)

[37] Gleason, C.J. and Durand, M.T. (2020). Remote Sensing of River Discharge: A Review and a Framing for the Discipline. Remote Sensing Vol. 12, No. 1107. https://doi.org/10.3390/rs12071107. (pages 1-3)

[38] Masafu, C., Williams, R., and Hurst, M.D. (2023). Satellite Video Remote Sensing for Estimation of River Discharge. Geophysical Research Letters, 50, e2023GL105839. https://doi.org/10.1029/2023GL105839. (pages 1-3)

[39] Gleason, C.J. and Durand, M.T. (2020). Remote Sensing of River Discharge: A Review and a Framing for the Discipline. Remote Sensing Vol. 12, No. 1107. https://doi.org/10.3390/rs12071107. (pages 1-3)

[40] The reflectance of the surface of a material is its effectiveness in reflecting radiant energy. Interferometric phase observations are a form of active remote sensing. Emittance is the radiant flux or heat emitted by a surface per unit area

[41] Masafu, C., Williams, R., and Hurst, M.D. (2023). Satellite Video Remote Sensing for Estimation of River Discharge. Geophysical Research Letters, 50, e2023GL105839. https://doi.org/10.1029/2023GL105839. (pages 1-3)

[42] Masafu, C., Williams, R., and Hurst, M.D. (2023). Satellite Video Remote Sensing for Estimation of River Discharge. Geophysical Research Letters, 50, e2023GL105839. https://doi.org/10.1029/2023GL105839. (pages 1-3)

can be calibrated with stream gage measurements at the USGS Lower Narrows, Hodge,[43] and Barstow gages.

Remote sensing data is combined with other data to approximate river parameters such as discharge. In particular, the stream geometry can be combined with the remote sensing data to approximate discharge.[44] Methods associated with remote sensing hydrologic evaluations include surface velocimetry, doppler radar (used with combined hand-held or bridge-mounted sensors), bathymetry measurements (for river depths), and altimetry (for river surface altitudes). Surface velocimetry is the measurement of stream surface velocity using time-lapse images of moving features on the river surface. Velocimetry is a technique for calculating the movement of identified surface features (e.g., foam, debris). This can be assisted by specialized techniques, such as using high sensitivity thermal cameras.[45]

6.3 Remote Sensing of Riparian and Agricultural Evapotranspiration

Remote sensing has also become a useful tool for estimating ET. Traditional methods of measuring ET have relied on field surveys and have been limited to small areas. In contrast, regional evaluation is commonly restricted by complexity of hydrology and land surface factors.[46,47] However, remote sensing can provide efficient and economically feasible regional coverage.[48] Remote sensing for ET relies on multiple measurable meteorological and biophysical variables.

Several different ranges of EM spectrum wavelengths are utilized with remote sensing to estimate ET. Traditionally, information in the visible to shortwave infrared spectrum is summarized in vegetation indices like leaf area index, which can estimate areal vegetation fraction. The microwave range of the spectrum provides information on water content and temperature from the soil, vegetation, and atmospheric layers.

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[43] However, the reliability of the new Hodge gage is yet to be determined; it has been in service for only two years.

[44] Masafu, C., Williams, R., and Hurst, M.D. (2023). Satellite Video Remote Sensing for Estimation of River Discharge. Geophysical Research Letters, 50, e2023GL105839. https://doi.org/10.1029/2023GL105839. (pages 1-3)

[45] Conaway, J., Eggleston, J., Legleiter, C.J., Jones, J.W., Kinzel, P.J., Fulton, J.W. (2019). Remote Sensing of Streamflow in Alaska Rivers—New Technology to Improve Safety and Expand Coverage of USGS Streamgaging. U.S. Geological Survey Fact Sheet 2019–3024. April. https://pubs.usgs.gov/fs/2019/3024/fs20193024.pdf (pages 2-3)

[46] Holmes, T.R.H. (2019). Chapter 5 – Remote sensing techniques for estimating evapotranspiration. In: Extreme Hydroclimatic Events and Multivariate Hazards in a Changing Environment. June 6. https://ntrs.nasa.gov/api/citations/20210011848/downloads/26861.pdf. (pages 13-133)

[47] Cha, M., Li, M., Wang, X. (2020). Estimation of Seasonal Evapotranspiration for Crops in Arid Regions Using Multisource Remote Sensing Images. July 21. https://doi.org/10.3390/rs12152398. (pages 1-2)

[48] Kustas, W.P., Norman, J.M. (2009). Use of remote sensing for evapotranspiration monitoring over land surfaces. December 24. https://doi.org/10.1080/02626669609491522. (page 1)

6.4 Transition Zone Water Budget

The analyses performed to date by **aquilogic** and others suggest that groundwater flow dynamics and the TZ water budget are complex. The analyses provide a foundation for deeper evaluation of the TZ water budget and its evolution through time. The objective of such an evaluation would be to provide an in-depth analysis of the volume of water that flows into Centro annually. A complete water budget would include all inflows, outflows, and the change of groundwater storage over time. Previous work by others can be leveraged to support development of a complete water budget. The water budget for the TZ should be developed with sufficient detail and rigor to at least meet SGMA regulations for historic and current water budgets.

Groundwater flow into Centro occurs in the Mojave River alluvium, in deeper horizons across the Helendale Fault, and other areas along the TZ-Centro boundary (**Appendix B**). This flow rate is difficult to assess without using a groundwater flow model. A groundwater model can contribute to an improved water budget evaluation by calculating the transient change in groundwater storage and groundwater flow rates that cannot otherwise be determined due to lack of data in key locations. **Aquilogic** strongly recommends that the current UMRB model used by Watermaster be updated to include the entire basin, as soon as possible. In its current form, it is premature to use the model for any analyses involving the TZ.

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TABLES

Table 3-1: Water Year 2024 FPA and Estimated Production Safe Yield

Golden State Water Company - Mojave

Subarea	Base Annual Production (AF)	WY 2024 FPA (AF)	Production Safe Yield (AF)	Percent Difference[1]	WY 2023 Verified Production (AF)
Alto	116,412	59,771	62,005	-1.9%	68,751
Baja	66,157	15,414	12,749	4.0%	9,191
Centro	51,030	28,793	31,420	-5.1%	14,840
Este	20,205	11,568	6,582	24.7%	3,547
Oeste	7,095	3,667	3,634	0.5%	2,607

Table 4-1: Data Availability and Uncertainty in Analytical Water Budget

Golden State Water Company - Mojave

Basin and Component	Sub-Component	Availability of information for Use in Water Balance	
		Model Data	Analytical Data
Inflow			
Recharge	Net Infiltration of Direct Precipitation	Available Aggregated- Recharge	Precipitation available Crop use available
	Net Infiltration of Indirect Precipitation (Run-On)		Unavailable
	Irrigation Return Flow- From Local Groundwater		Irrigation known. Aggregated Irrigation Return Flow could be estimated
	Urban Irrigation Return Flow -From Local Groundwater		
	Distribution System Leakage		Unavailable
	State Water Project water	Available	Available
	Recharge from Mojave River	Available	Unavailable – insufficient river flow data
Underflow	Bedrock underflow	Unavailable – insufficient data	Unavailable – insufficient data and well coverage
Outflows			
Pumping	Agricultural	Extraction-Aggregated	Extraction known -Aggregated
	Municipal and Industrial		
	Domestic		
Evapotranspiration	Evapotranspiration – Agricultural land	Available	Can be estimated from land-use
	Evapotranspiration – Open Land	Available	
Surface flow	Mojave River	Available	Can be estimated from downstream gauge

Table 4-2: Centro Annual Pumping

Golden State Water Company - Mojave

Year	Golden State Water Company Centro Annual Pumping (AF)	Centro Total Verified Production (AF)
2005	8,659	19,742
2006	8,936	21,140
2007	9,139	23,348
2008	8,420	23,038
2009	7,871	22,492
2010	7,295	21,847
2011	6,938	21,130
2012	6,737	21,326
2013	6,499	19,183
2014	5,973	19,616
2015	5,254	18,522
2016	5,147	19,195
2017	5,478	17,905
2018	5,603	19,112
2019	5,476	18,231
2020	5,722	16,756
2021	6,005	18,132
2022	5,604	15,422
2023	5,433	14,840

Notes:

AF: Acre-Feet

Table 4-3: Components of Transition Zone Estimated Water Budget

Golden State Water Company - Mojave

Inflows (Water Supply) 2001-2020	Consumptive Uses and Outflow 2001-2020
Surface Water Inflow (Measured at Lower Narrows gage)	**Surface Water Outflow (Assumed & Calculated)**
Average discharge 2001-2020 at Lower Narrows	Based on Lower Narrows data and Imports less consumptive uses under assumption that Transition zone change in storage is zero
24,808 AFY	36,725 AFY
Groundwater Discharge to Transition Zone (Assumed)	**Subsurface Outflow (Assumed)**
Estimated/assumed groundwater discharge (recharge) lost to Transition Zone below Lower Narrows	Judgment, Exhibit G (1)(e) from Transition Zone to Centro
5,112 AF	2,000 AFY
Subsurface Inflow (Modeled)	**Consumptive Use – Agriculture & Urban (Measured & Estimated)**
Portion of water lost to Transition Zone from Alto from Upper Basin Model	Measured pumping and estimated Minimal Pool pumping less estimated return flows.
7, 053 AFY	949 AFY (Agriculture)
	6,456 AFY (Urban)
Este/Oeste Inflow (Modeled)	**Phreatophytes (Assumed)**
Subsurface Inflow to Alto from Este and Oeste Subareas from Upper Basin Model	USGS Water-Resources Investigation Report 96-4241 "Riparian Vegetation and Its Water Use During 1995 Along the Mojave River, Southern California" 1996. Lines and Bilhorn
62 AFY	6,000 AFY
Imports (non-native) (Measured at VVWRA discharge)	---
Total discharge to Transition Zone from Victor Valley Water Reclamation Authority 2021-2022	---
15,095 AFY	
<u>Total</u>: 52,130 AFY	**<u>Total</u>: 52,130 AFY**
Surface Water Inflow (Assumed)	**Surface Water Outflow (Measured & Assumed)**
Based on Lower Narrows gage data and Imports less consumptive uses under assumption that Transition zone change in storage is zero	Reported flows at Barstow gage adjusted for losses between gage and Waterman Fault
36,725 AFY	7,500 AFY
Subsurface Inflow (Assumed)	**Barstow Treatment Plant Discharge (Assumed)**

Table 4-3: Components of Transition Zone Estimated Water Budget

Golden State Water Company - Mojave

Inflows (Water Supply) 2001-2020	Consumptive Uses and Outflow 2001-2020
Judgment, Appendix G (1)(e)	Estimated based on discharges and return flows from Barstow Treatment Plant, however, unclear data source
2,000 AFY	2,475 AFY
---	**Subsurface Outflow (Assumed)**
---	Judgment, Exhibit G (1)(c) based on USGS Stamos (2001) study
	1,462 AFY
---	**Consumptive Uses – Agriculture & Urban (Measured & Estimated)**
---	Measured pumping and estimated Minimal Pool pumping less estimated return flows.
	5,863 AFY (Agriculture)
	6,885 AFY (Urban)
---	**Phreatophytes (Assumed)**
---	USGS Water-Resources Investigation Report 96-4241 "Riparian Vegetation and Its Water Use During 1995 Along the Mojave River, Southern California" 1996. Lines and Bilhorn
	Phreatophytes (Assumed)
Total: 38,725 AFY	**Total: 27,185 AFY**

Notes:

AFY: Acre-Feet per Year

USGS: United States Geological Survey

Table 5-1: Mann-Kendall Statistics

Golden State Water Company - Mojave

Well	Period	Analysis	S	Z	P-Value	Sen's Slope	Tau	Correlation/Trend[1]
Agate Well No. 4	2020-2024	Depth to Water vs. Time	-248	-2.3630	0.0181	-0.1250	-0.2490	Weakly Negative
		Depth to Water vs. Pumping	58	0.5453	0.5855	0.0000	0.0583	None
Agate Well No. 5	2020-2024	Depth to Water vs. Time	-241	-2.6044	0.0092	-0.2031	-0.2830	Weakly Negative
		Depth to Water vs. Pumping	271	2.9300	0.0034	0.1765	0.3180	Moderately Positive
Arrowhead Well No. 2	2005-2024	Depth to Water vs. Time	15937	14.6040	<0.00005	0.1436	0.6650	Strongly Positive
		Depth to Water vs. Pumping	-671	-0.6140	0.5392	-0.0064	-0.0280	None
Bradshaw Well No. 1	2005-2024	Depth to Water vs. Time	13472	13.0480	<0.00005	0.1522	0.6040	Strongly Positive
		Depth to Water vs. Pumping	-4590	-4.4449	<0.00005	-0.0600	-0.2060	Weakly Negative
Bradshaw Well No. 2	2005-2024	Depth to Water vs. Time	12238	12.2840	<0.00005	0.1691	0.5760	Moderately Positive
		Depth to Water vs. Pumping	5844	5.8653	<0.00005	0.0876	0.2749	Weakly Positive
Bradshaw Well No. 4	2005-2024	Depth to Water vs. Time	9845	10.4820	<0.00005	0.1331	0.5015	Moderately Positive
		Depth to Water vs. Pumping	-2039	-2.1701	0.0300	-0.0267	-0.1039	Weakly Negative
Bradshaw Well No. 5	2005-2024	Depth to Water vs. Time	13493	12.4480	<0.00005	0.1426	0.5669	Moderately Positive
		Depth to Water vs. Pumping	-5099	-4.7035	<0.00005	-0.0590	-0.2142	Weakly Negative
Bradshaw Well No. 6	2005-2024	Depth to Water vs. Time	15483	13.6270	<0.00005	0.1528	0.6104	Strongly Positive
		Depth to Water vs. Pumping	5297	4.6613	<0.00005	0.0625	0.2088	Weakly Positive
Bradshaw Well No. 7	2005-2024	Depth to Water vs. Time	15526	13.3980	<0.00005	0.2042	0.5964	Strongly Positive
		Depth to Water vs. Pumping	-2426	-2.0927	0.0364	-0.0278	-0.0932	Weakly Negative
Bradshaw Well No. 10	2005-2024	Depth to Water vs. Time	14034	13.2170	<0.00005	0.1708	0.6063	Strongly Positive
		Depth to Water vs. Pumping	14034	13.2170	<0.00005	0.1708	0.6063	Strongly Positive
Bradshaw Well No. 11	2005-2024	Depth to Water vs. Time	10568	11.6010	<0.00005	0.1600	0.5614	Moderately Positive
		Depth to Water vs. Pumping	3932	4.3156	<0.00005	0.0513	0.2089	Weakly Positive
Bradshaw Well No. 12	2005-2024	Depth to Water vs. Time	8327	8.6697	<0.00005	0.1222	0.4116	Moderately Positive
		Depth to Water vs. Pumping	-93	-0.0958	0.9237	0.0000	-0.0046	None
Bradshaw Well No. 13	2006-2024	Depth to Water vs. Time	13895	13.7470	<0.00005	0.1667	0.6409	Strongly Positive
		Depth to Water vs. Pumping	915	0.9044	0.3658	0.0103	0.0422	None
Bradshaw Well No. 14	2006-2024	Depth to Water vs. Time	8966	10.3940	<0.00005	0.1484	0.5119	Moderately Positive
		Depth to Water vs. Pumping	-3316	-3.8434	0.0001	-0.0577	-0.1893	Weakly Positive
Crooks Well No. 1	2011-2020	Depth to Water vs. Time	2214	8.8718	<0.00005	0.1350	0.6749	Strongly Positive
		Depth to Water vs. Pumping	-2	-0.1237	0.9015	-0.1750	-0.0714	None
Glen Road Well No.1	2005-2024	Depth to Water vs. Time	13582	12.8810	<0.00005	0.1515	0.5928	Moderately Positive
		Depth to Water vs. Pumping	4876	4.6238	<0.00005	0.0536	0.2128	Weakly Negative
Glen Road Well No.2	2005-2024	Depth to Water vs. Time	12197	11.4870	<0.00005	0.1629	0.5267	Moderately Positive
		Depth to Water vs. Pumping	-3465	-3.2626	0.0011	-0.0558	-0.1496	Weakly Negative

Notes:

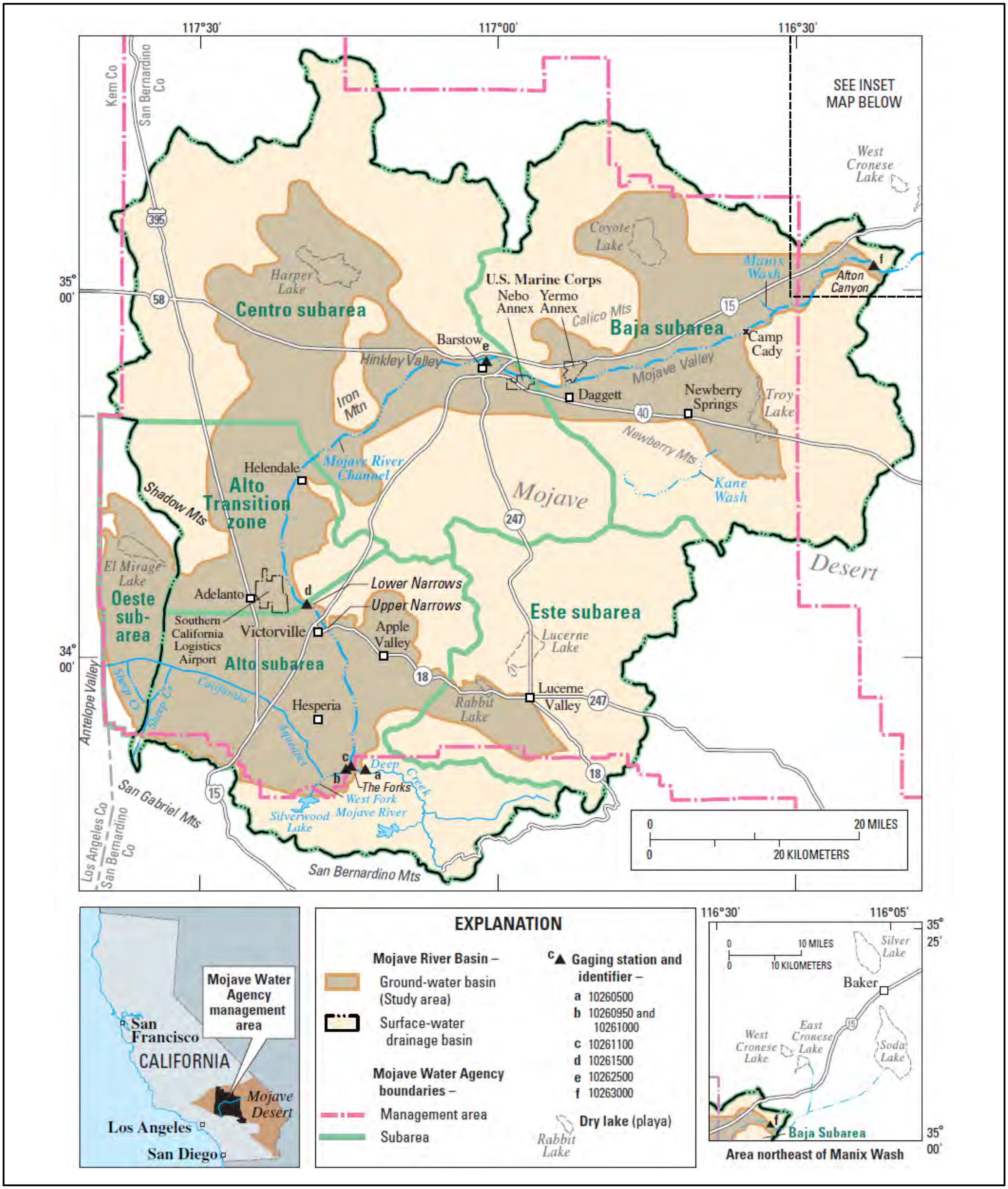
1. At the 95% confidence level, a negative correlation/trend indicates that depth to water (DTW) decreases as time or pumping increases; a positive correlation/trend indicates that DTW increases as time or pumping increases.

S: Mann-Kendall Statistic.

Tau: Mann-Kendall Rank Correlation Coefficient.

Z: Standard Normal Variate.

FIGURES



Notes: BAP = Base Annual Production, PSY = Production Safe Yield, FPA = Free Product Allowance.
Source: Stamos, C.L., Martin, P., Nishikawa, T., and Cox, B.F, Simulation of Ground-Water Flow in the Mojave River Basin, California. Water-Resources Investigations Report 01-4002 Version 3, US Geological Survey, Sacramento, CA, Fig. 1 (page 4) (2001) https://pubs.usgs.gov/wri/wri014002/"

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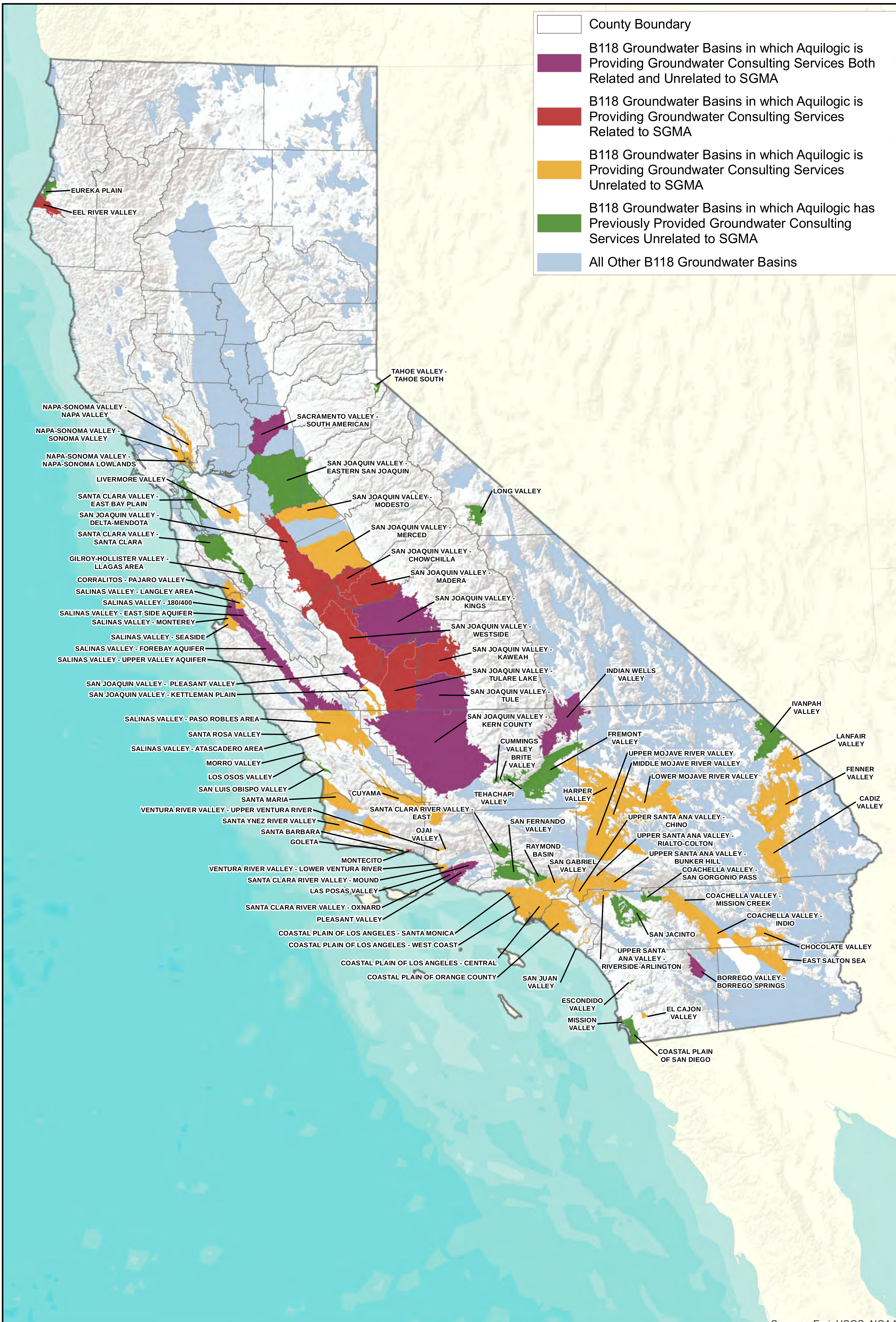
Area and Subareas of Mojave Groundwater Basin

Date: 9/3/2024	Project #: 018-10	**Figure 1-1**



0 60
Miles

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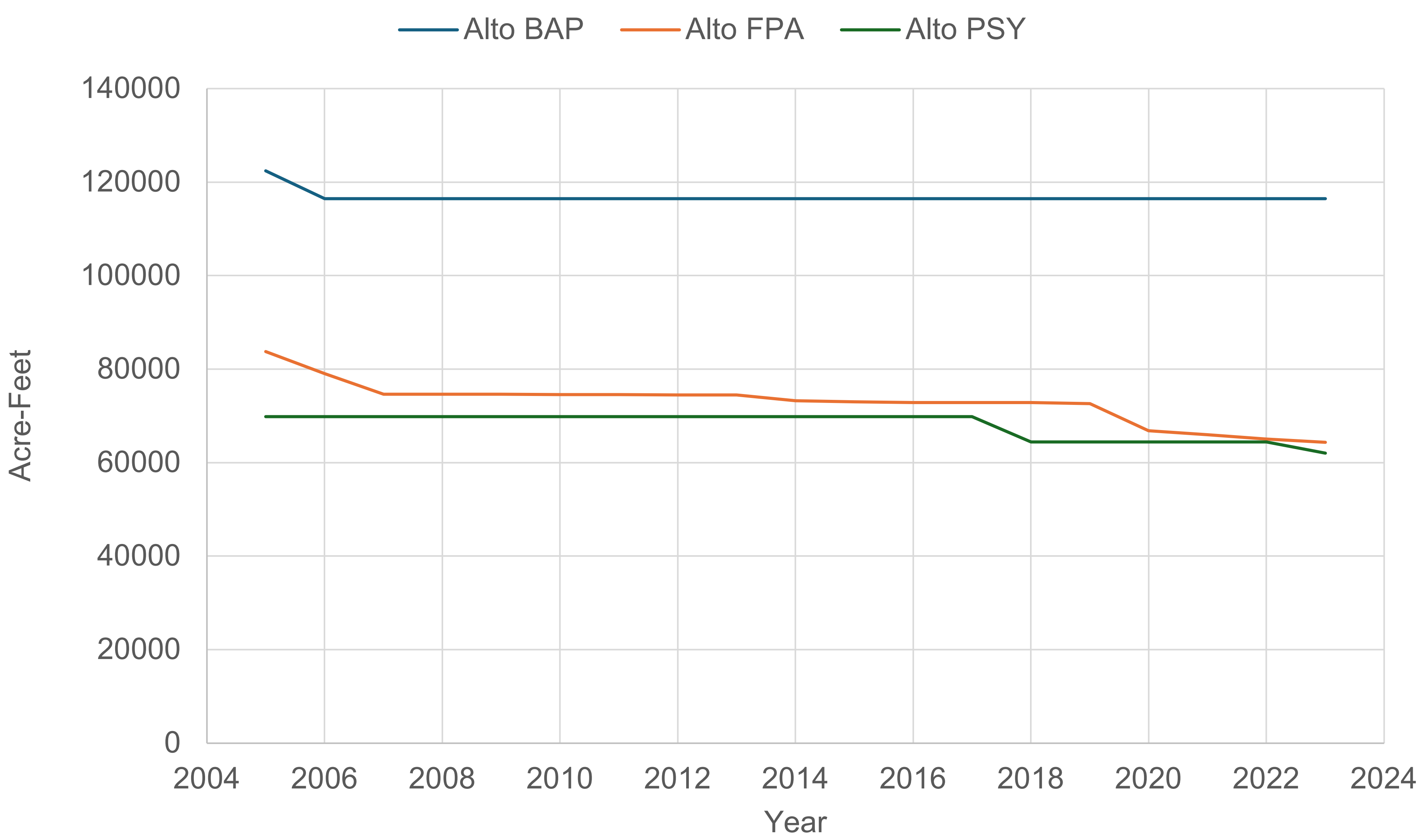
Basins Served by Aquilogic

Date: 9/3/2024	Project #: 018-10	Figure 1-2

GSWC 0052



Notes:
BAP = Base Annual Production
FPA = Free Product Allowance
PSY = Production Safe Yield

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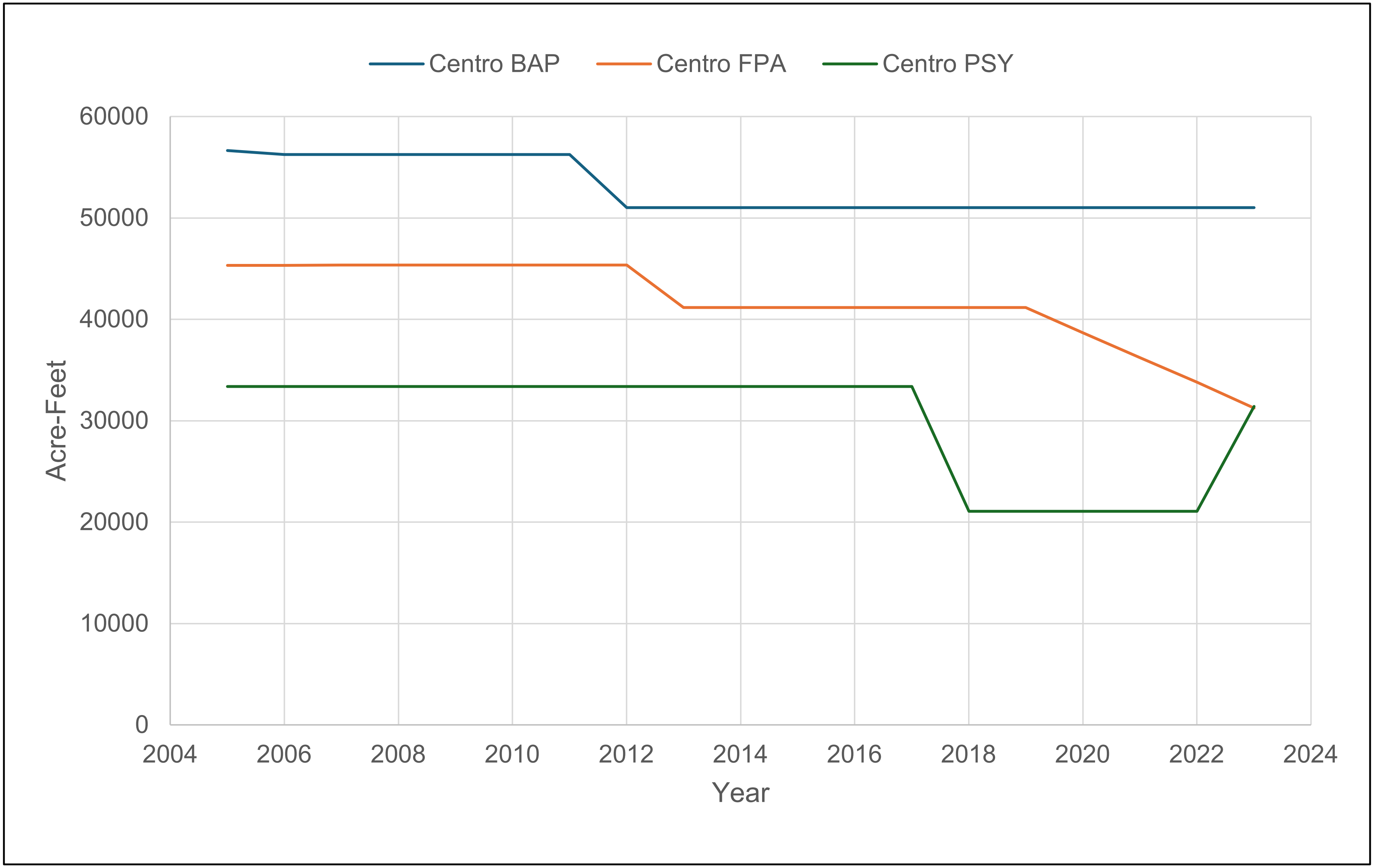
BAP, FPA, PSY, and Surface Water Inflow in the Alto Subarea

Date: 9/3/2024 | Project #: 018-10 | **Figure 3-1**



Notes:
BAP = Base Annual Production
FPA = Free Product Allowance
PSY = Production Safe Yield

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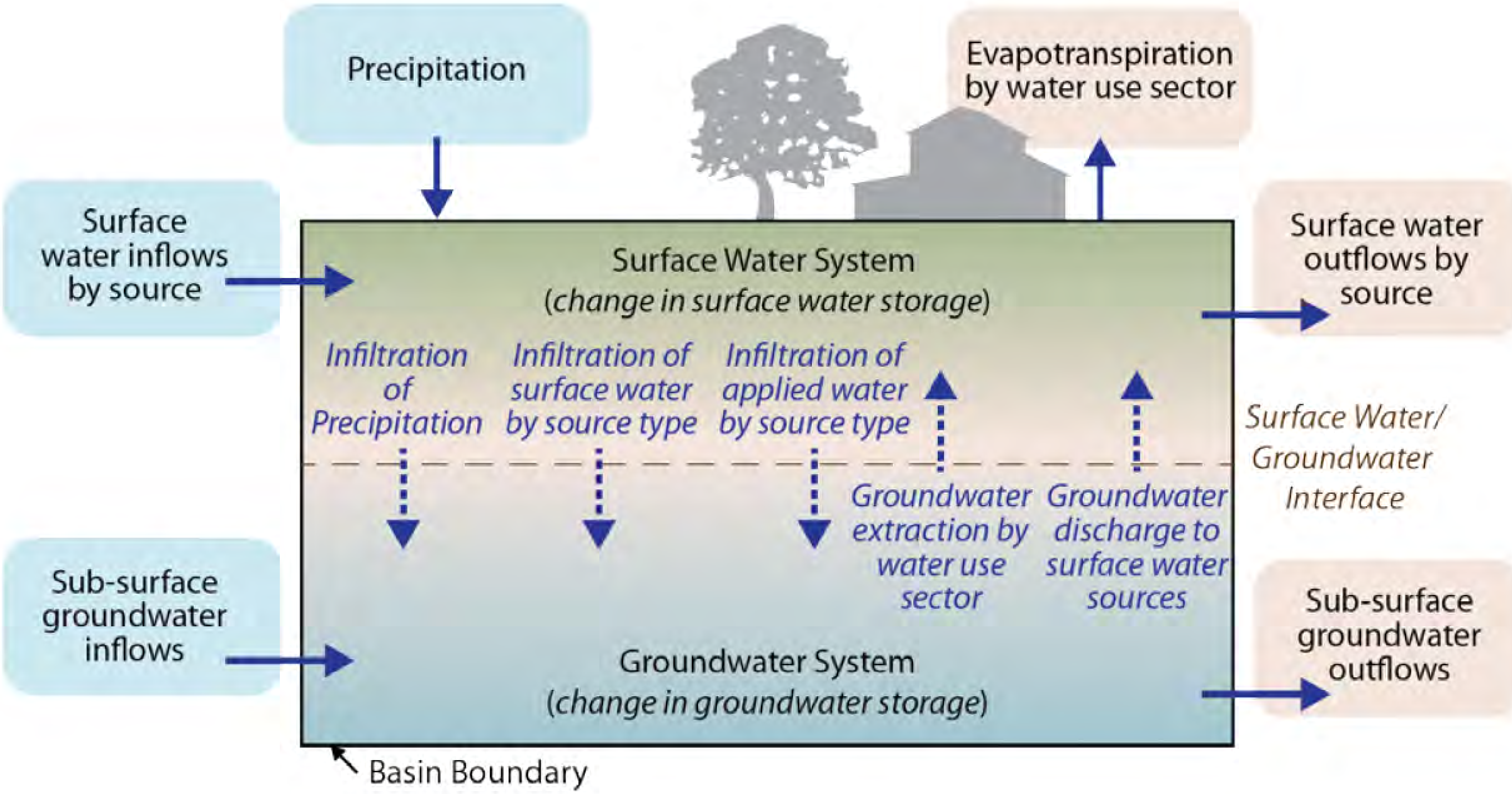
BAP, FPA, PSY, and Surface Water Inflow in the Centro Subarea

Date: 9/3/2024	Project #: 018-10	**Figure 3-2**

GSWC 0054



Source: Figure 5 (page 18) of DWR. (2016). Water Budget BMP. December.

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Graphical Representation of a Water Budget

Date: 9/3/2024	Project #: 018-10	**Figure 4-1**

GSWC 0055

HYDROLOGICAL INVENTORY BASED ON VARIOUS SUPPLY ASSUMPTIONS AND 2021-22 CONSUMPTIVE USE, RETURN FLOW AND IMPORTS

(ALL AMOUNTS IN ACRE-FEET)

	ALTO	TRANSITION ZONE	CENTRO
WATER SUPPLY	2001-2020	2001-2020	2001-2020
Surface Water Inflow [1]	61,635	24,808	36,725
Mountain Front Recharge [2]	8,511	0	0
Groundwater Discharge to the Transition Zone [3]	0	5,112	0
Subsurface Inflow [4]	0	7,053	2,000
Este/Oeste Inflow [5]	4,785	62	
Imports[6]	0	15,095	
TOTAL	74,931	52,130	38,725
CONSUMPTIVE USE AND OUTFLOW			
Surface Water Outflow	36,725 [7]	36,725 [7]	7,500 [14]
Barstow Treatment Plant Discharge			2,475
Subsurface Outflow [8]	2,000	2,000	1,462
Consumptive use [9]			
Agriculture	949	949	5,863
Urban	40,171	6,456	6,885
Phreatophytes[10]	11,000	6,000	3,000
TOTAL	90,845	52,130	27,185
Surplus / (Deficit) [11]	(15,914)		11,540
Total Estimated Production[12]	78,147		16,995
Potential Return Flow from Surplus	0		2,885
PRODUCTION SAFE YIELD [13]	62,233		31,420

1 Average discharge of Mojave River by USGS, 2001-2020 (USGS stations at West Fork Mojave River Near Hesperia, CA (10261000), Deep Creek Near Hesperia, CA (10260500) and Lower Narrows Near Victorville, CA (10261500)).

2 Mountain front recharge as developed from Upper Basin Alto Model.

3 Groundwater discharge lost to Transition Zone below the Narrows.

4 Portion of water lost to Transition Zone from Alto (Upper Basin Model). Groundwater discharge to Harper Lake (USGS Stamos 2001).

5 Subsurface Inflow to Alto from Este and Oeste Subareas (Upper Basin Model).

6 Total discharge to Transition Zone from VVWRA, 2021-22 Water Year.

7 Estimated based on reported flows at USGS gaging station, Mojave River at Victorville Narrows and 2001-2020

8 Groundwater discharge to Baja 1462 AF; 3501 AF groundwater discharge from Barstow area to Harper Lake. (USGS Stamos 2001)

9 Includes consumptive use of "Minimals Pool" (estimated Minimal's production is 2,104 af).

10 From USGS Water-Resources Investigation Report 96-4241 "Riparian Vegetation and Its Water Use During 1995 Along the Mojave River, Southern California" 1996. Lines and Bilhorn

11 Amount necessary to offset overdraft under the above assumptions.

12 Water production for 2021-22. Included in the production values are the estimated minimal producer's water use.

13 Imported State Water Project water purchased by MWA is not reflected in the above table.

14 Reported flows at USGS gaging station, Mojave River at Barstow (10262500).

Note: WY = Water Year
Source: Table 5-1 (page 42) Watermaster. (2024). Annual Report for Water Year 2022-2023. May.

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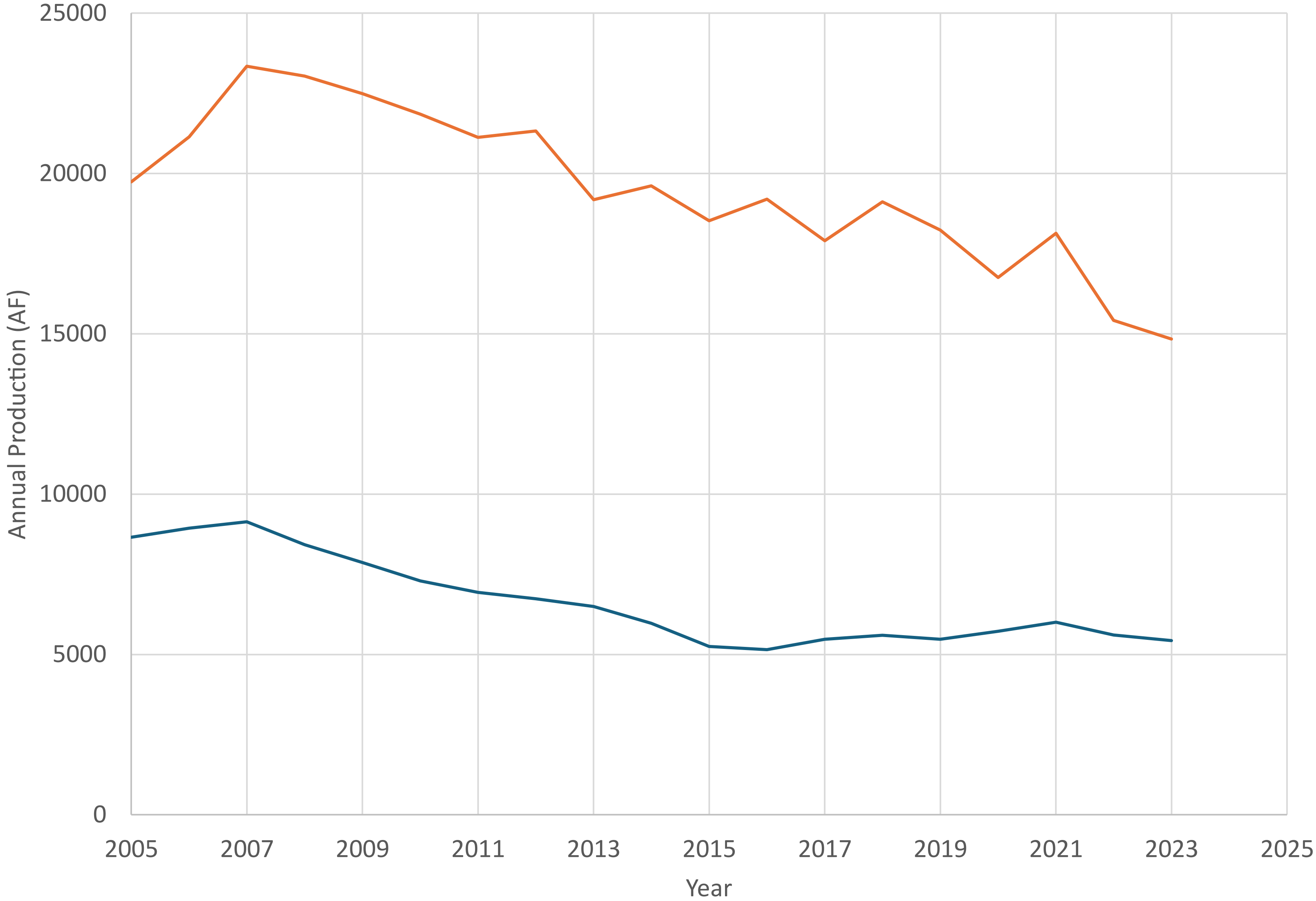
Watermaster WY 2023 Proposed Hydrological Inventory - Alto and Centro

Date: 9/3/2024	Project #: 018-10	**Figure 4-2**

GSWC 0056



Annual Pumping

Centro Verified Pumping

Notes: Golden State Water Company data, available at https://bhfs.sharefile.com/share/view/sc4bbae97dcb44d288d59e7da82922368.

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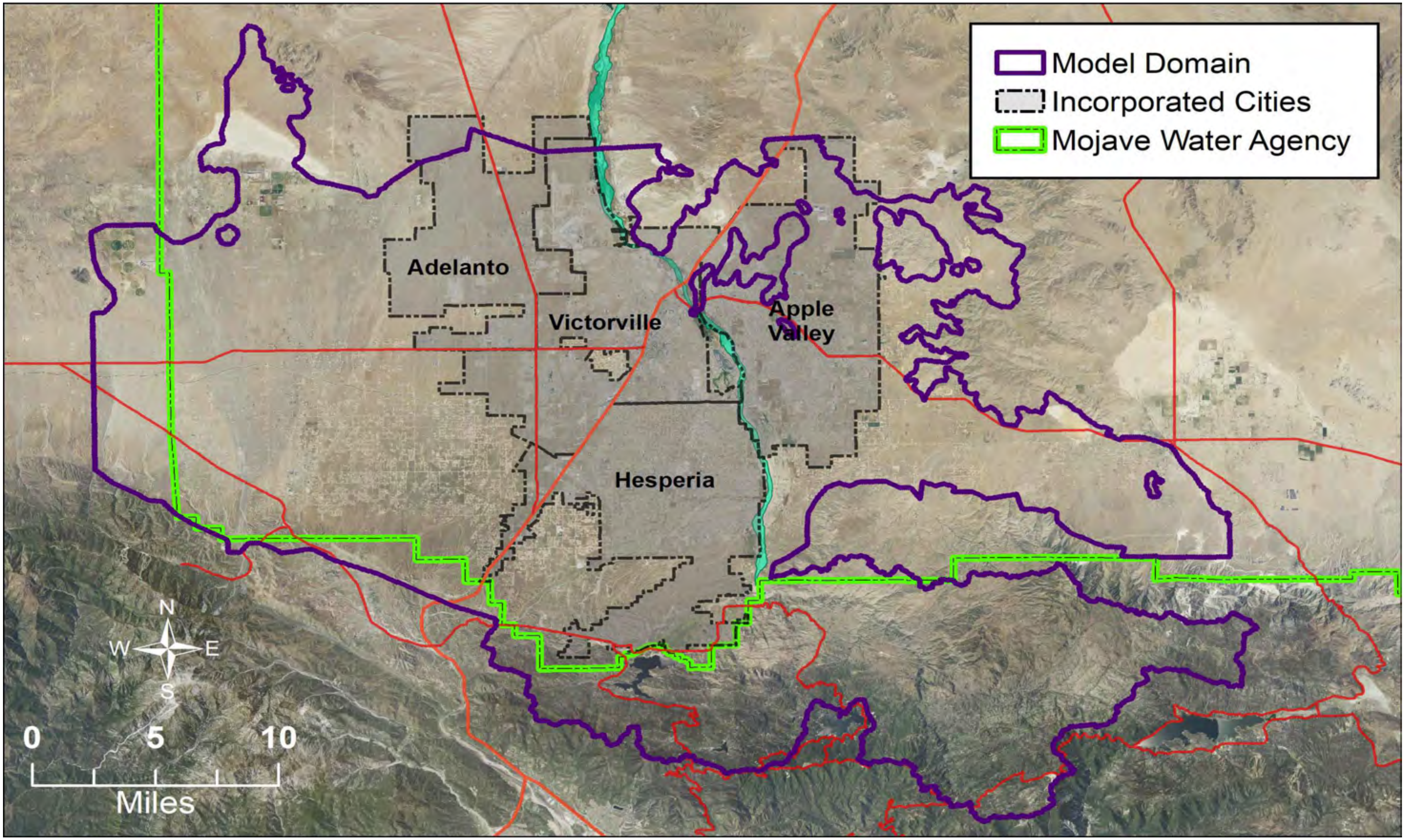
Centro Groundwater Production

Date: 9/4/2024	Project #: 018-10	**Figure 4-3**

GSWC 0057



Source: Wagner & Bonsignore, Consulting Civil Engineers, Production Safe Yield & Consumptive Use Update, App. G, Fig. 1 (page 6) (Feb. 28, 2024)

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UMRB Model Domain

Date: 9/4/2024	Project #: 018-10	**Figure 4-4**

Active
Destroyed
Inactive
Standby

Faults and Flow Barriers Identified by Watermaster
Focus Area

0 0.8
Miles

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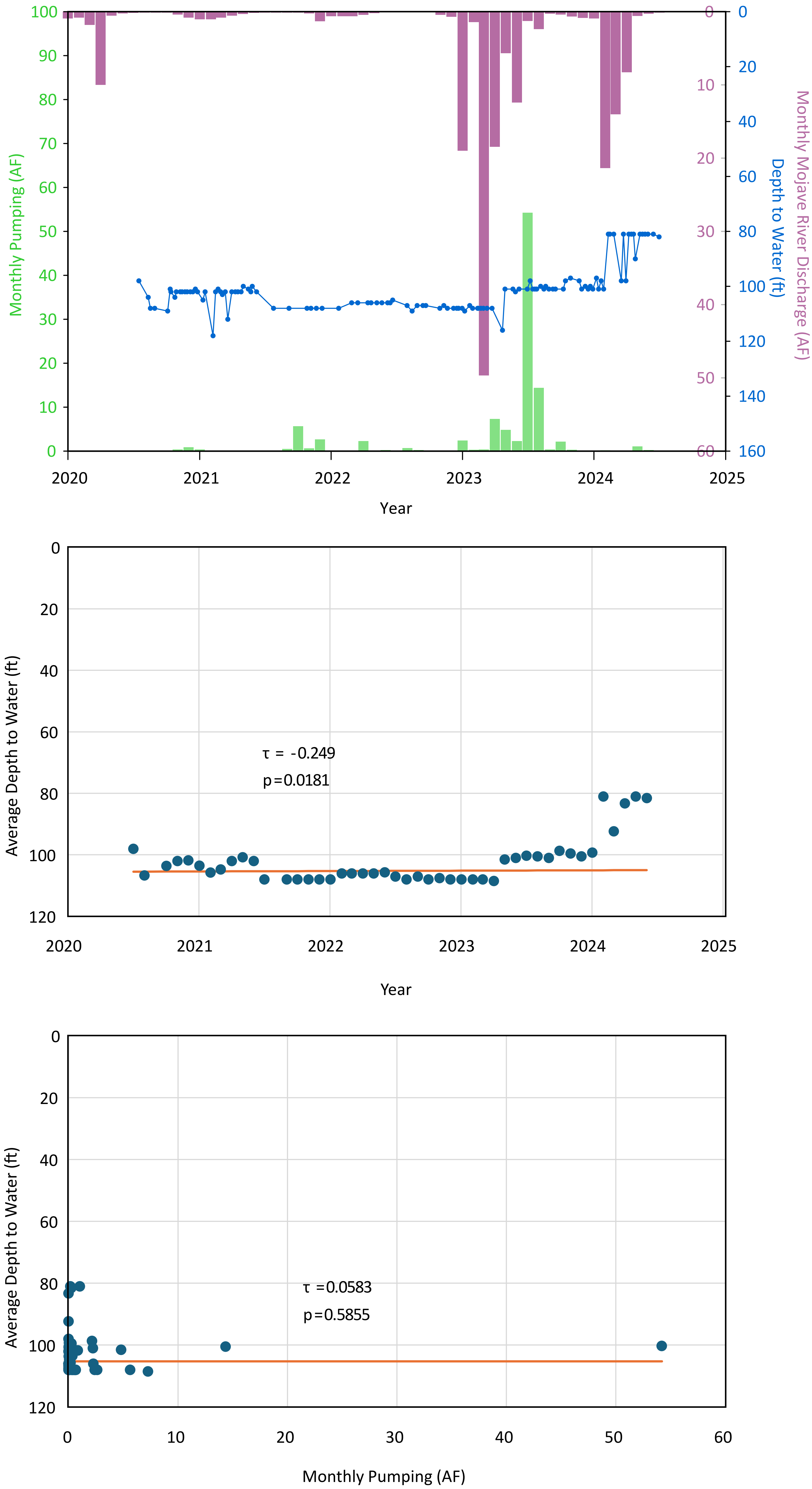
Well Locations

Date: 9/3/2024 | Project #: 018-10 | **Figure 5-1**



Notes: Tau (τ) is the Kendall correlation coefficient. The p-value is the attained significance. The null hypothesis is that there is no trend or correlation in the data. The smaller the p-value, the stronger the evidence for rejection of the null hypothesis and the more likely a trend and correlation exists in the data. In general, p-values less than 0.05 are considered to strongly support the calculated trend and correlation coefficient (95% confidence level). Higher p-values indicate that the null hypothesis is more likely to be correct (i.e., no trend or correlation).

Top Graph Legend
- Depth to Water (ft) (top graph)
- Monthly Pumping (AF)
- Monthly Mojave River Discharge at Lower Narrows Gage (AF)

Middle Graph Legend
- Depth to Water (ft)
- Sen's Slope

Bottom Graph Legend
- Depth to Water (ft)
- Sen's Slope

Generated using Golden State Water Company Data, available at https://bhfs.sharefile.com/share/view/sc4bbae97dcb44d288d59e7da82922368.

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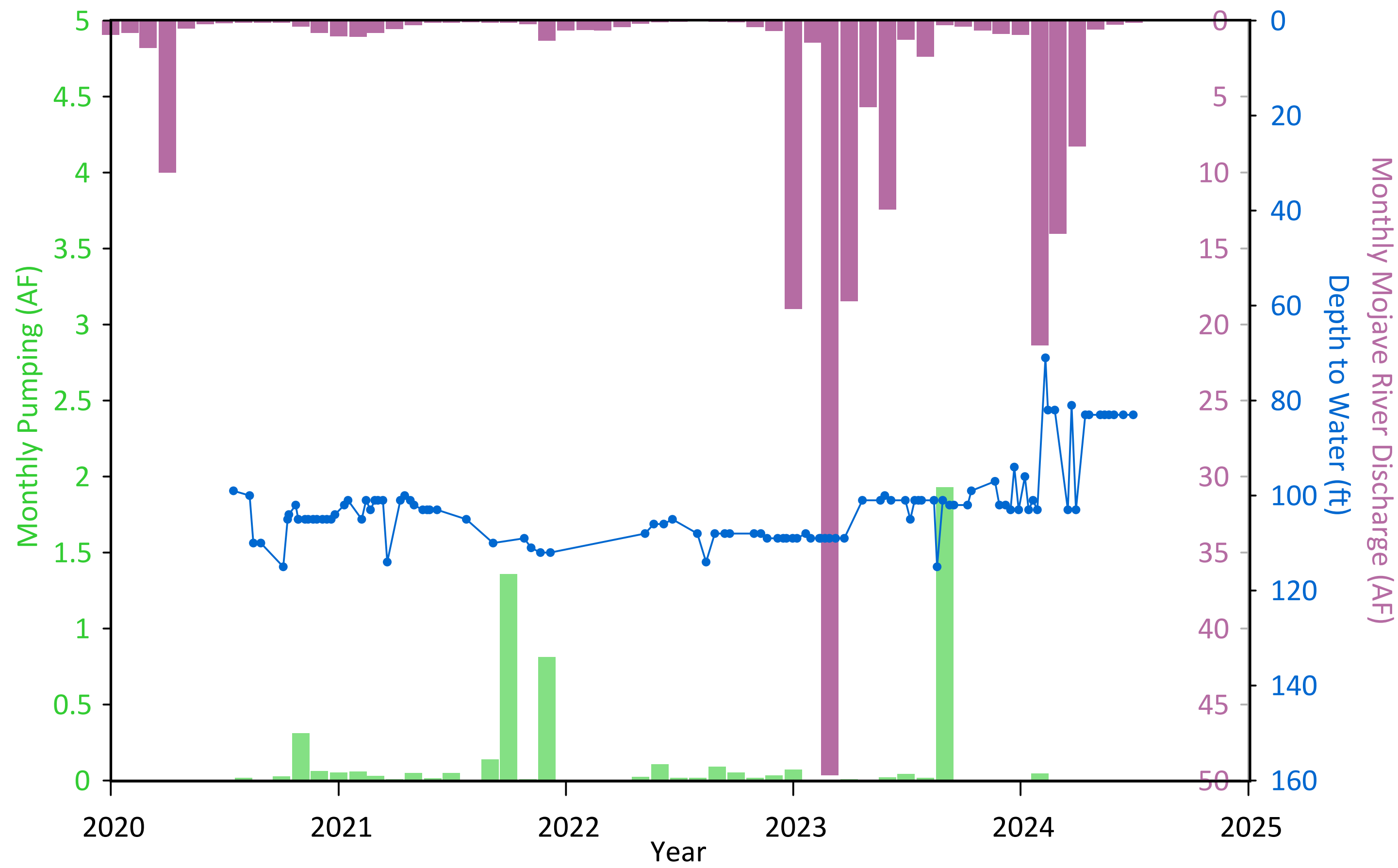
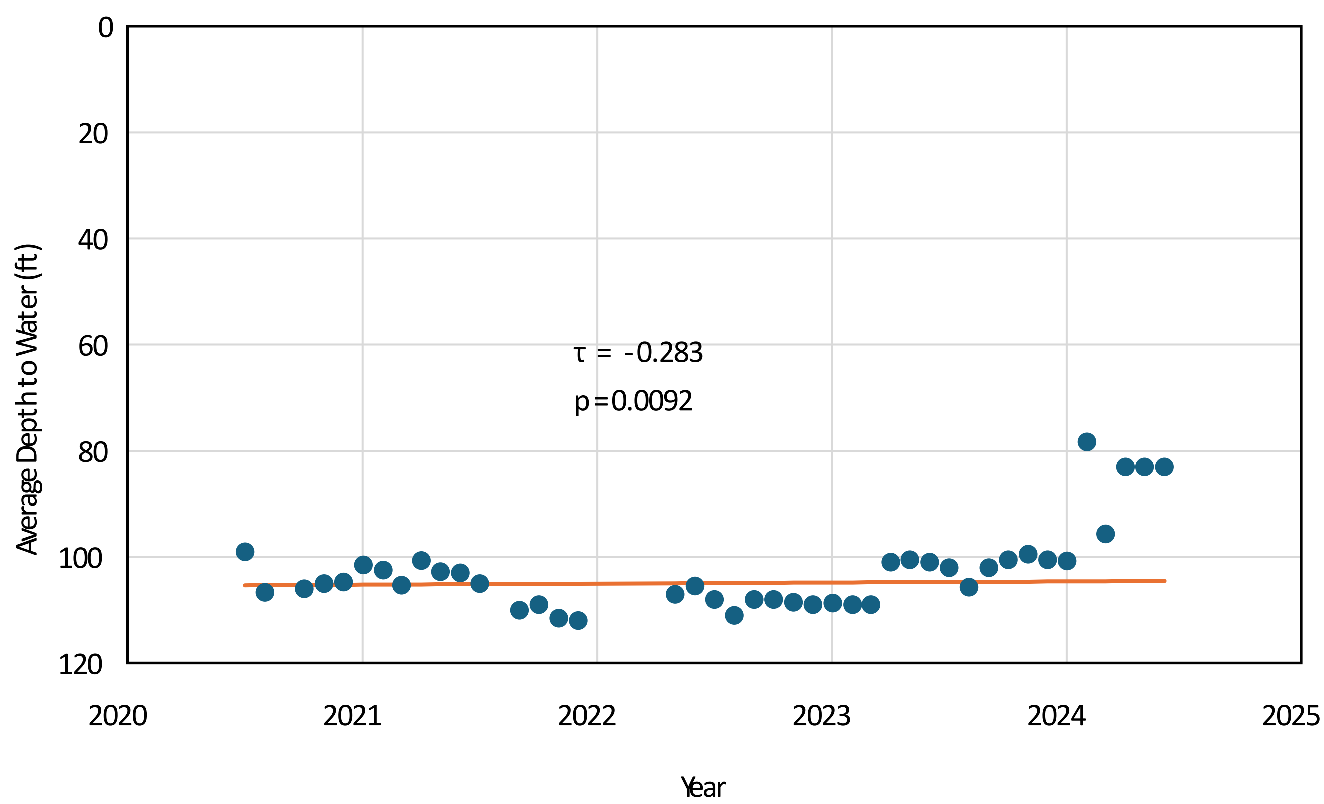
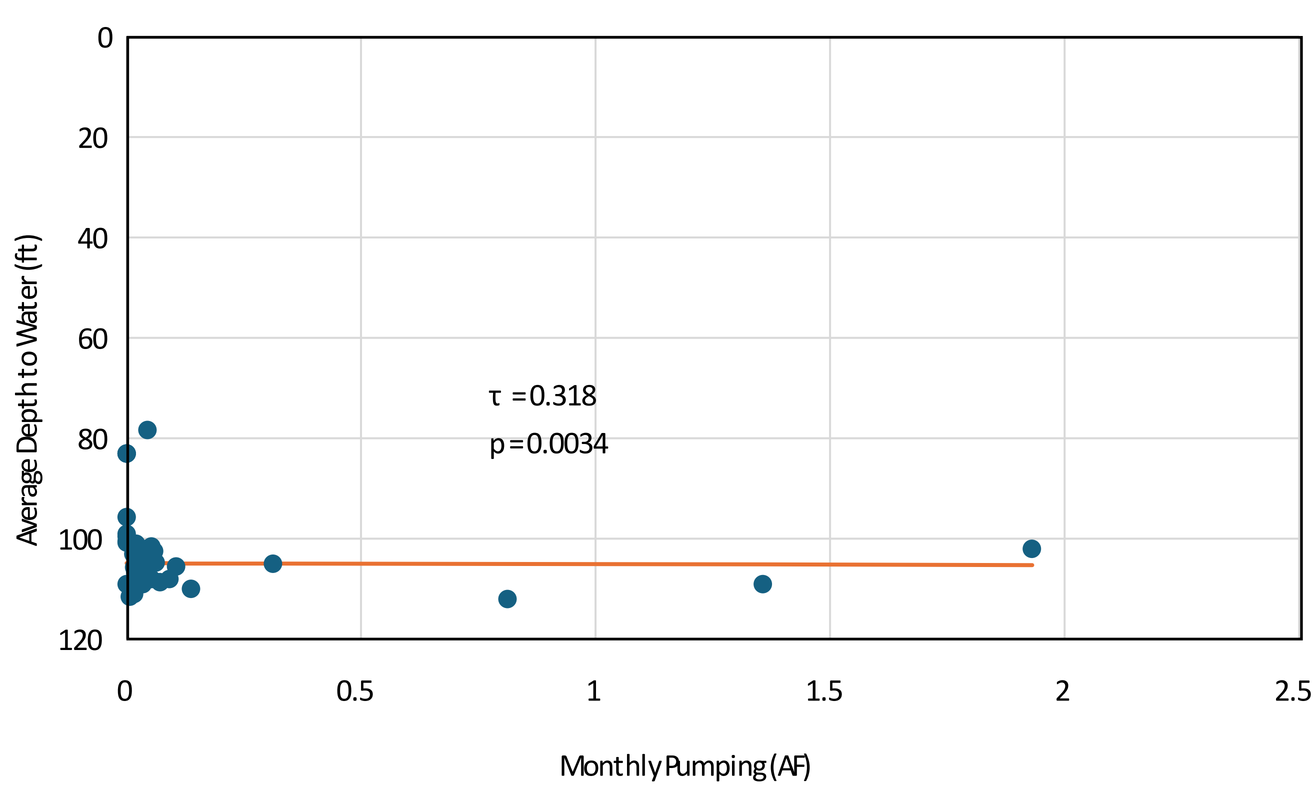
Agate Well No. 4

Date: 9/3/2024	Project #: 018-10	**Figure 5-2**







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- Monthly Mojave River Discharge at Lower Narrows Gage (AF)

Middle Graph Legend
- Depth to Water (ft)
- Sen's Slope

Bottom Graph Legend
- Depth to Water (ft)
- Sen's Slope

Generated using Golden State Water Company Data, available at https://bhfs.sharefile.com/share/view/sc4bbae97dcb44d288d59e7da82922368.

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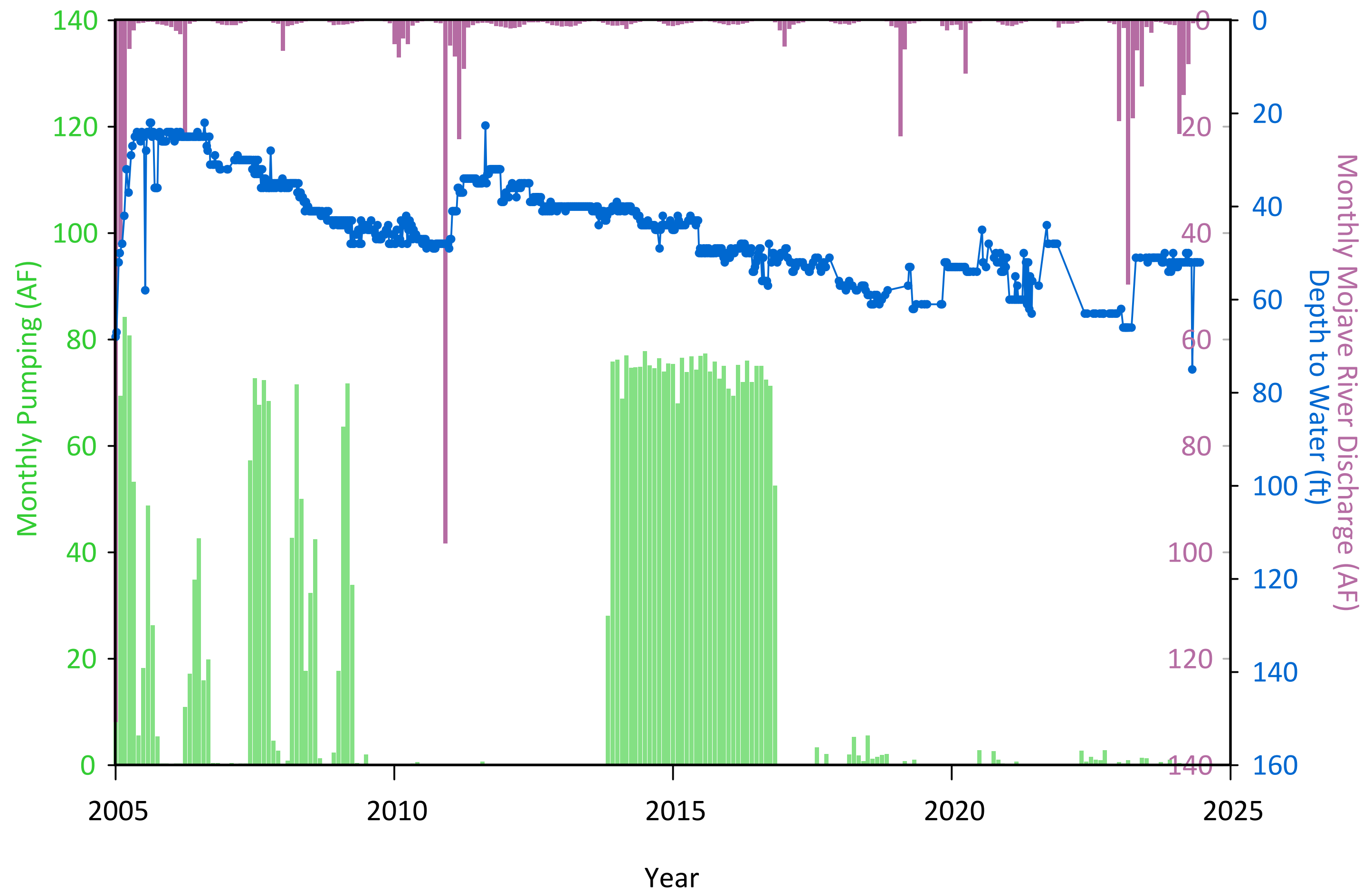
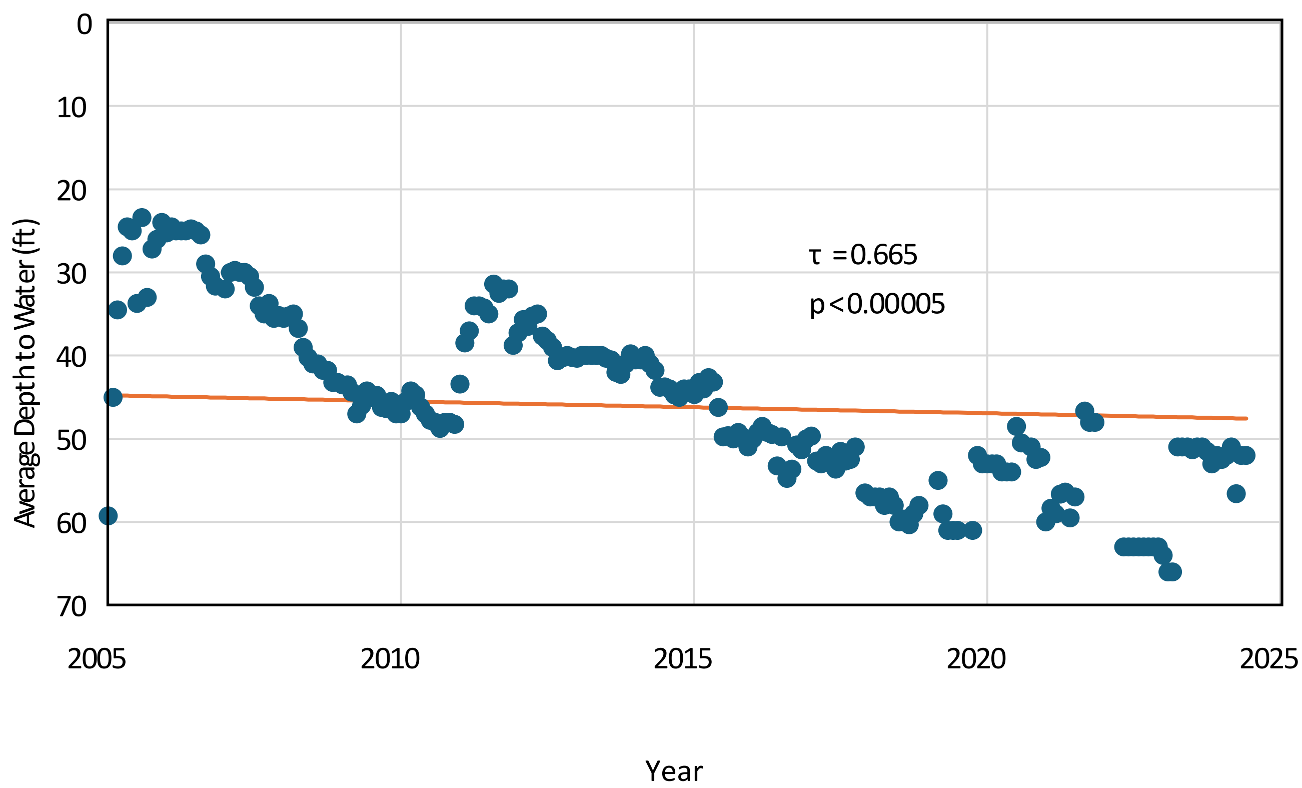
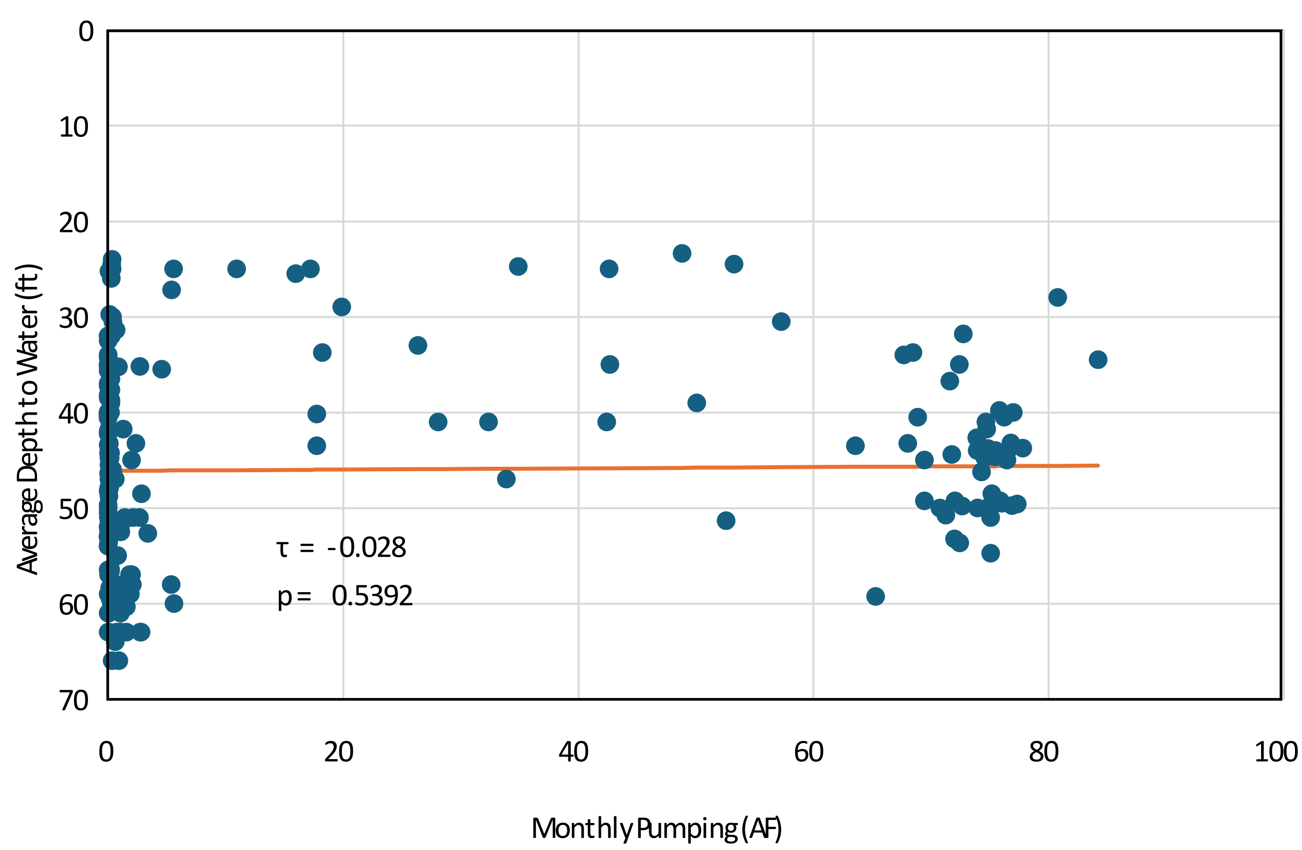
Agate Well No. 5

Date: 9/3/2024	Project #: 018-10	**Figure 5-3**

GSWC 0061







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Top Graph Legend

- Depth to Water (ft) (top graph)
- Monthly Pumping (AF)
- Monthly Mojave River Discharge at Lower Narrows Gage (AF)

Middle Graph Legend

- Depth to Water (ft)
- Sen's Slope

Bottom Graph Legend

- Depth to Water (ft)
- Sen's Slope

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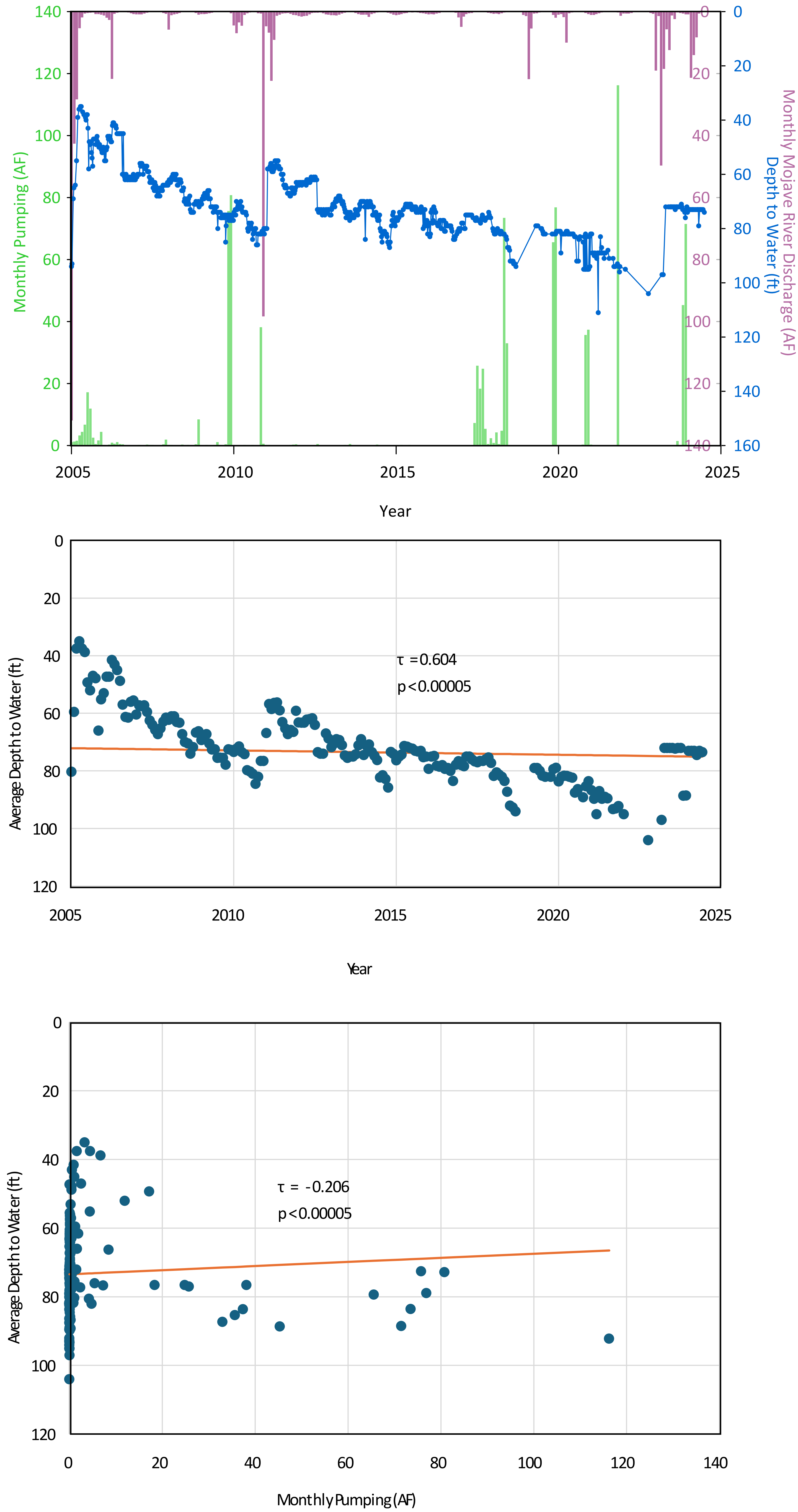
Arrowhead Well No. 2

Date: 9/3/2024	Project #: 018-10	**Figure 5-4**

GSWC 0062



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- Monthly Pumping (AF)
- Monthly Mojave River Discharge at Lower Narrows Gage (AF)

Middle Graph Legend
- Depth to Water (ft)
- Sen's Slope

Bottom Graph Legend
- Depth to Water (ft)
- Sen's Slope

Generated using Golden State Water Company Data, available at https://bhfs.sharefile.com/share/view/sc4bbae97dcb44d288d59e7da82922368.

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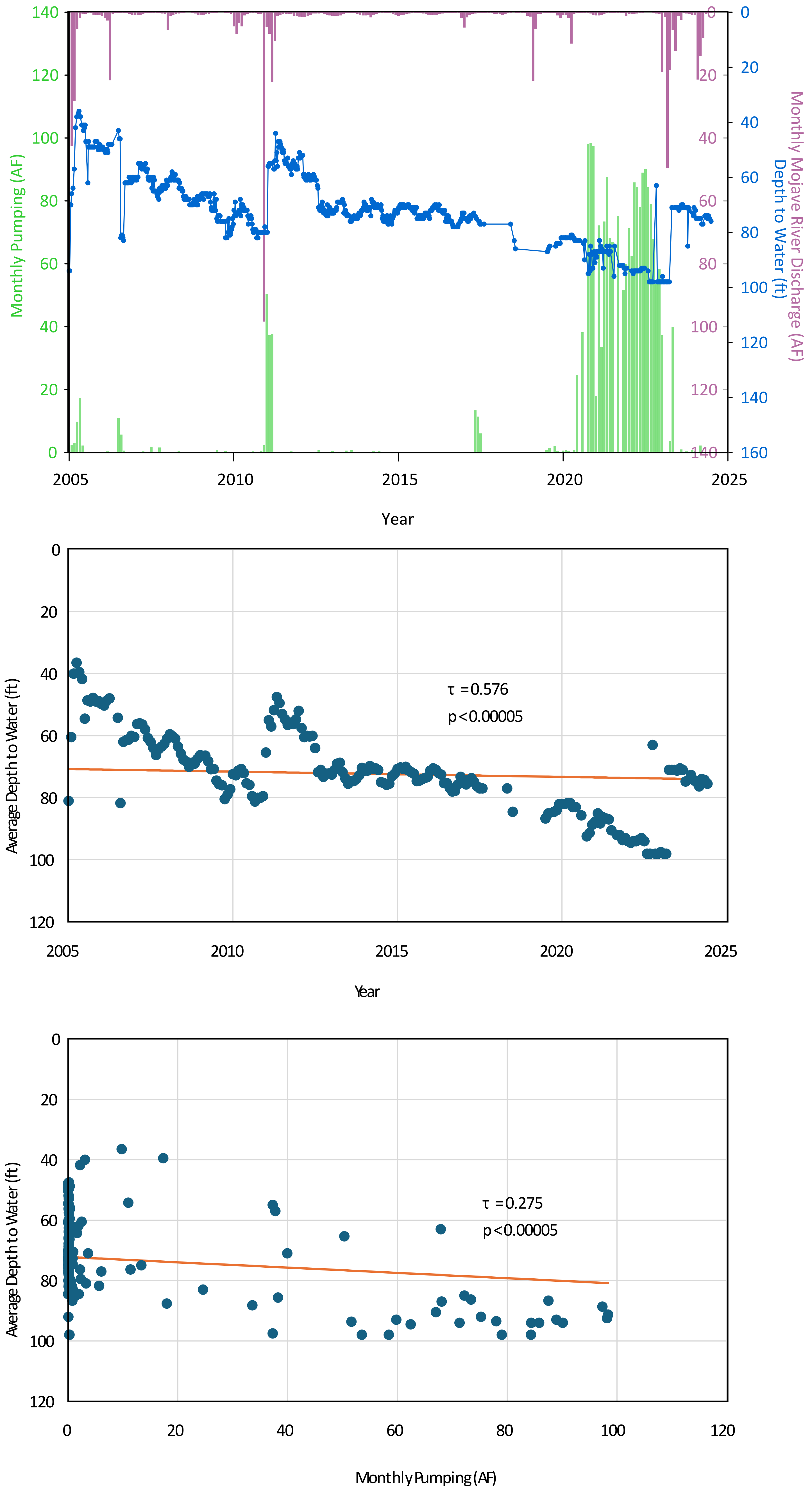
Bradshaw Well No. 1

Date: 9/3/2024 | Project #: 018-10 | **Figure 5-5**

GSWC 0063



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Middle Graph Legend

- Depth to Water (ft)
- Sen's Slope

Bottom Graph Legend

- Depth to Water (ft)
- Sen's Slope

Generated using Golden State Water Company Data, available at https://bhfs.sharefile.com/share/view/sc4bbae97dcb44d288d59e7da82922368.

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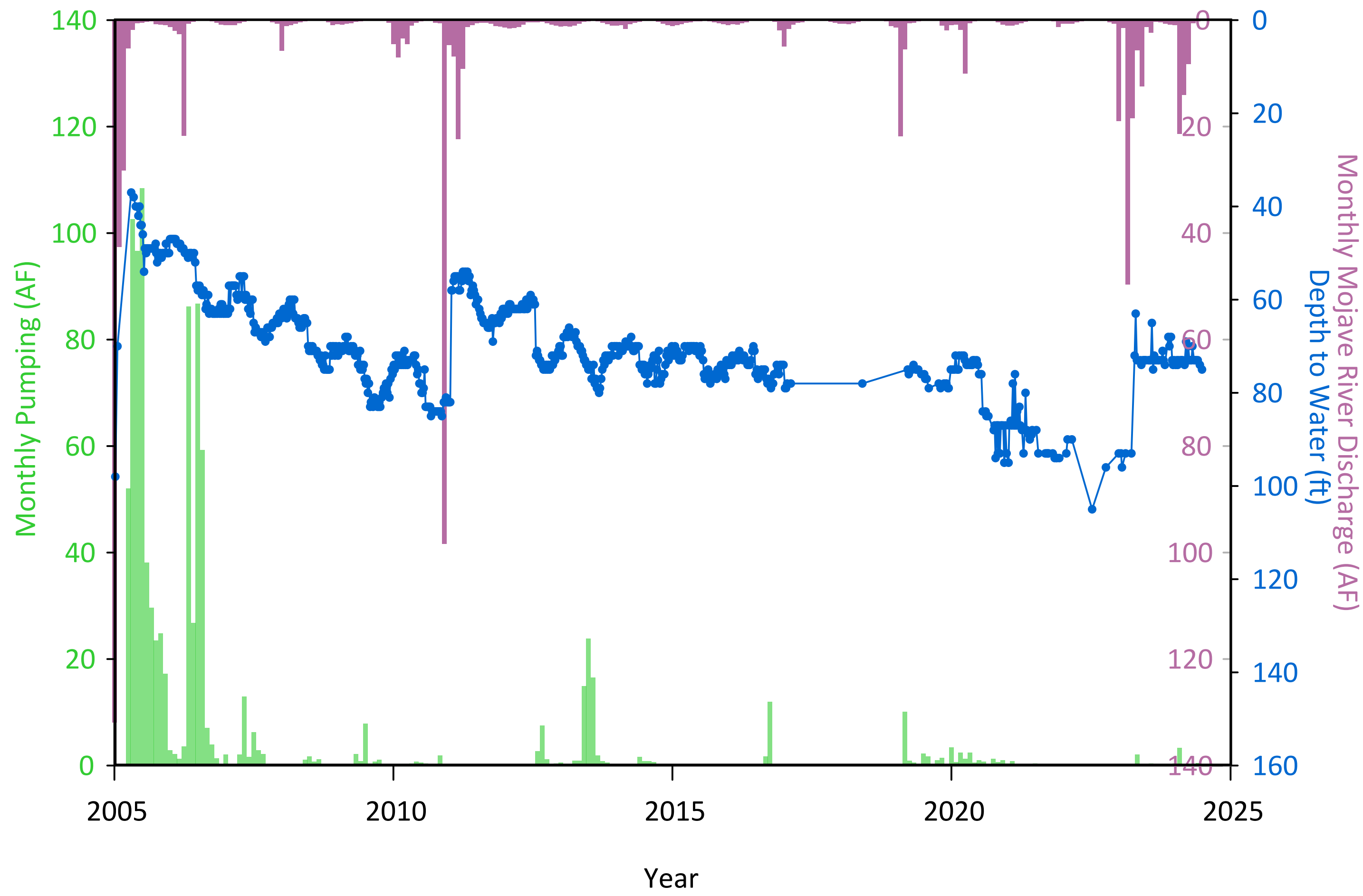
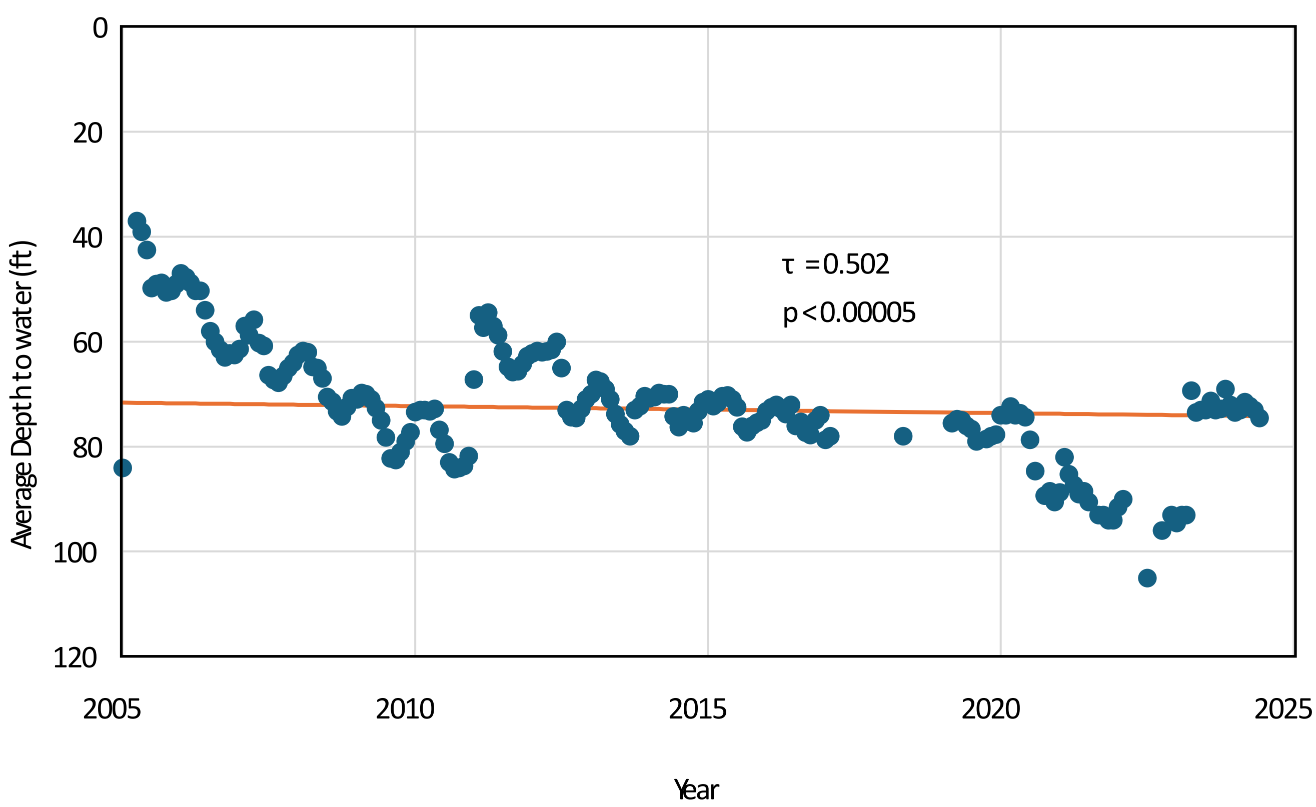
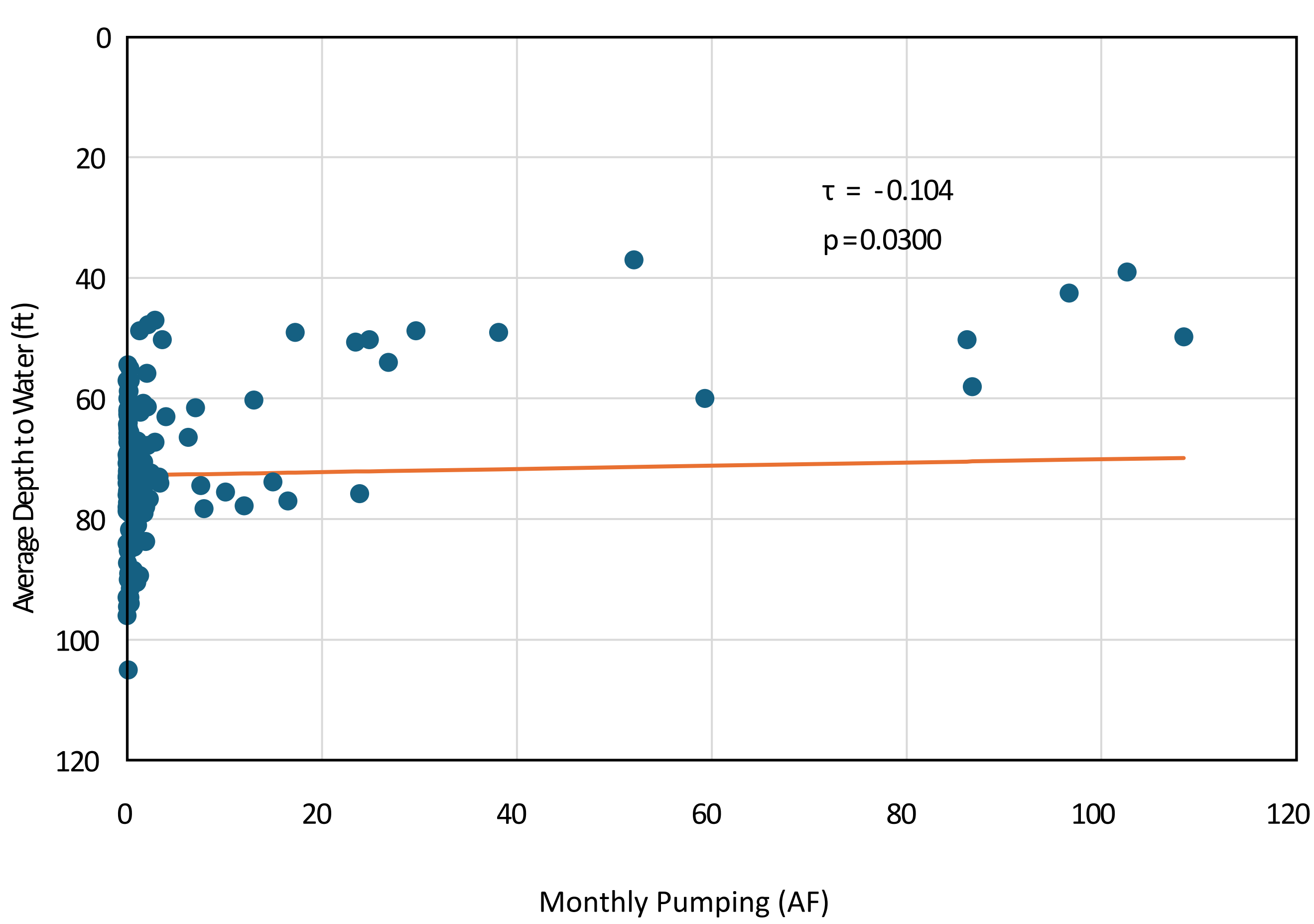
Bradshaw Well No. 2

Date: 9/3/2024	Project #: 018-10	**Figure 5-6**

GSWC 0064







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Middle Graph Legend

- Depth to Water (ft)
- Sen's Slope

Bottom Graph Legend

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- Sen's Slope

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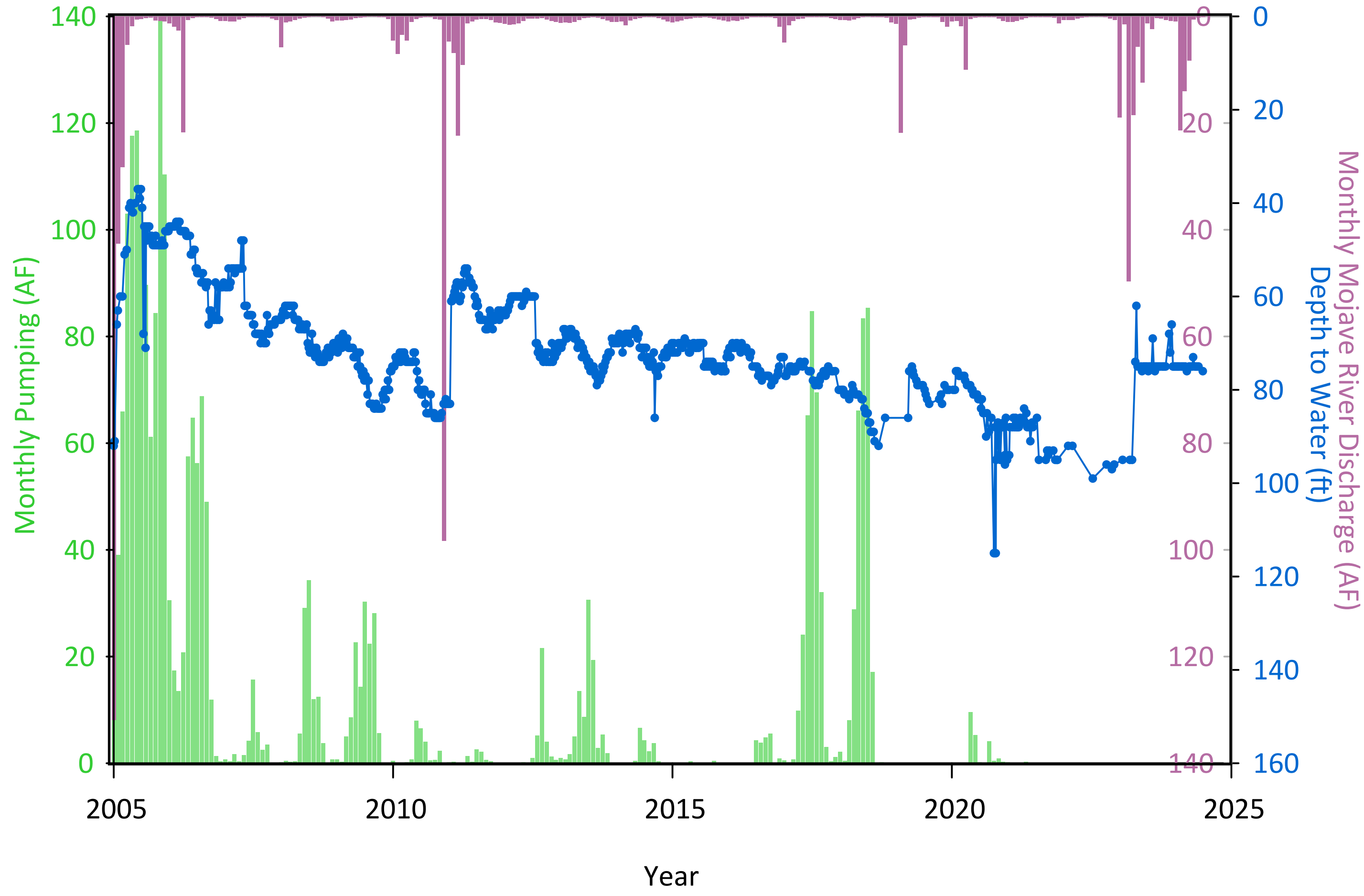
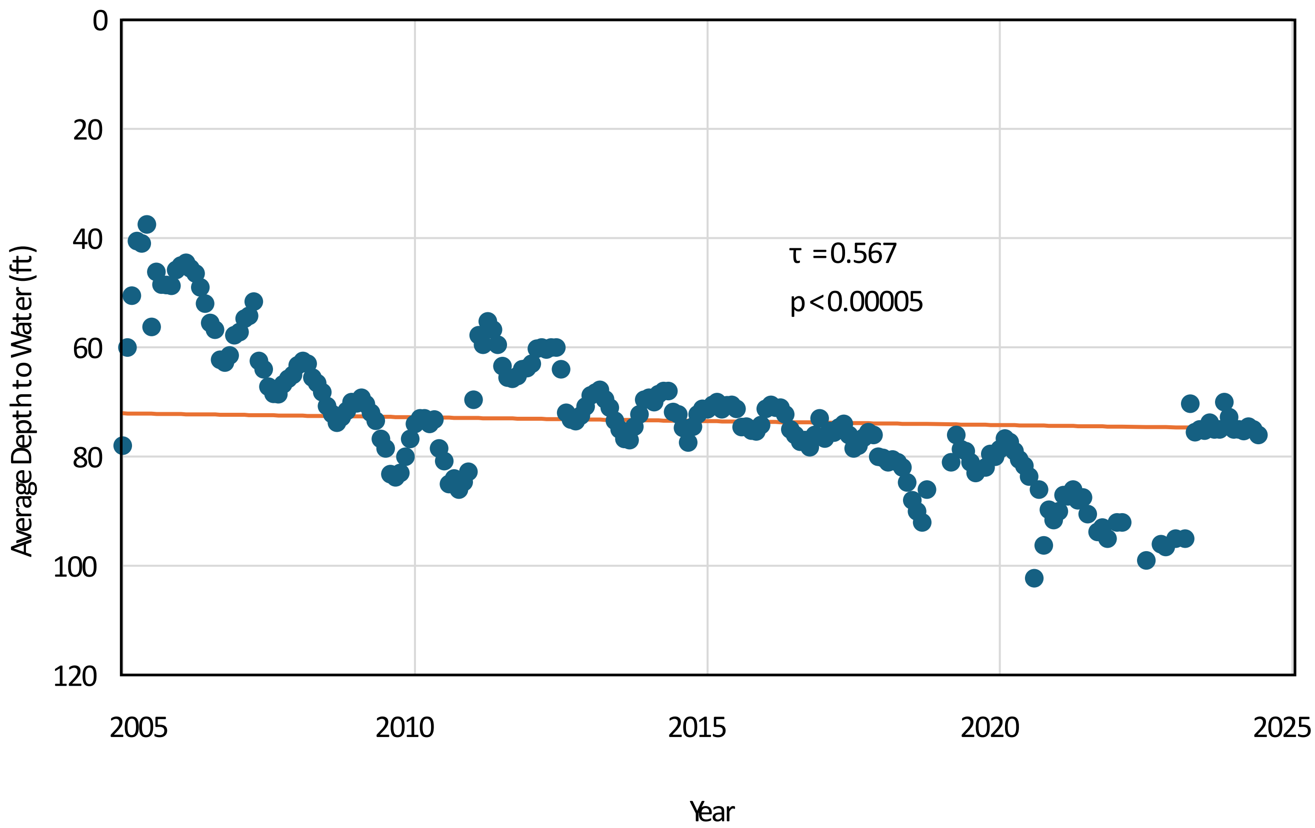
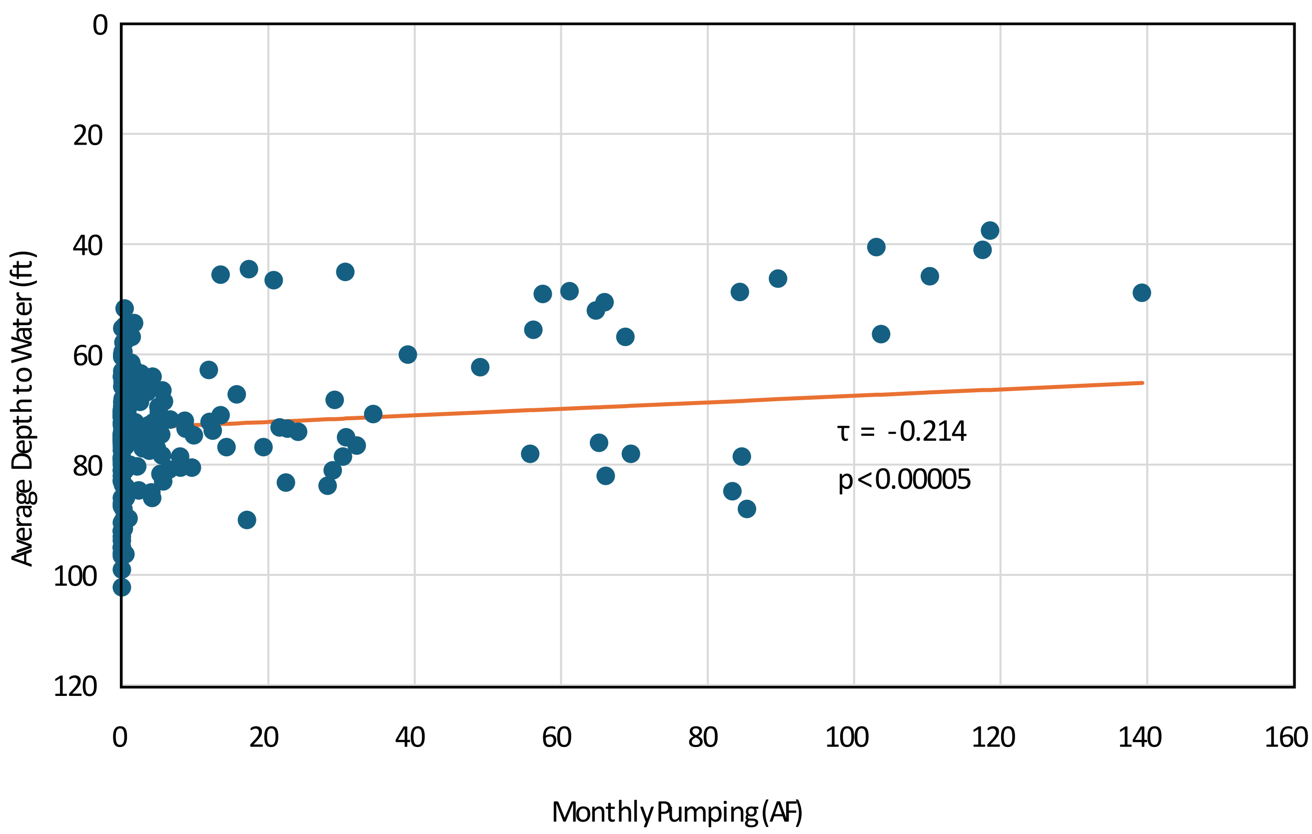
Bradshaw Well No. 4

Date: 9/3/2024	Project #: 018-10	**Figure 5-7**

GSWC 0065







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Middle Graph Legend
- Depth to Water (ft)
- Sen's Slope

Bottom Graph Legend
- Depth to Water (ft)
- Sen's Slope

Generated using Golden State Water Company Data, available at https://bhfs.sharefile.com/share/view/sc4bbae97dcb44d288d59e7da82922368.

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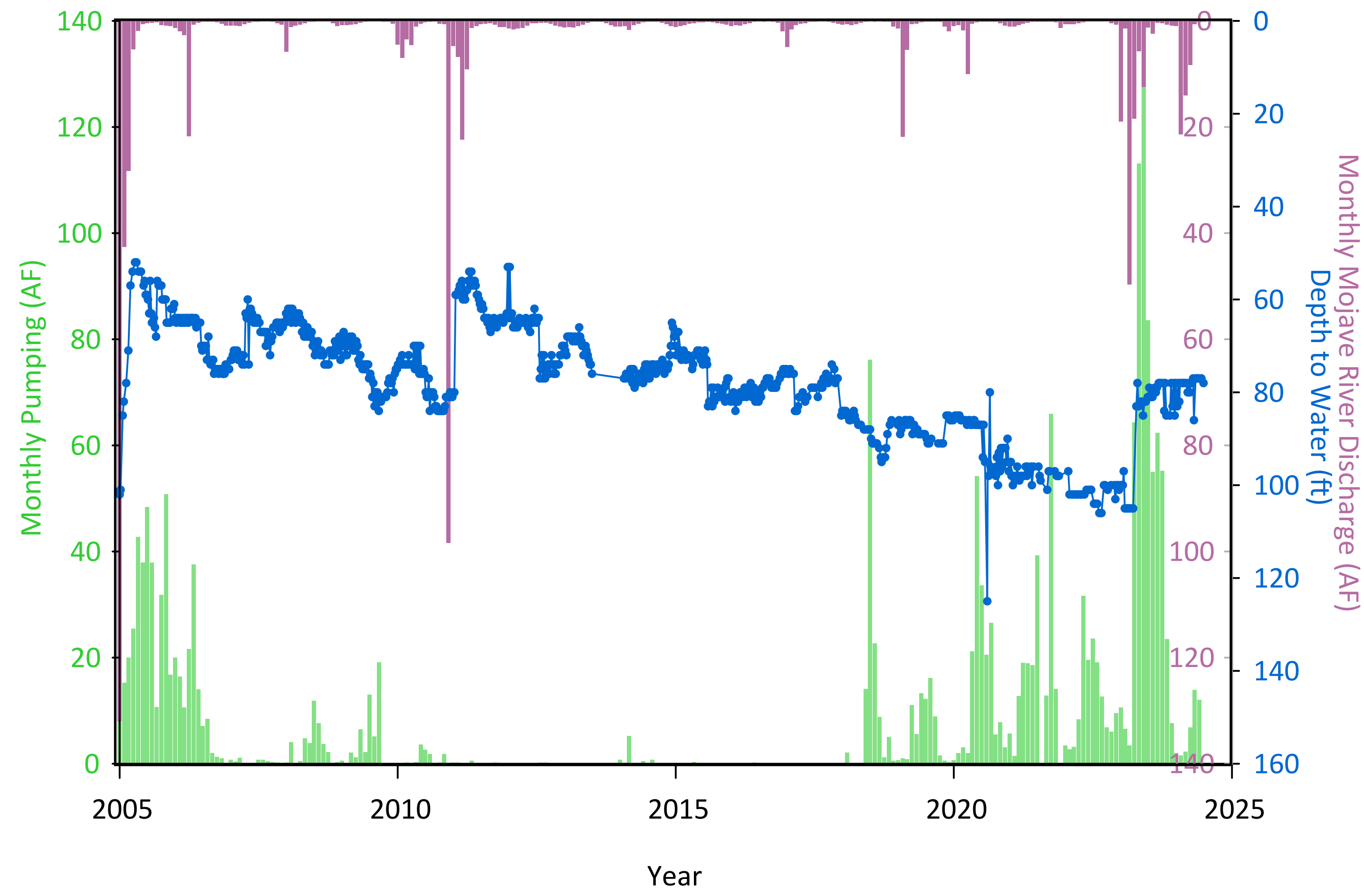
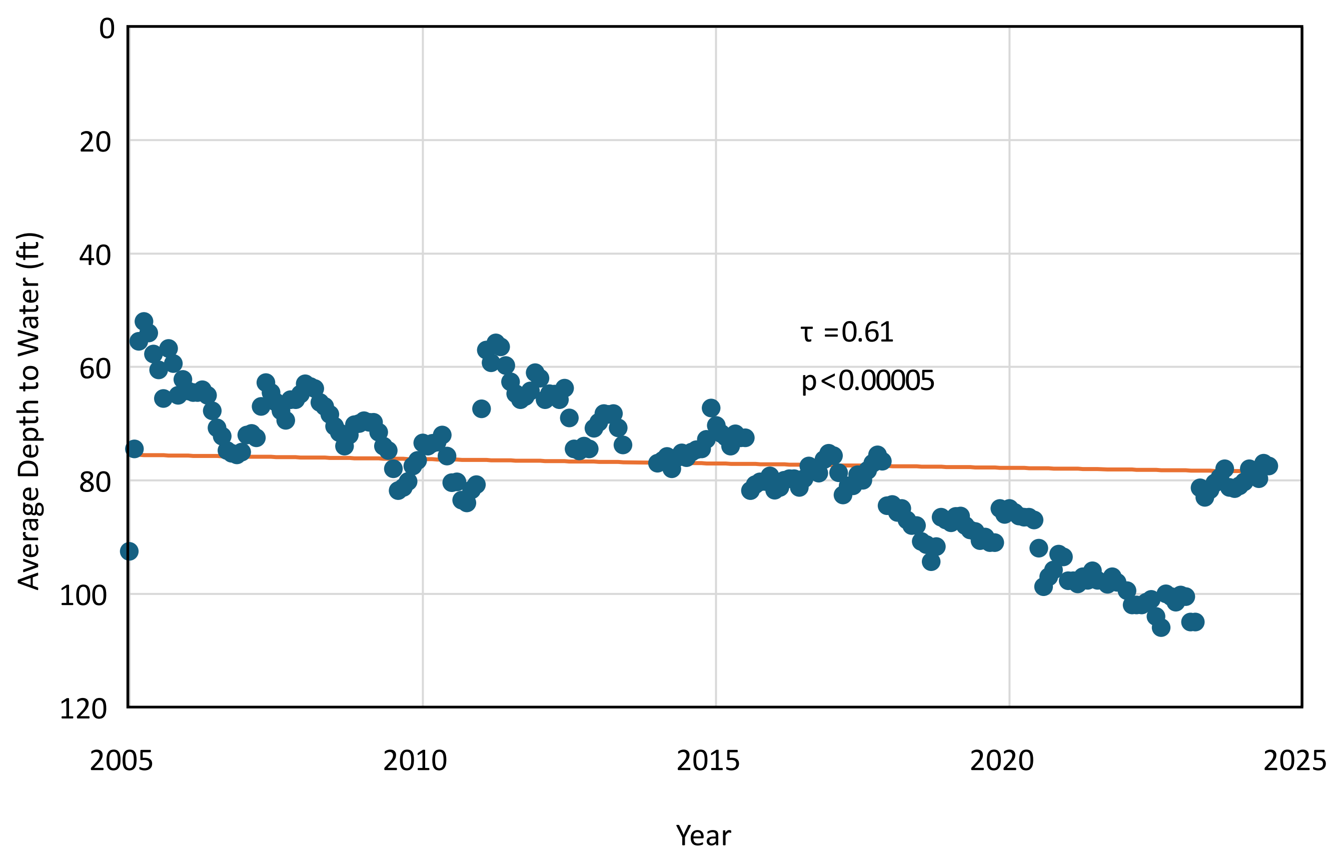
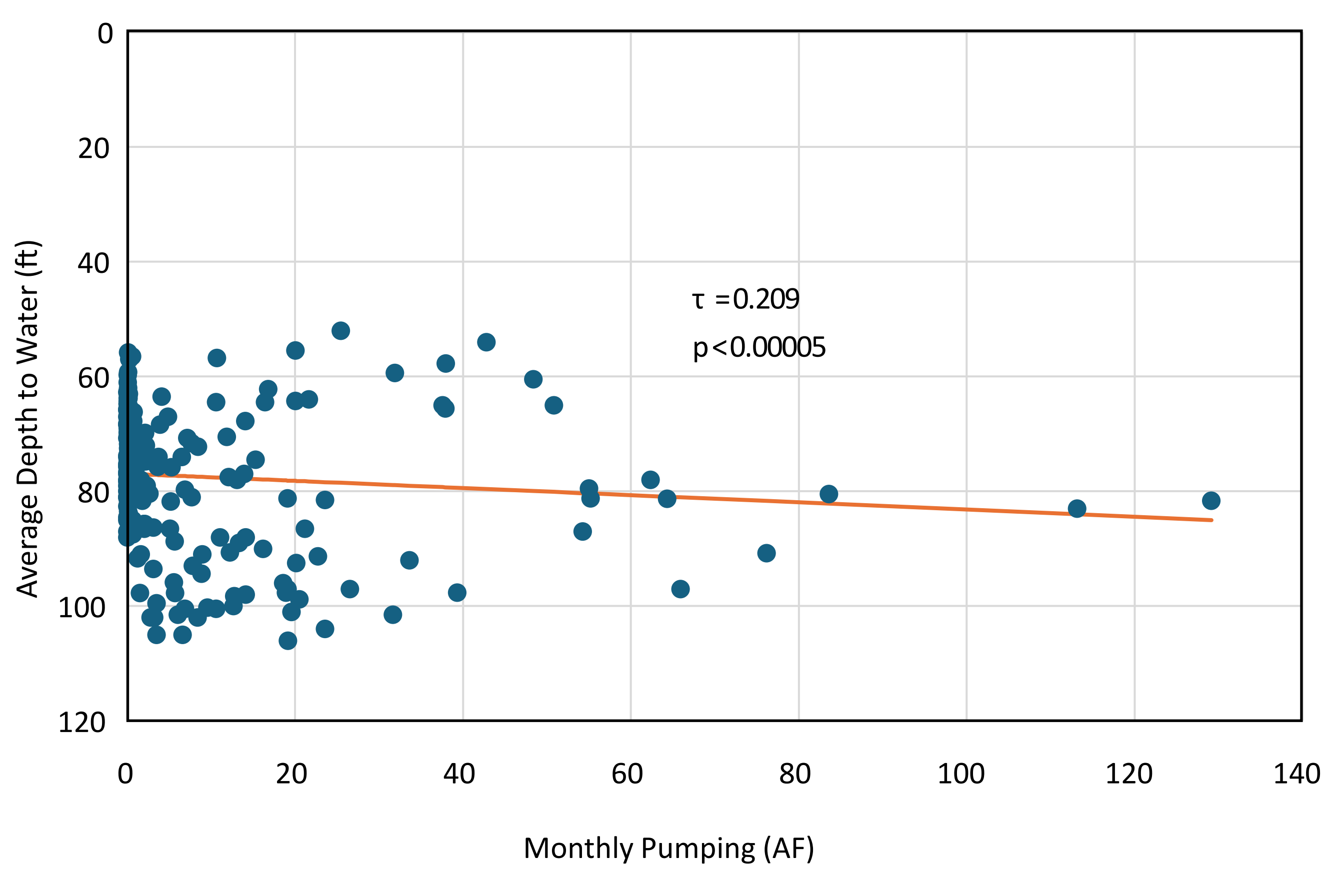
Bradshaw Well No. 5

Date: 9/3/2024 | Project #: 018-10 | **Figure 5-8**







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- Monthly Mojave River Discharge at Lower Narrows Gage (AF)

Middle Graph Legend

- Depth to Water (ft)
- Sen's Slope

Bottom Graph Legend

- Depth to Water (ft)
- Sen's Slope

Generated using Golden State Water Company Data, available at https://bhfs.sharefile.com/share/view/sc4bbae97dcb44d288d59e7da82922368.

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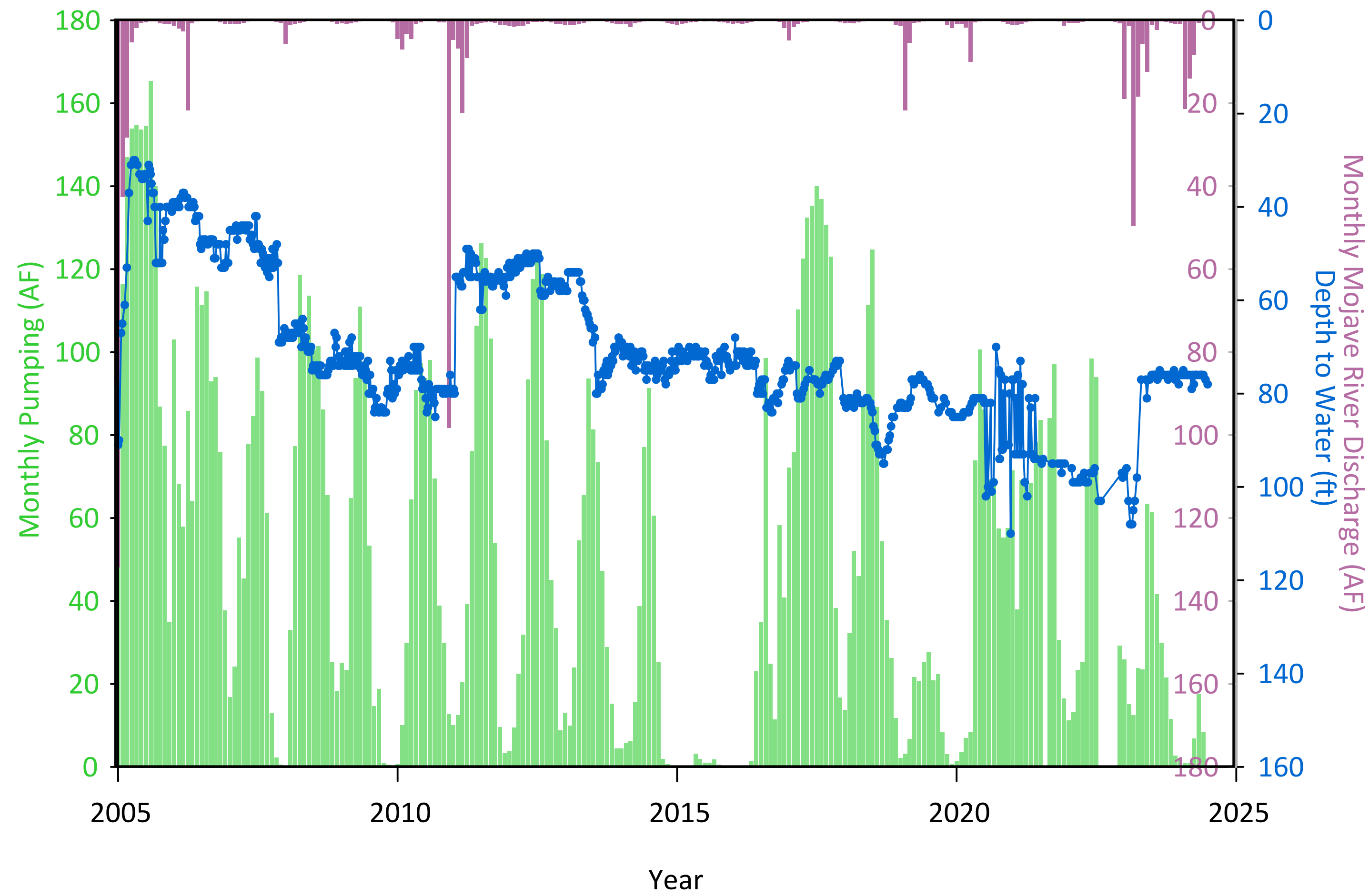
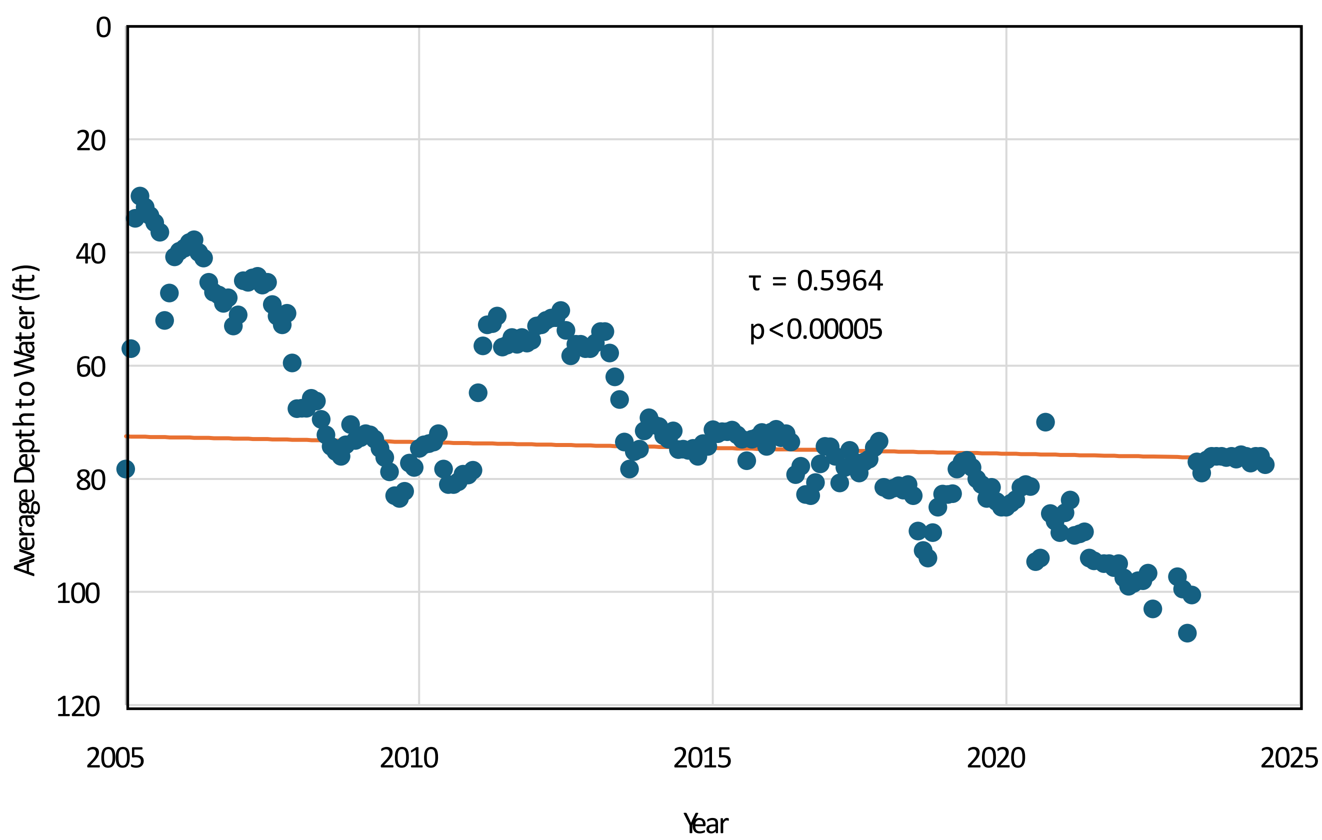
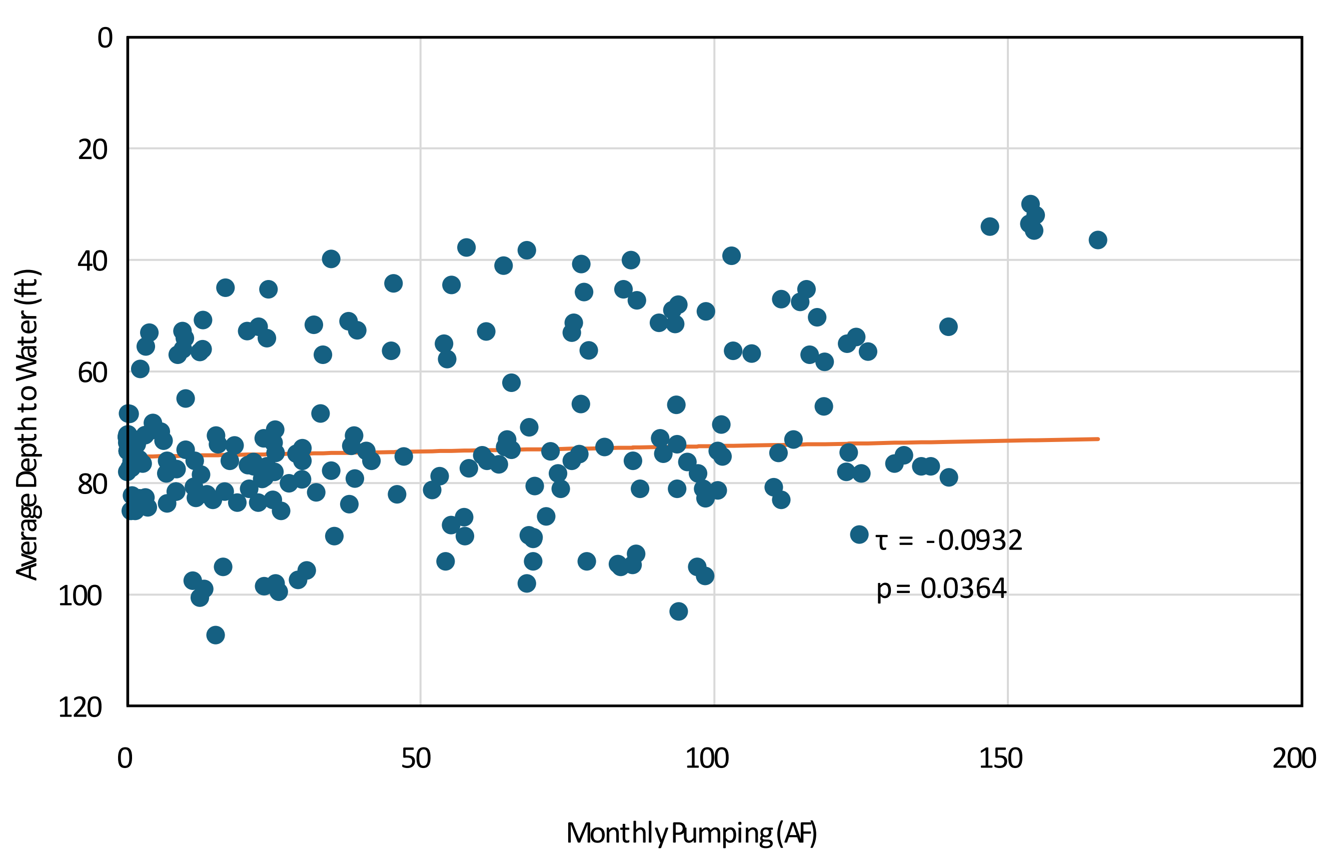
Bradshaw Well No. 6

Date: 9/3/2024	Project #: 018-10	**Figure 5-9**

GSWC 0067







Notes: Tau (τ) is the Kendall correlation coefficient. The p-value is the attained significance. The null hypothesis is that there is no trend or correlation in the data. The smaller the p-value, the stronger the evidence for rejection of the null hypothesis and the more likely a trend and correlation exists in the data. In general, p-values less than 0.05 are considered to strongly support the calculated trend and correlation coefficient (95% confidence level). Higher p-values indicate that the null hypothesis is more likely to be correct (i.e., no trend or correlation).

Top Graph Legend

- Depth to Water (ft) (top graph)
- Monthly Pumping (AF)
- Monthly Mojave River Discharge at Lower Narrows Gage (AF)

Middle Graph Legend

- Depth to Water (ft)
- Sen's Slope

Bottom Graph Legend

- Depth to Water (ft)
- Sen's Slope

Generated using Golden State Water Company Data, available at https://bhfs.sharefile.com/share/view/sc4bbae97dcb44d288d59e7da82922368.

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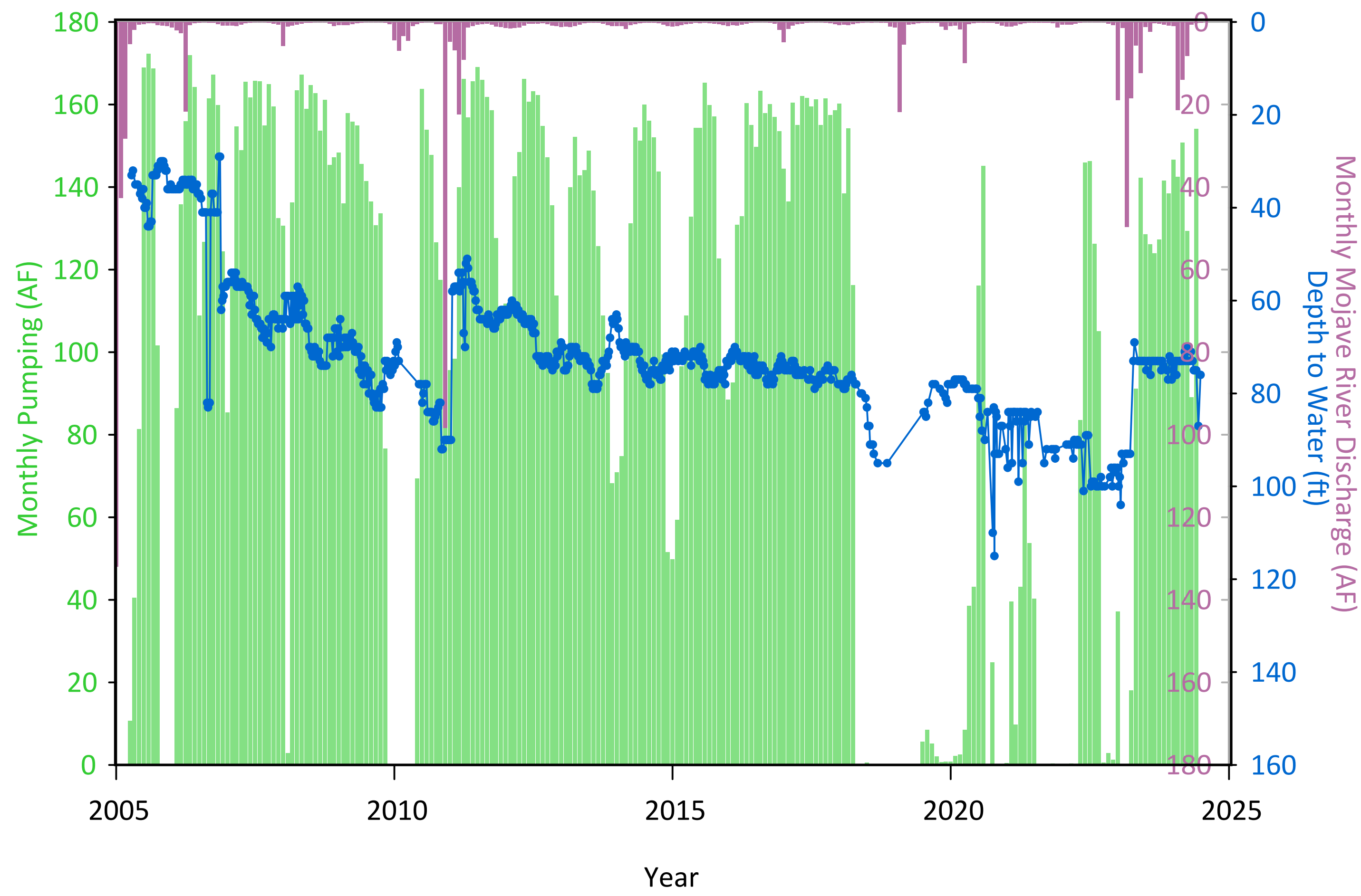
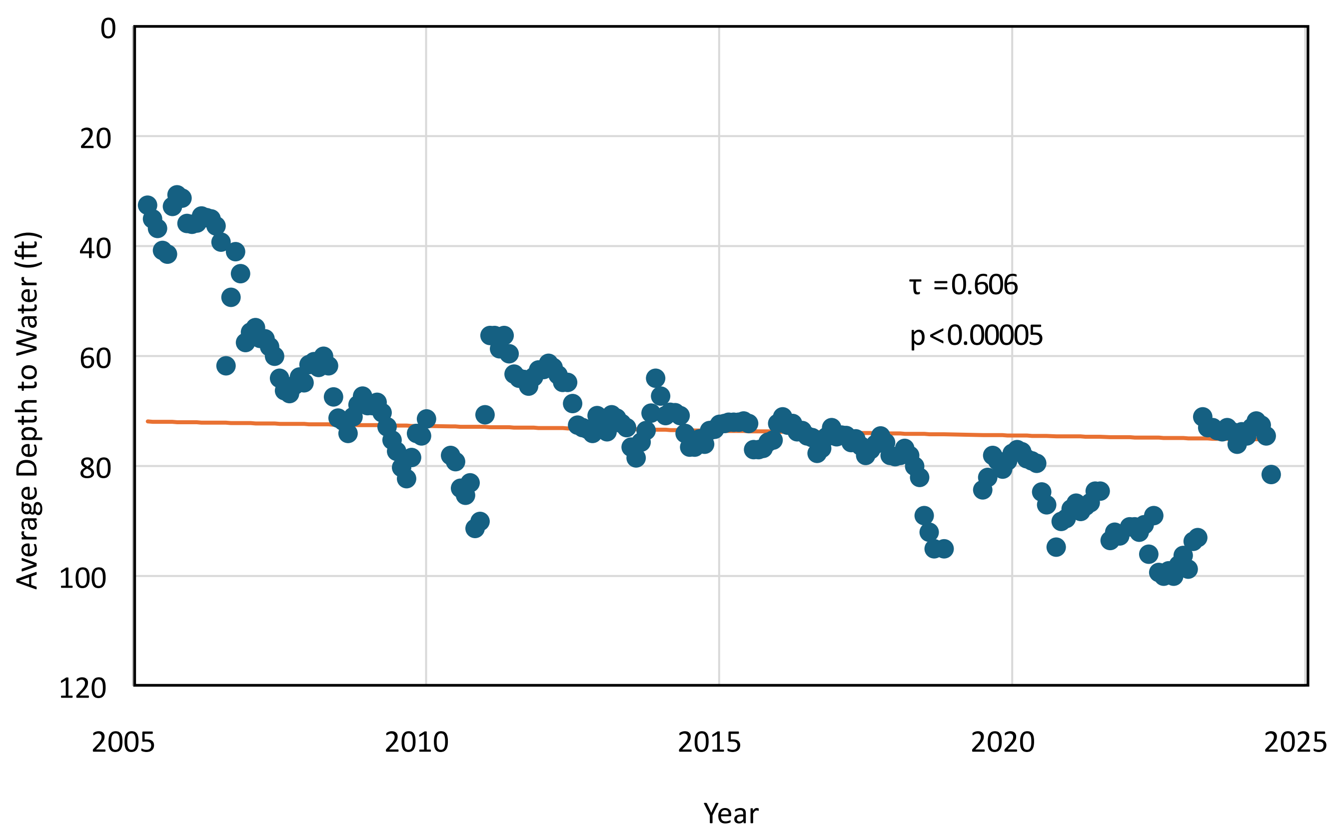
Golden State Water Company - Mojave

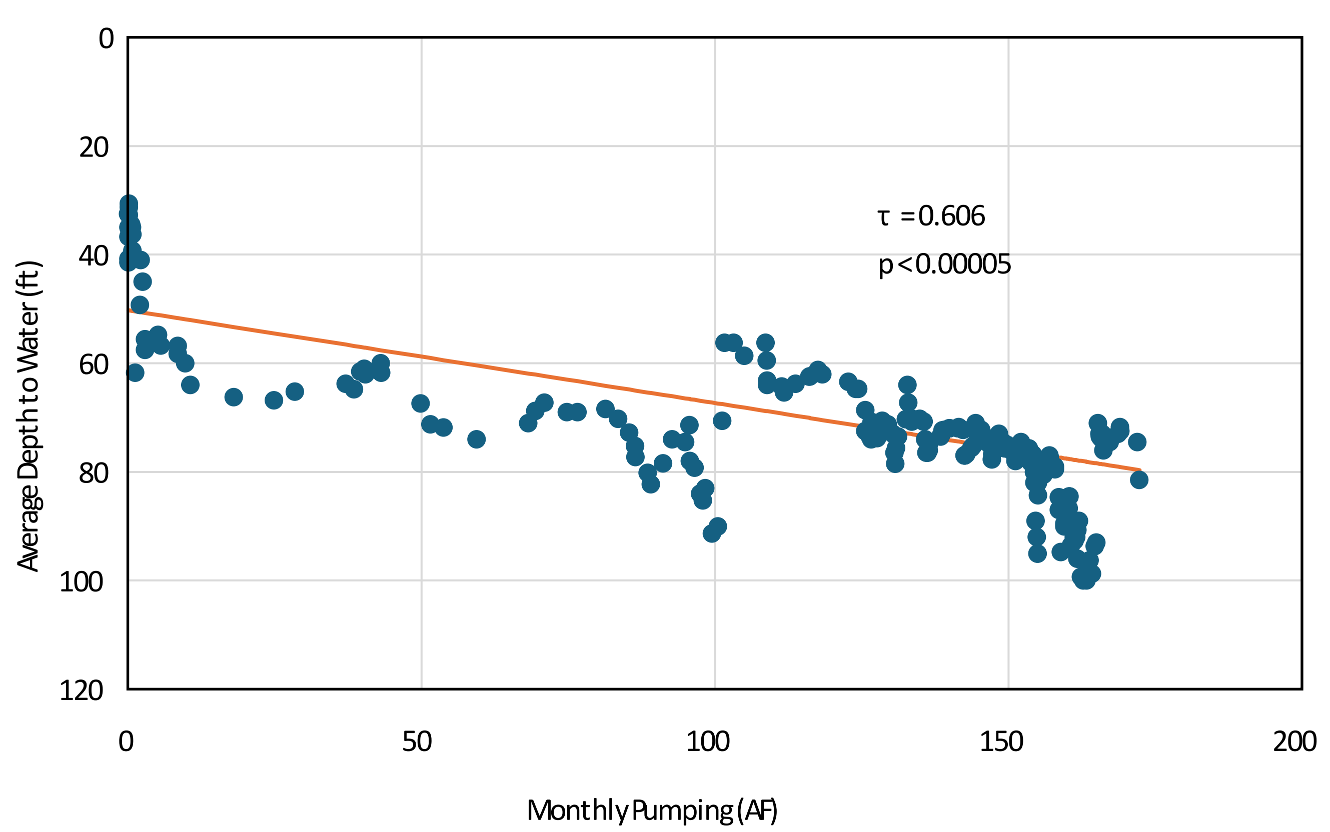
Bradshaw Well No. 7

Date: 9/4/2024	Project #: 018-10	**Figure 5-10**

GSWC 0068







Notes: Tau (τ) is the Kendall correlation coefficient. The p-value is the attained significance. The null hypothesis is that there is no trend or correlation in the data. The smaller the p-value, the stronger the evidence for rejection of the null hypothesis and the more likely a trend and correlation exists in the data. In general, p-values less than 0.05 are considered to strongly support the calculated trend and correlation coefficient (95% confidence level). Higher p-values indicate that the null hypothesis is more likely to be correct (i.e., no trend or correlation).

Top Graph Legend
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- Monthly Pumping (AF)
- Monthly Mojave River Discharge at Lower Narrows Gage (AF)

Middle Graph Legend
- Depth to Water (ft)
- Sen's Slope

Bottom Graph Legend
- Depth to Water (ft)
- Sen's Slope

Generated using Golden State Water Company Data, available at https://bhfs.sharefile.com/share/view/sc4bbae97dcb44d288d59e7da82922368.

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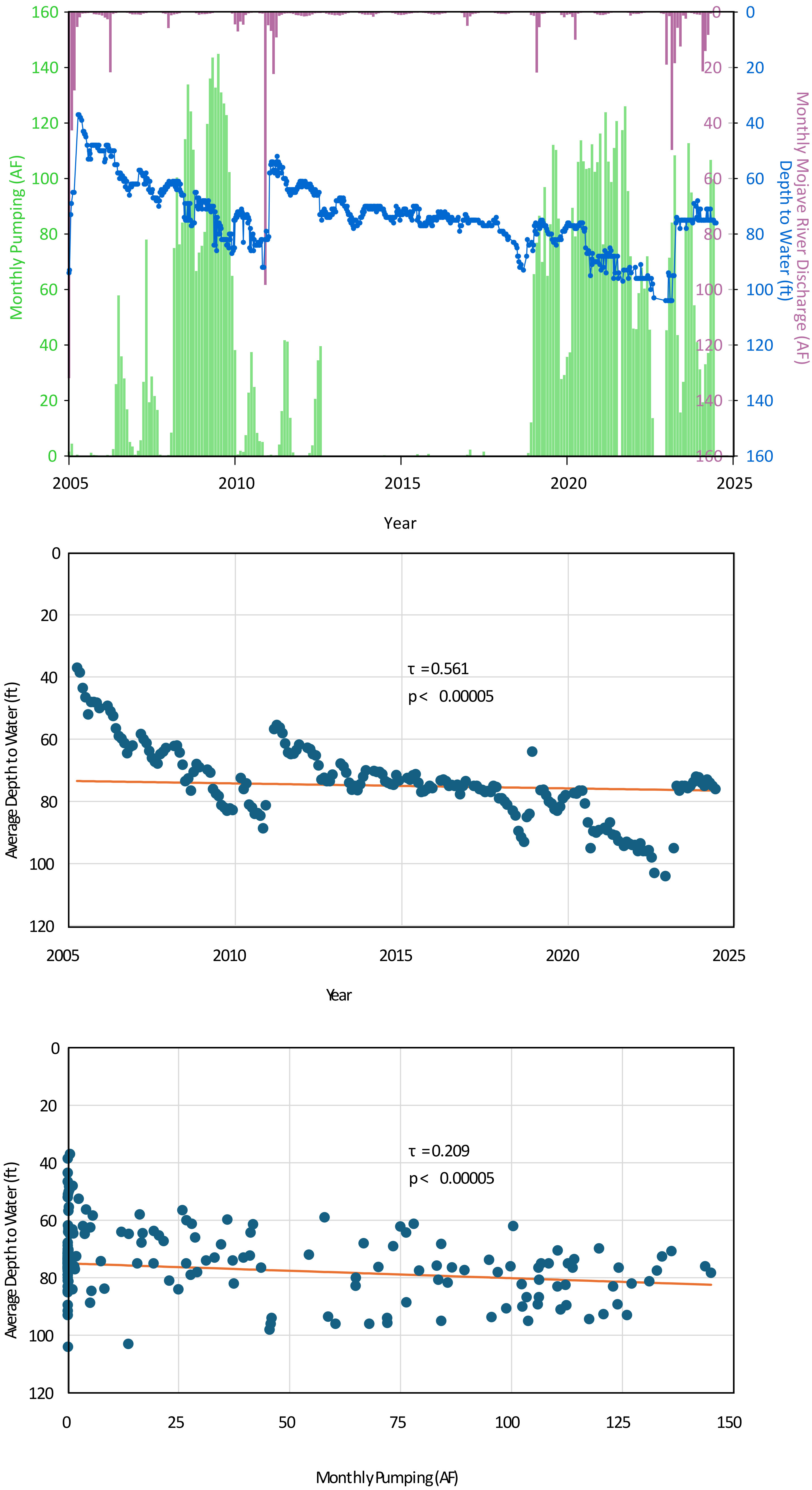
Bradshaw Well No. 10

Date: 9/3/2024 | Project #: 018-10 | **Figure 5-11**



Notes: Tau (τ) is the Kendall correlation coefficient. The p-value is the attained significance. The null hypothesis is that there is no trend or correlation in the data. The smaller the p-value, the stronger the evidence for rejection of the null hypothesis and the more likely a trend and correlation exists in the data. In general, p-values less than 0.05 are considered to strongly support the calculated trend and correlation coefficient (95% confidence level). Higher p-values indicate that the null hypothesis is more likely to be correct (i.e., no trend or correlation).

Top Graph Legend

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- Monthly Pumping (AF)
- Monthly Mojave River Discharge at Lower Narrows Gage (AF)

Middle Graph Legend

- Depth to Water (ft)
- Sen's Slope

Bottom Graph Legend

- Depth to Water (ft)
- Sen's Slope

Generated using Golden State Water Company Data, available at https://bhfs.sharefile.com/share/view/sc4bbae97dcb44d288d59e7da82922368.

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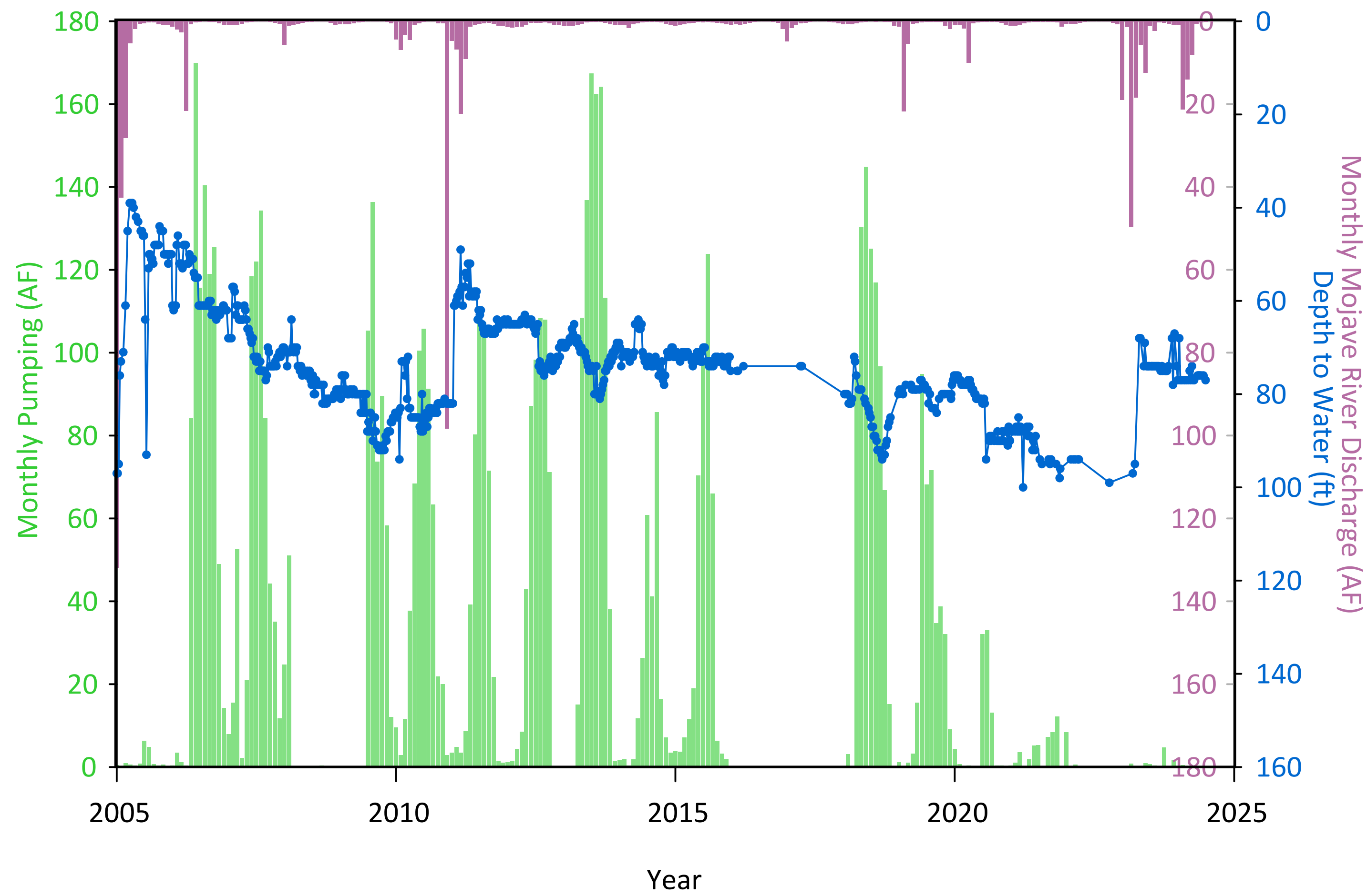
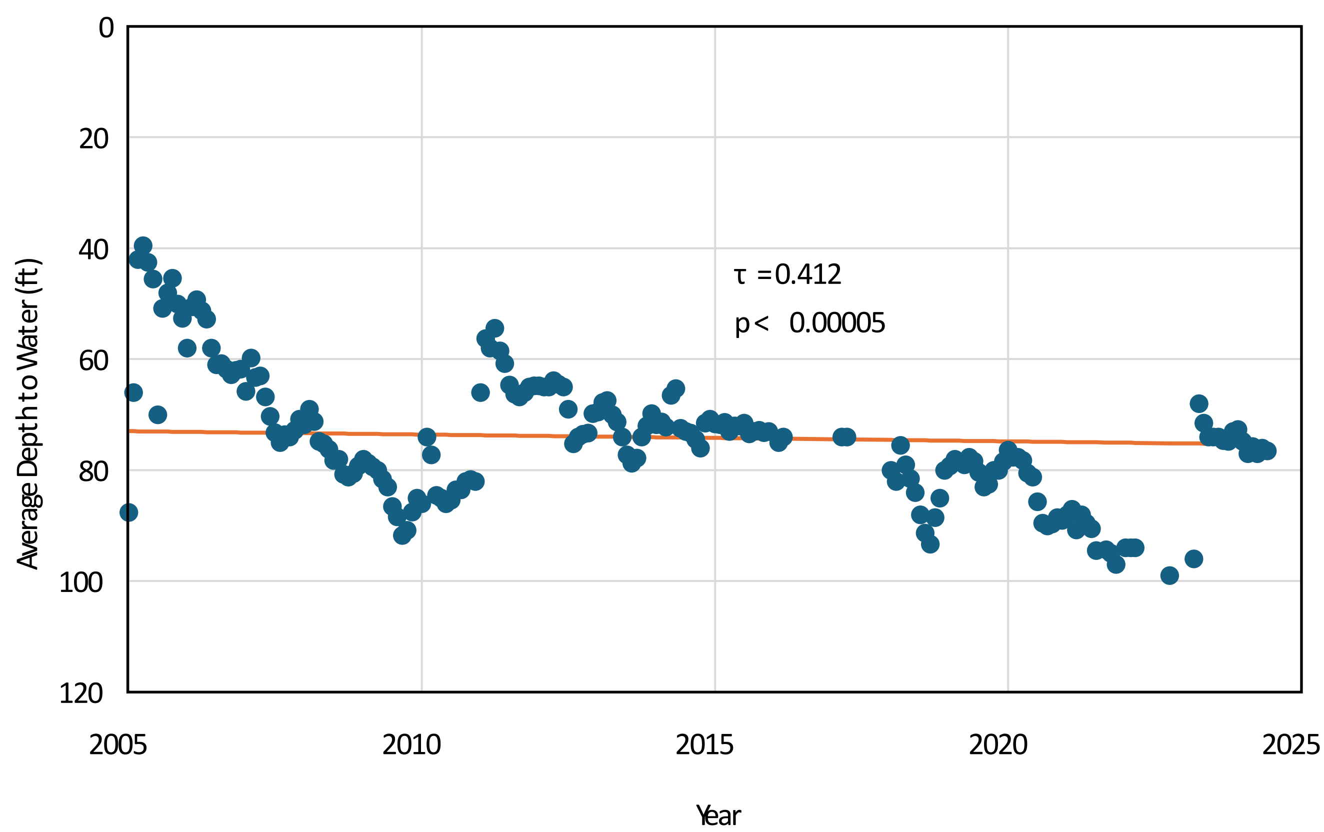
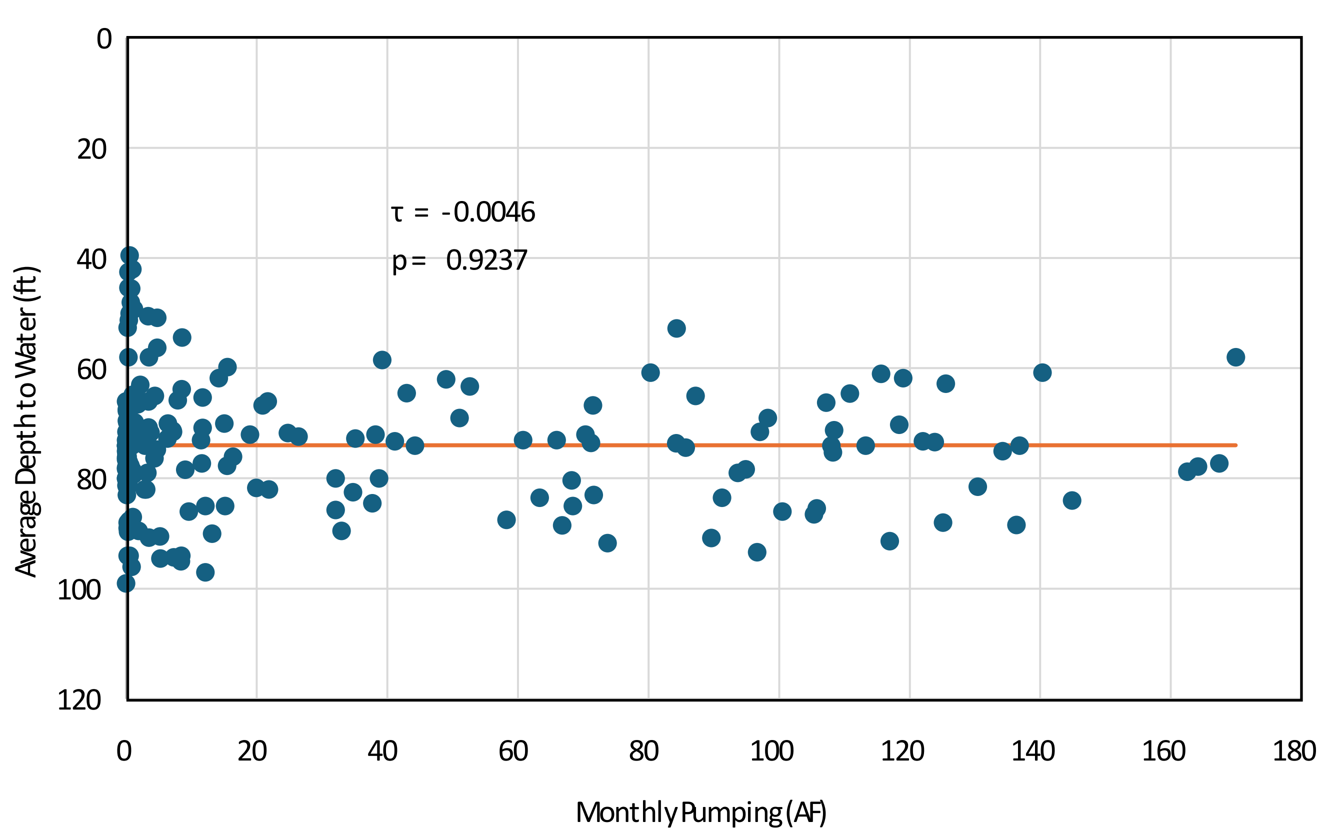
Bradshaw Well No. 11

Date: 9/3/2024 | Project #: 018-10 | **Figure 5-12**

GSWC 0070







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Top Graph Legend
- Depth to Water (ft) (top graph)
- Monthly Pumping (AF)
- Monthly Mojave River Discharge at Lower Narrows Gage (AF)

Middle Graph Legend
- Depth to Water (ft)
- Sen's Slope

Bottom Graph Legend
- Depth to Water (ft)
- Sen's Slope

Generated using Golden State Water Company Data, available at https://bhfs.sharefile.com/share/view/sc4bbae97dcb44d288d59e7da82922368.

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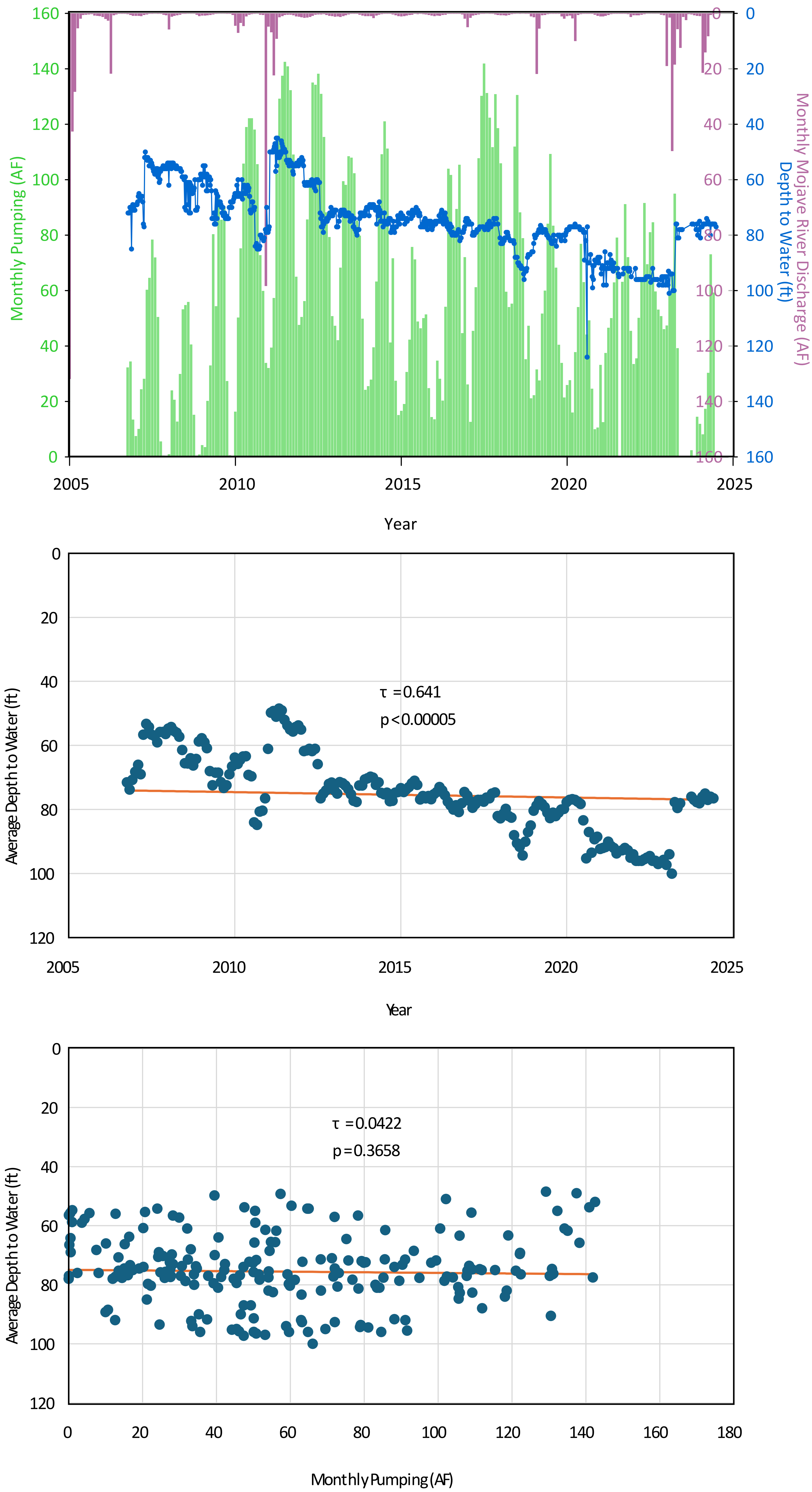
Golden State Water Company - Mojave

Bradshaw Well No. 12

Date: 9/3/2024 | Project #: 018-10 | **Figure 5-13**

GSWC 0071



Notes: Tau (τ) is the Kendall correlation coefficient. The p-value is the attained significance. The null hypothesis is that there is no trend or correlation in the data. The smaller the p-value, the stronger the evidence for rejection of the null hypothesis and the more likely a trend and correlation exists in the data. In general, p-values less than 0.05 are considered to strongly support the calculated trend and correlation coefficient (95% confidence level). Higher p-values indicate that the null hypothesis is more likely to be correct (i.e., no trend or correlation).

Top Graph Legend

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- Monthly Pumping (AF)
- Monthly Mojave River Discharge at Lower Narrows Gage (AF)

Middle Graph Legend

- Depth to Water (ft)
- Sen's Slope

Bottom Graph Legend

- Depth to Water (ft)
- Sen's Slope

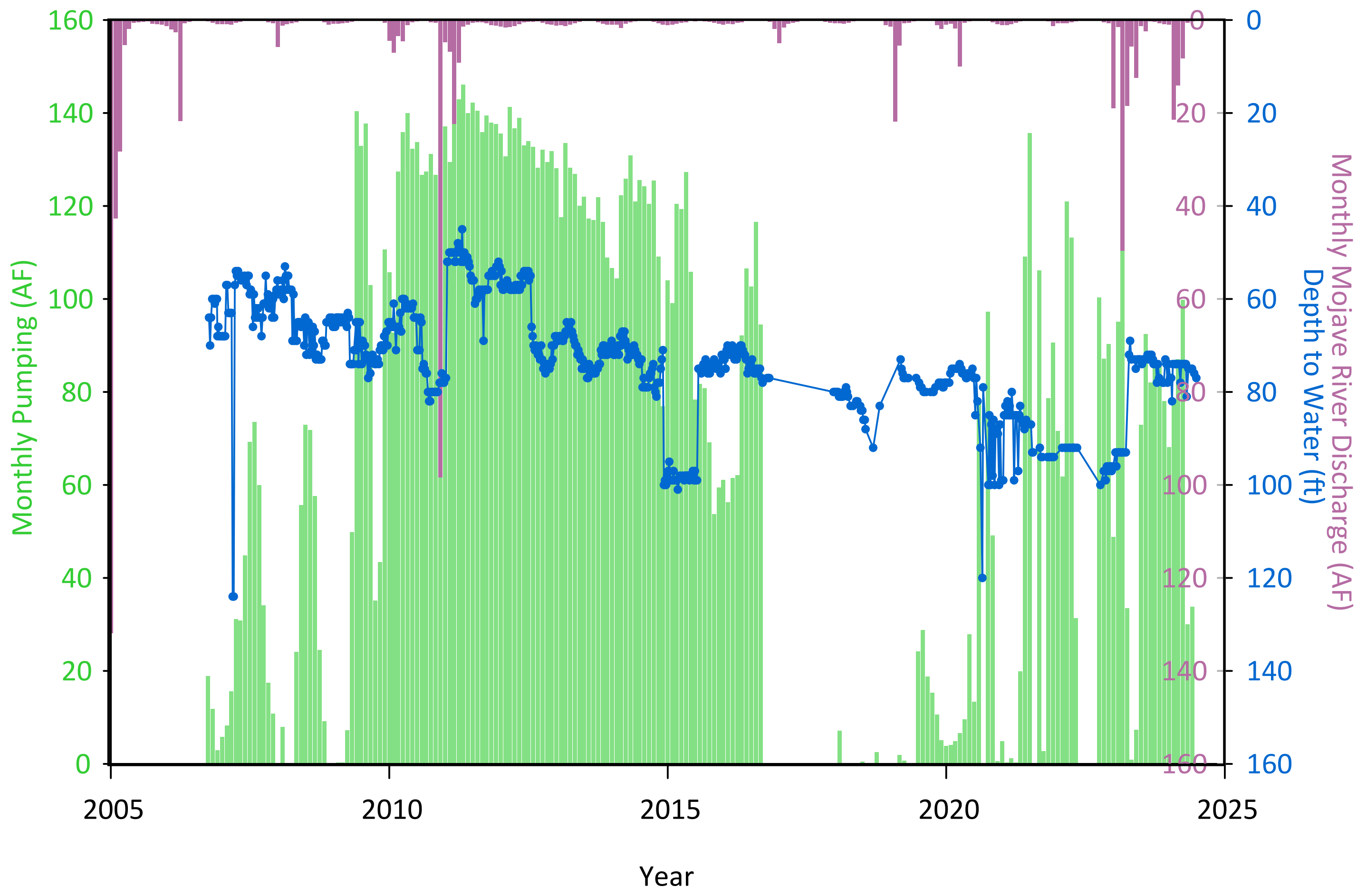
Generated using Golden State Water Company Data, available at https://bhfs.sharefile.com/share/view/sc4bbae97dcb44d288d59e7da82922368.

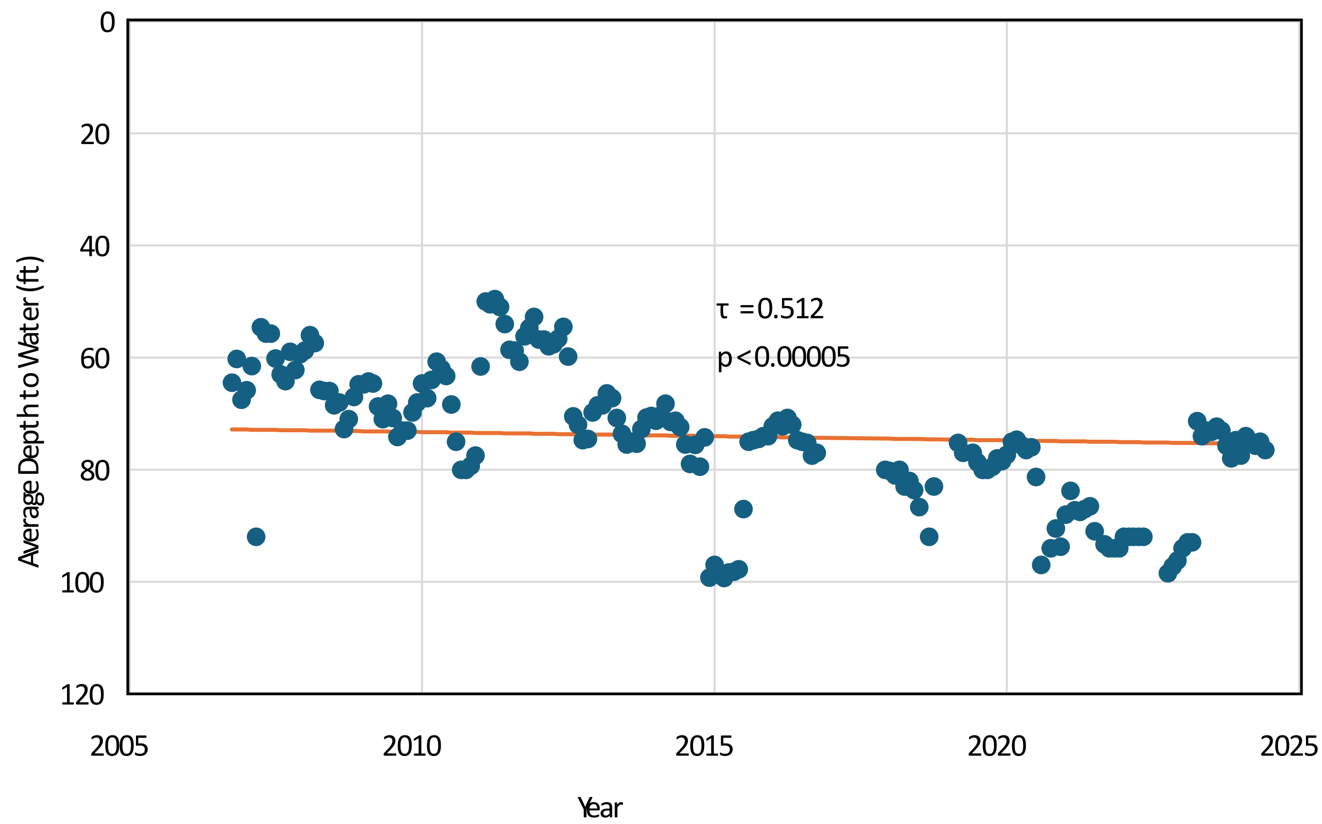
aquilogic, Inc. Golden State Water Company - Mojave

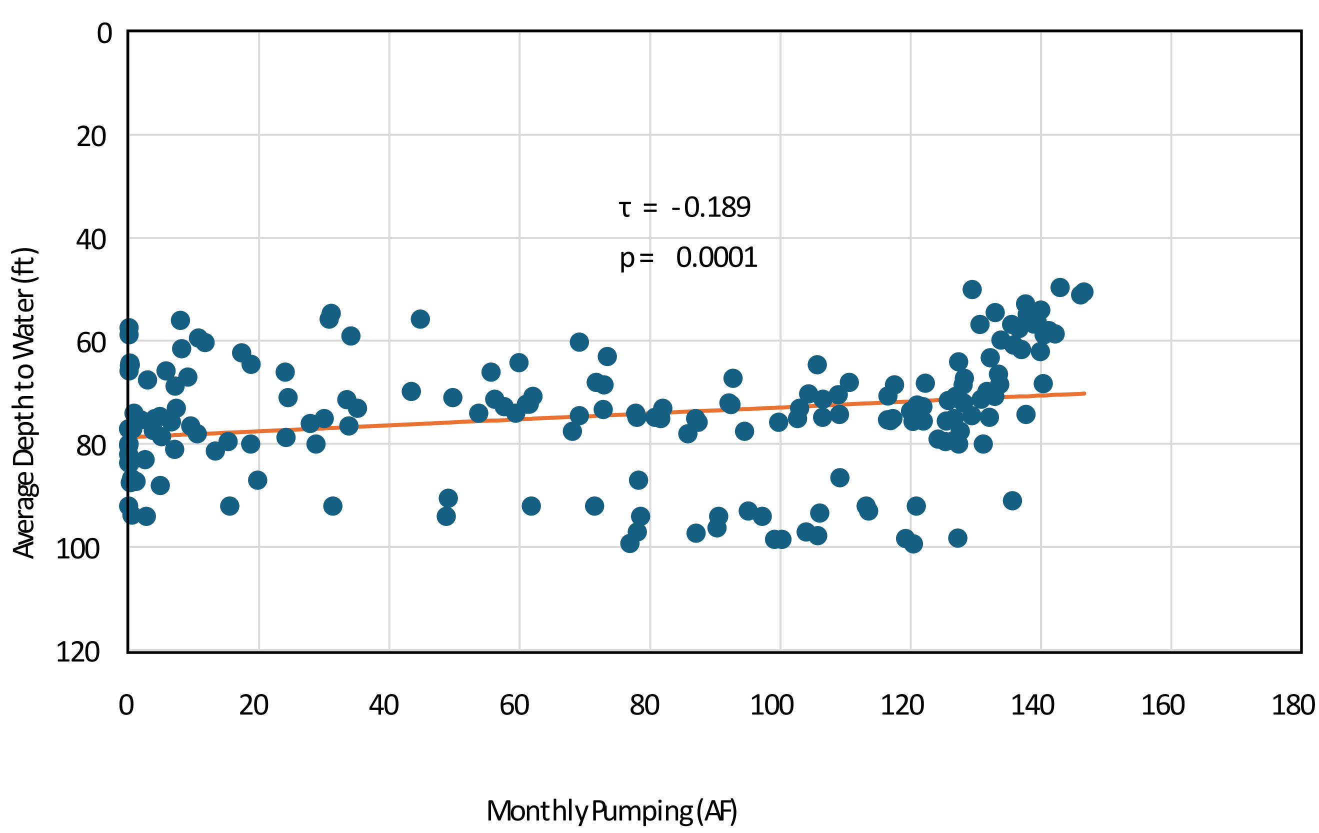
Bradshaw Well No. 13

Date: 9/3/2024 | Project #: 018-10 | **Figure 6-14**

GSWC 0072







Notes: Tau (τ) is the Kendall correlation coefficient. The p-value is the attained significance. The null hypothesis is that there is no trend or correlation in the data. The smaller the p-value, the stronger the evidence for rejection of the null hypothesis and the more likely a trend and correlation exists in the data. In general, p-values less than 0.05 are considered to strongly support the calculated trend and correlation coefficient (95% confidence level). Higher p-values indicate that the null hypothesis is more likely to be correct (i.e., no trend or correlation).

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- Monthly Pumping (AF)
- Monthly Mojave River Discharge at Lower Narrows Gage (AF)

Middle Graph Legend

- Depth to Water (ft)
- Sen's Slope

Bottom Graph Legend

- Depth to Water (ft)
- Sen's Slope

Generated using Golden State Water Company Data, available at https://bhfs.sharefile.com/share/view/sc4bbae97dcb44d288d59e7da82922368.

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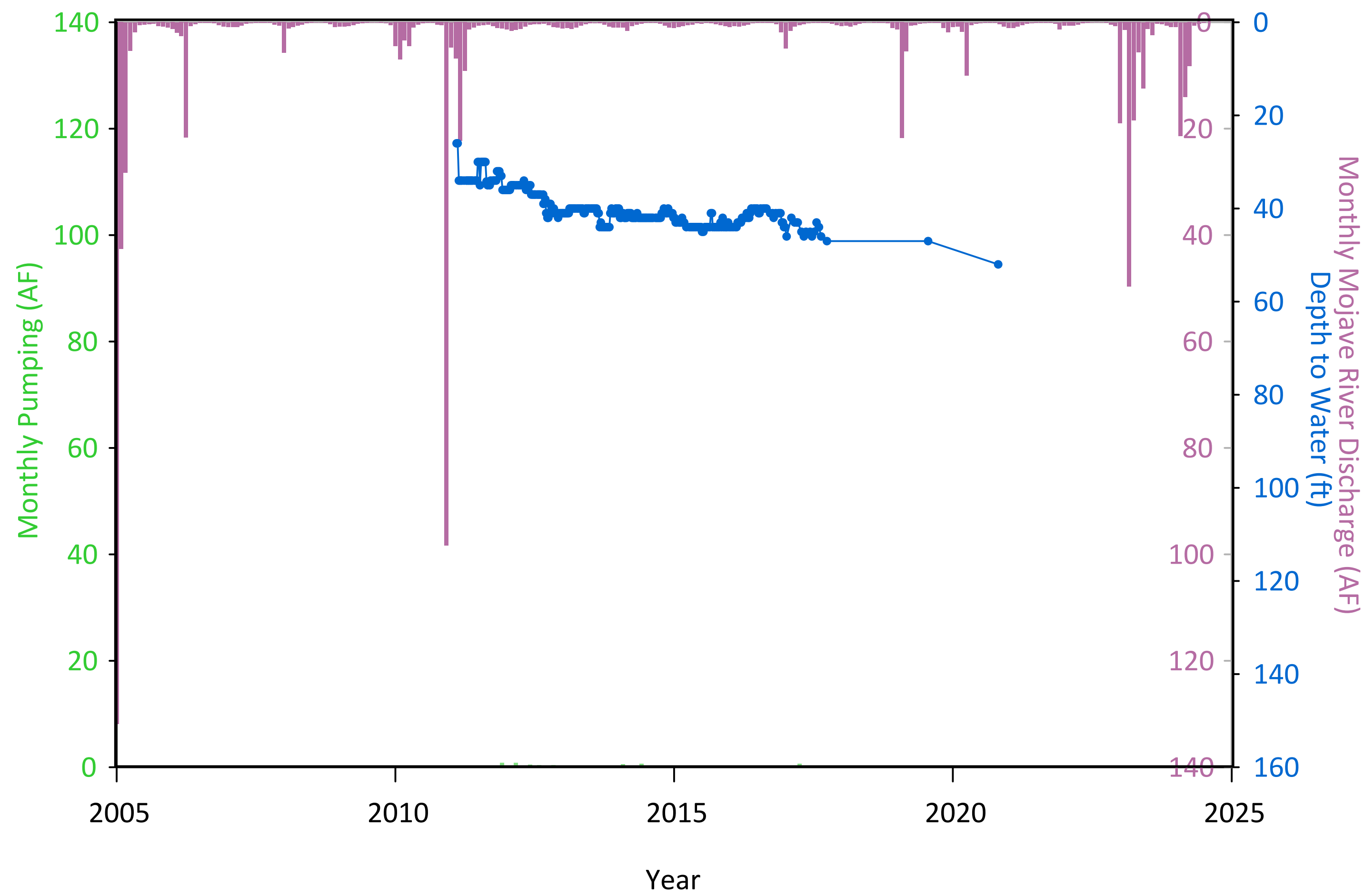
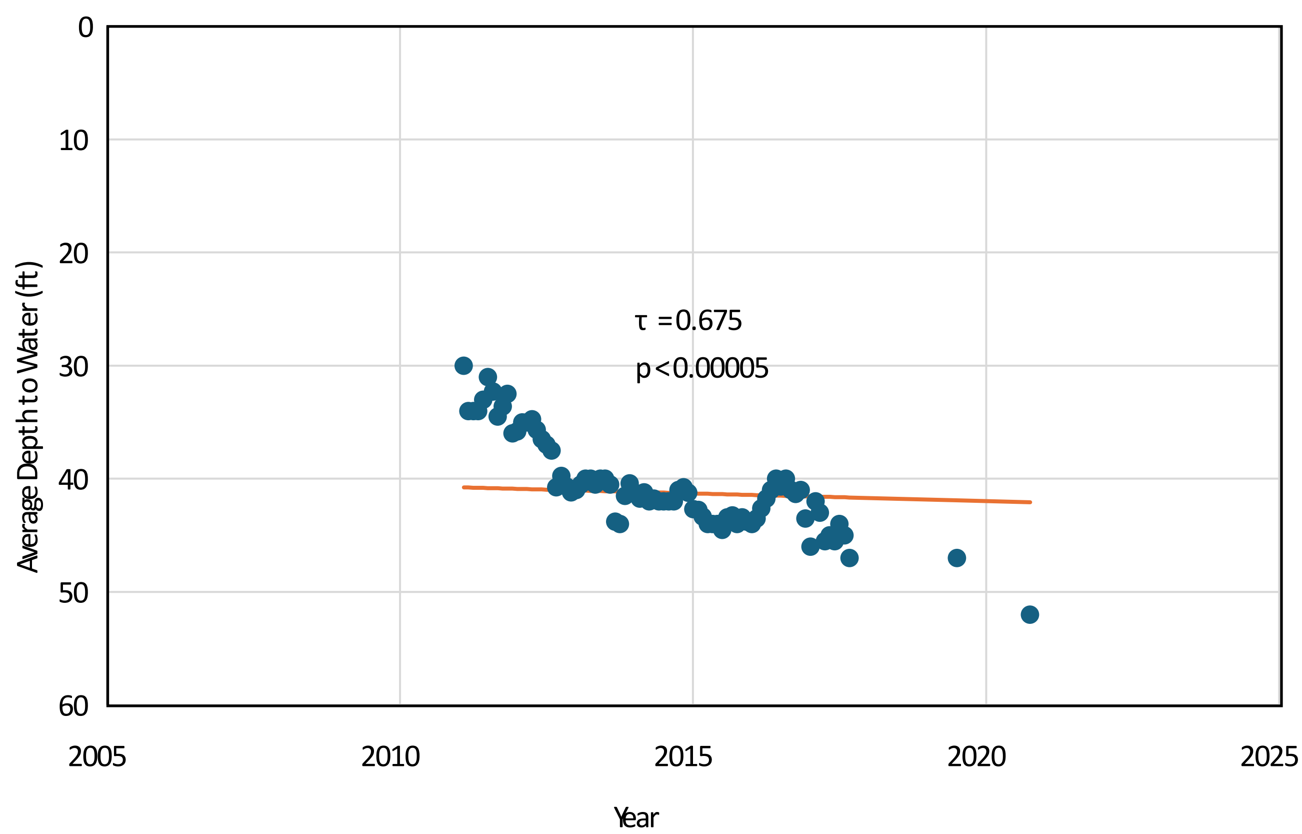
Golden State Water Company - Mojave

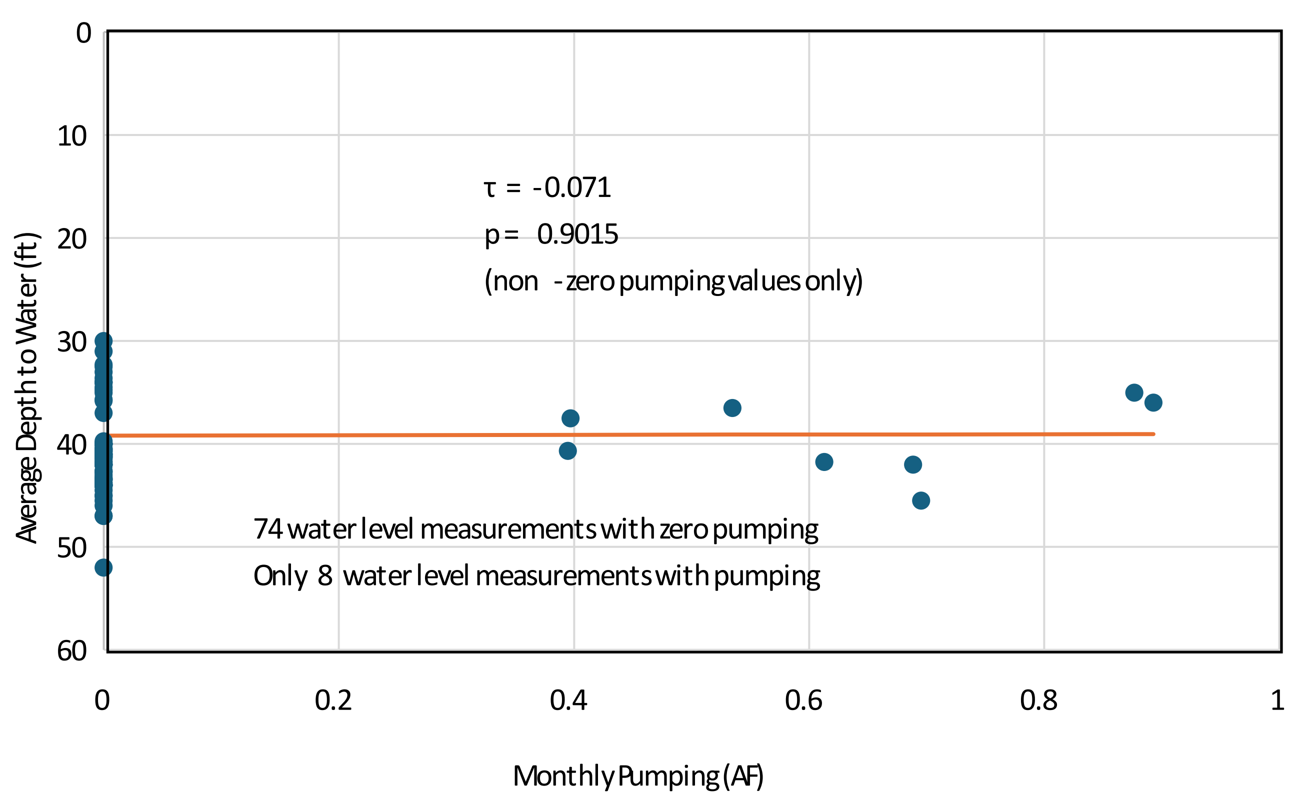
Bradshaw Well No. 14

Date: 9/3/2024	Project #: 018-10	**Figure 5-15**

GSWC 0073







Notes: Tau (τ) is the Kendall correlation coefficient. The p-value is the attained significance. The null hypothesis is that there is no trend or correlation in the data. The smaller the p-value, the stronger the evidence for rejection of the null hypothesis and the more likely a trend and correlation exists in the data. In general, p-values less than 0.05 are considered to strongly support the calculated trend and correlation coefficient (95% confidence level). Higher p-values indicate that the null hypothesis is more likely to be correct (i.e., no trend or correlation).

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- Monthly Mojave River Discharge at Lower Narrows Gage (AF)

Middle Graph Legend
- Depth to Water (ft)
- Sen's Slope

Bottom Graph Legend
- Depth to Water (ft)
- Sen's Slope

Generated using Golden State Water Company Data, available at https://bhfs.sharefile.com/share/view/sc4bbae97dcb44d288d59e7da82922368.

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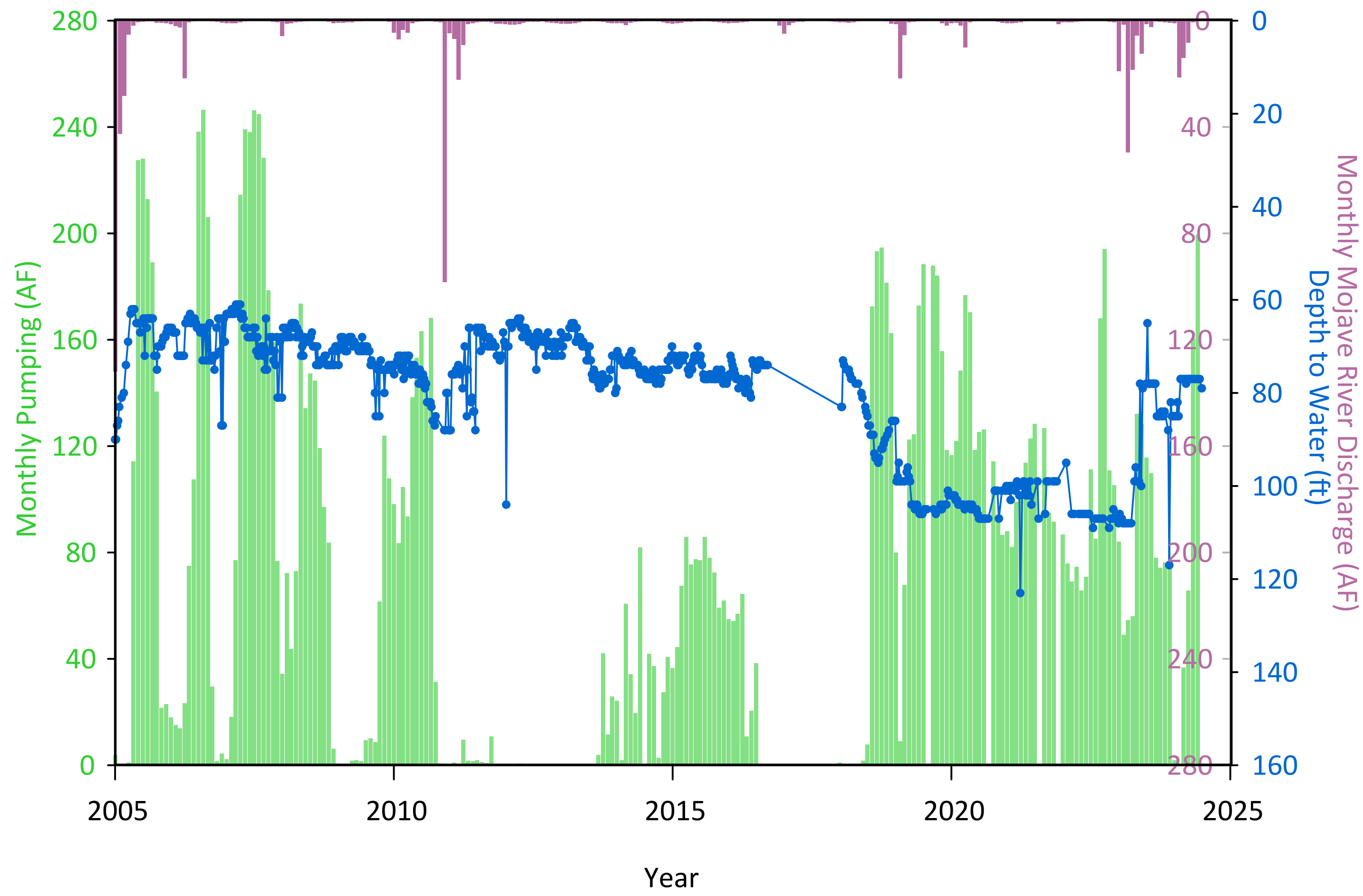
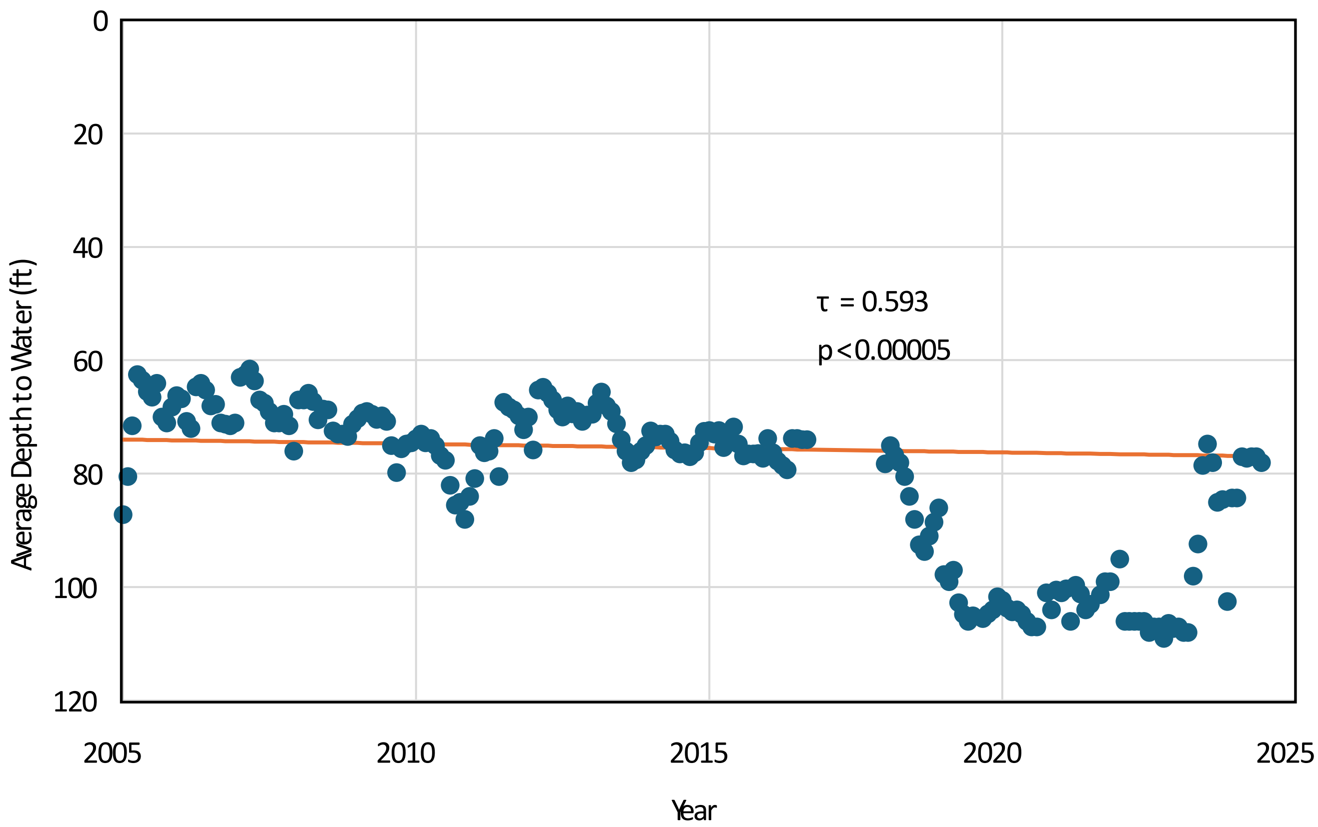
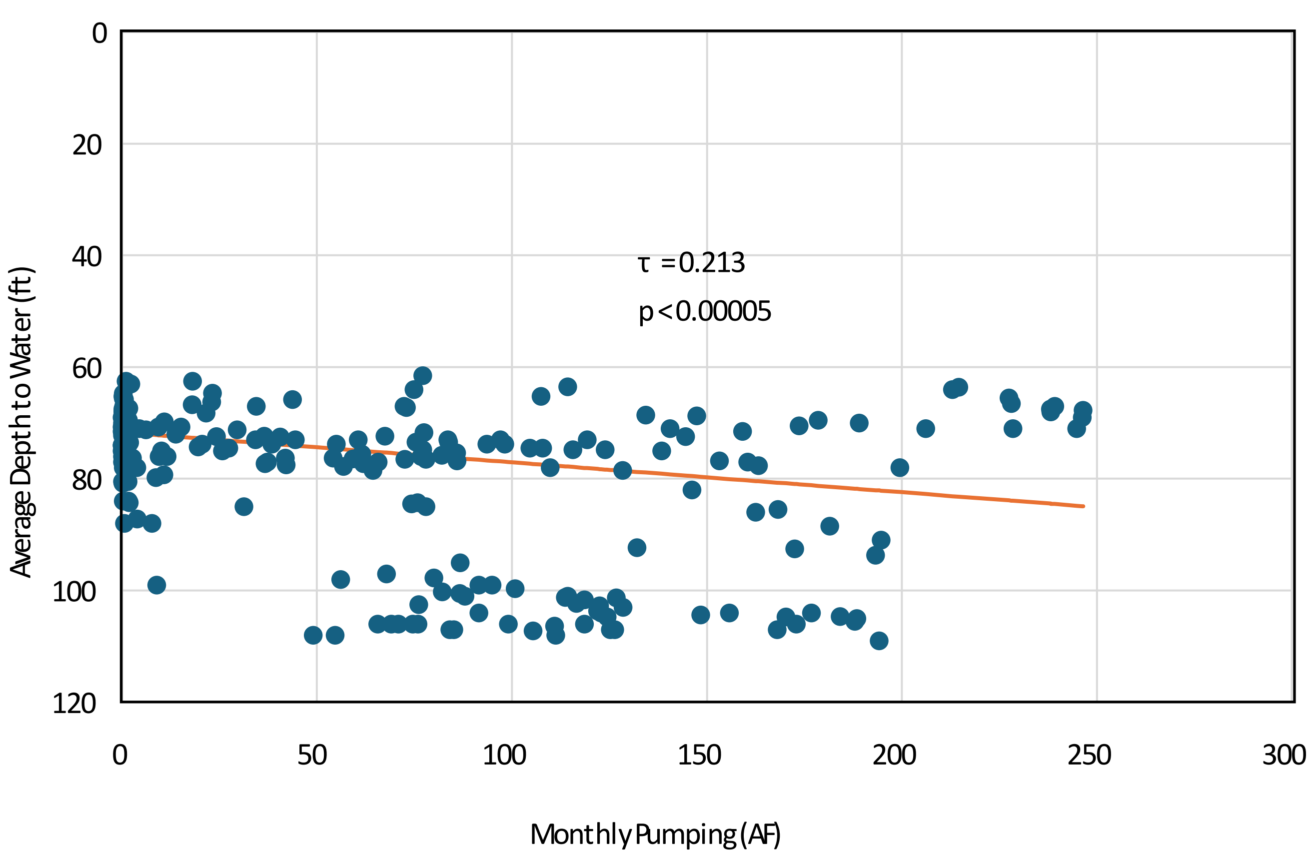
Golden State Water Company - Mojave

Crooks Well No. 1

Date: 9/3/2024	Project #: 018-10	Figure 5-16







Notes: Tau (τ) is the Kendall correlation coefficient. The p-value is the attained significance. The null hypothesis is that there is no trend or correlation in the data. The smaller the p-value, the stronger the evidence for rejection of the null hypothesis and the more likely a trend and correlation exists in the data. In general, p-values less than 0.05 are considered to strongly support the calculated trend and correlation coefficient (95% confidence level). Higher p-values indicate that the null hypothesis is more likely to be correct (i.e., no trend or correlation).

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Middle Graph Legend

- Depth to Water (ft)
- Sen's Slope

Bottom Graph Legend

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Generated using Golden State Water Company Data, available at https://bhfs.sharefile.com/share/view/sc4bbae97dcb44d288d59e7da82922368.

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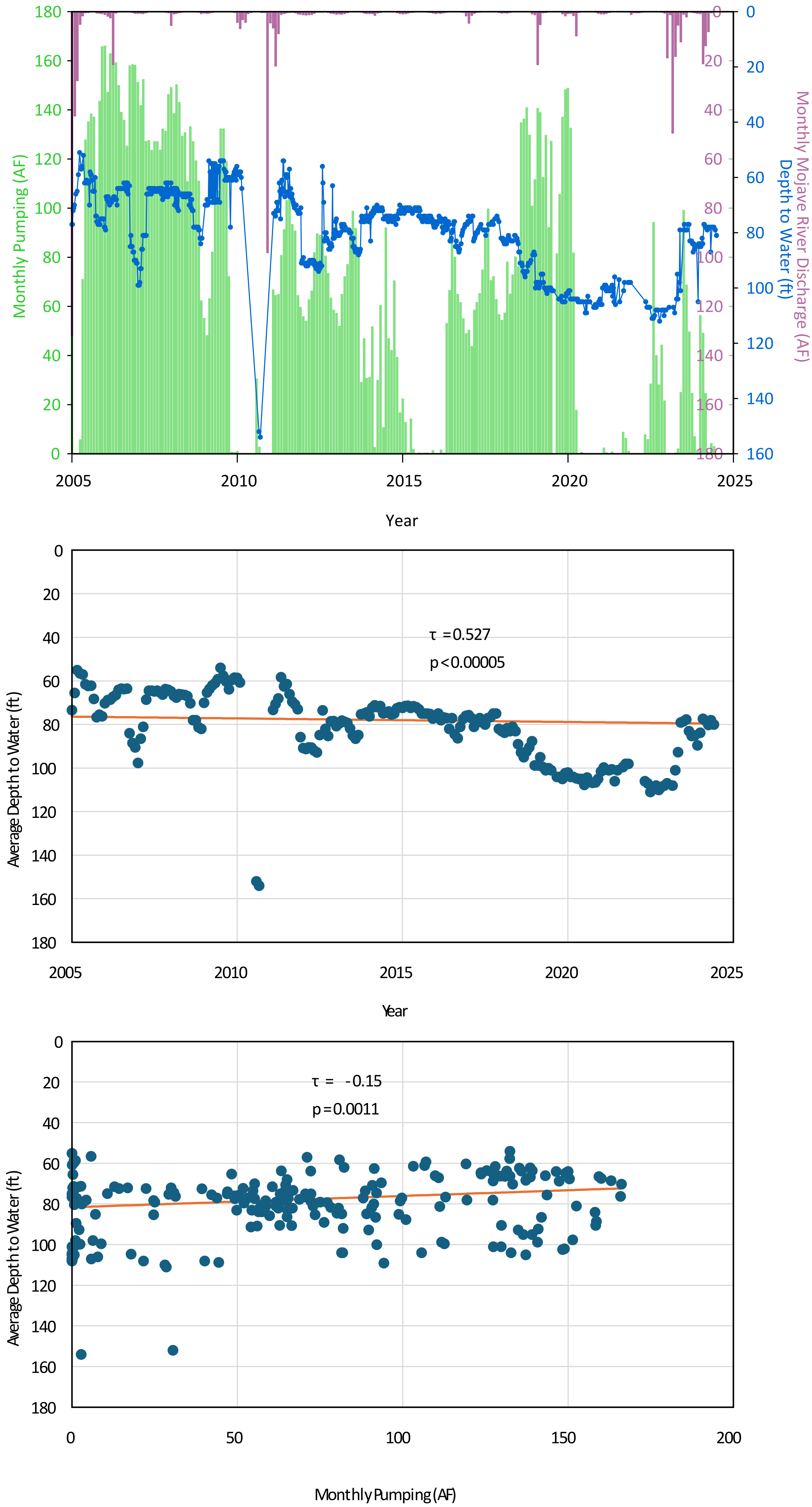
Golden State Water Company - Mojave

Glen Road Well No. 1

Date: 9/3/2024	Project #: 018-10	**Figure 5-17**

GSWC 0075



Notes: Tau (τ) is the Kendall correlation coefficient. The p-value is the attained significance. The null hypothesis is that there is no trend or correlation in the data. The smaller the p-value, the stronger the evidence for rejection of the null hypothesis and the more likely a trend and correlation exists in the data. In general, p-values less than 0.05 are considered to strongly support the calculated trend and correlation coefficient (95% confidence level). Higher p-values indicate that the null hypothesis is more likely to be correct (i.e., no trend or correlation).

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- Monthly Mojave River Discharge at Lower Narrows Gage (AF)

Middle Graph Legend
- Depth to Water (ft)
- Sen's Slope

Bottom Graph Legend
- Depth to Water (ft)
- Sen's Slope

Generated using Golden State Water Company Data, available at https://bhfs.sharefile.com/share/view/sc4bbae97dcb44d288d59e7da82922368.

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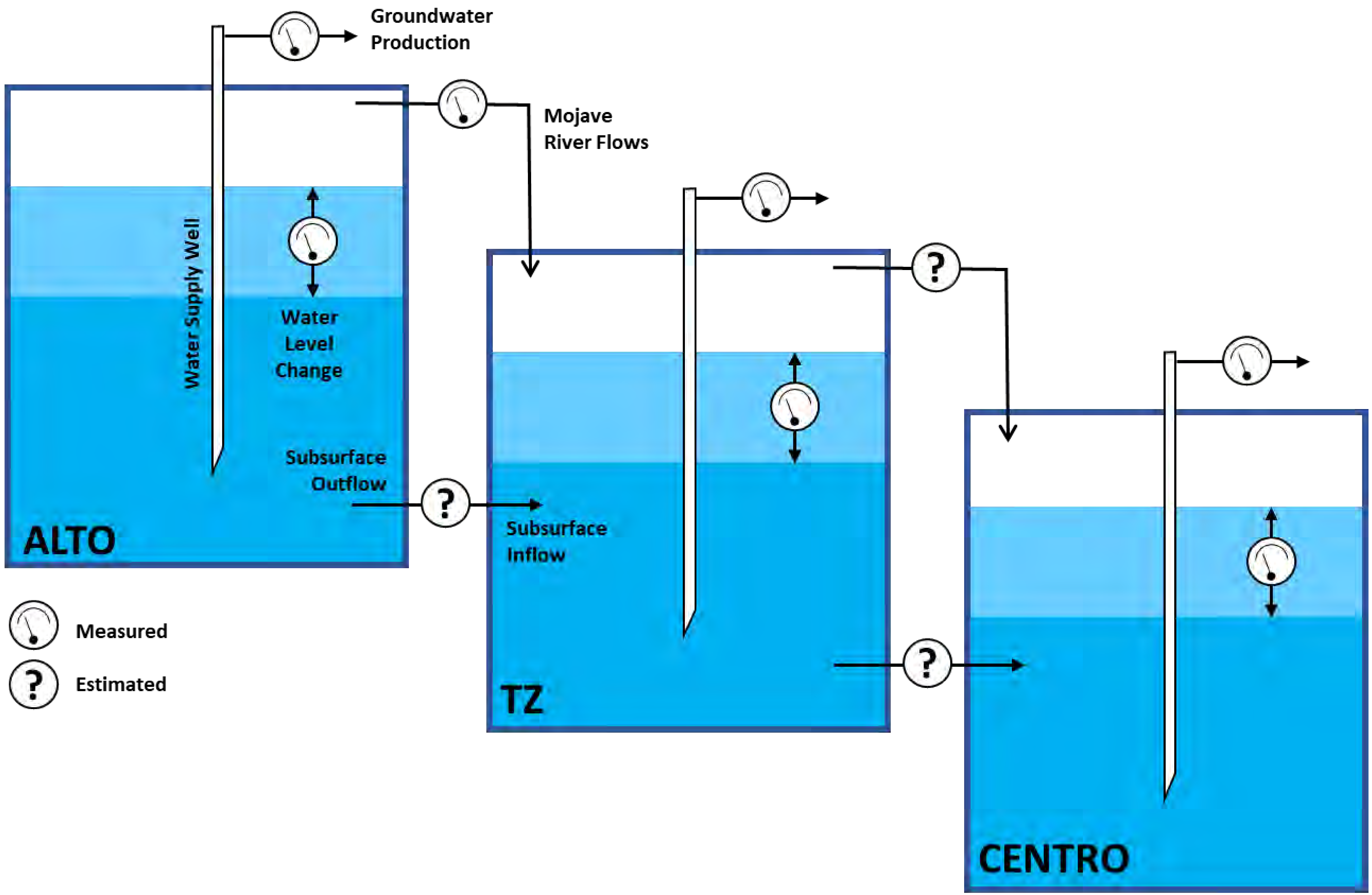
Golden State Water Company - Mojave

Glen Road Well No. 2

Date: 9/3/2024	Project #: 018-10	**Figure 5-18**

GSWC 0076



aquilogic, Inc.

Golden State Water Company – Mojave

Conceptual Water Budget

Date: 9/3/2024	Project #: 018-10	**Figure 6-1**

APPENDICES

APPENDIX A PROGRESS REPORT AND MOJAVE BASIN TRANSITION ZONE WATER BUDGET

aquilogic, Inc.
environment • water • strategy

245 Fischer Avenue, Suite D-2
Costa Mesa, CA 92626
Tel. +1.714.770.8040
Web: www.aquilogic.com

MEMORANDUM

To: Stephanie Hastings, Shareholder, Brownstein, Farber, Hyatt, Schreck, LLP
From: Anthony Brown, Principal-in-Charge, aquilogic, Inc.
Robert H. Abrams, Ph.D., P.G., CHg., Senior Principal Consultant, aquilogic, Inc.
Date: February 23, 2024

Subject: Progress Report and Mojave Basin Transition Zone Water Budget

Project No.: 018-10

Aquilogic, Inc. (**aquilogic**) has prepared this memorandum for two purposes. First, the memorandum documents preliminary work performed for the Golden State Water Company in the Mojave Basin pertaining to water outflow from the Transition Zone, which represents inflow the Centro Subarea (**Figure 1**). Preliminary work indicates this outflow may be overestimated by the Mojave Basin Watermaster (Watermaster). Consequently, inflow to the Centro Subarea may also be overestimated. Second, the memorandum outlines an approach to provide further assessment of this outflow/inflow, to be supported by data and analyses.

The Mojave Basin is subject to a Stipulated Judgment (Judgment) of water rights.[1] The Judgment stipulates that Alto Subarea Producers have an obligation to deliver 23,000 acre-feet per year (AFY) of Subsurface Flow[2] and Base Flow[3] to the Transition Zone. Watermaster appears to assume that surface water inflow to the Transition Zone provides the basis for estimating surface water inflow to the Centro Subarea.[4] However, there is no direct evidence to support this assumption. In fact, there is direct evidence that this assumption may be incorrect.

BACKGROUND

The Transition Zone is defined in the Judgment as part of the Alto Subarea. Watermaster assumes that the Alto Subarea Producers' obligation to the Transition Zone is satisfied by inflow to the Transition Zone from upstream portions of the Alto Subarea.[5] This inflow is comprised of Subsurface Flow and Base Flow. The obligation to the Transition Zone appears to be considered by Watermaster to also satisfy an obligation to the Centro Subarea. For example, the first annual report notes, "[s]*uch discharge records are used in the calculations of compliance by Alto*

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[1] Riverside (1996). Judgment after Trial, Mojave Basin Area Adjudication. City of Barstow et al. v. City of Adelanto et al. Riverside County Superior Court Case No. 208568. January 10.

[2] Subsurface Flow is defined in the Judgment as, "*Groundwater which flows beneath the earth's surface*."

[3] Base Flow is defined in the Judgment as, "*That portion of the total surface flow measured Annually at Lower Narrows which remains after subtracting Storm Flow*."

[4] After accounting for estimated gains/losses in the Transition Zone, such as sewage treatment plant outfall and estimated consumptive use, as stated or implied in multiple annual reports.

[5] Watermaster (1995). First annual report of the Mojave Basin Area Watermaster, 1993-1994, City of Barstow et al. v. City of Adelanto et al. Riverside County Superior Court Case No. 208568, Riverside County. February 28.

Subarea Producers with their obligation to the Centro Subarea."[6] Subsequent annual reports contain similar statements.

The Judgment specifies that 2,000 AFY of the Alto Producers' obligation to the Transition Zone is satisfied by Subsurface Flow. Watermaster assumes that groundwater inflow to the Centro Subarea from the Transition Zone is also 2,000 AFY.[7,8] Therefore, Watermaster appears to assume that 21,000 AFY of the obligation to the Centro Subarea must be satisfied by Base Flow from the Transition Zone.

Watermaster states that the change of groundwater storage in the Transition Zone is zero because water levels in key piezometers near both the upstream and downstream boundaries of the Transition Zone are relatively constant.[9] Because of this, Watermaster assumes Mojave River discharge measured at the Lower Narrows gage, adjusted by an estimated Transition Zone water balance, is essentially equivalent to Mojave River discharge entering the Centro Subarea[10] (**Figure 1**). However, there is no active stream gage at the upstream boundary of the Centro Subarea. Therefore, Watermaster's assumption regarding inflow to the Centro Subarea cannot be evaluated directly.

STREAM DISCHARGE

There are no stream gages in most of the Transition Zone. However, there is one long-term gage (i.e., water year [WY] 1931 to present) located at the upstream boundary of the Transition Zone (Lower Narrows gage) (**Figure 1**). Another long-term stream gage is located near the Centro Subarea-Baja Subarea boundary (Barstow gage). A stream gage has recently been re-established approximately eight miles downstream of the Transition Zone-Centro Subarea boundary (Hodge/Hinkley gage).

The Hodge/Hinkley and Barstow gages measure discharge across an ephemeral Mojave River channel that can be over 0.25 miles wide. Discharge is generally limited at these gages to Storm Flow (i.e., very little, if any, Base Flow is measured by these gages).[11] The wide channel leads to uncertainty in the stream discharge measurements from these gages because Storm Flows may

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[6] Watermaster (1995). First annual report of the Mojave Basin Area Watermaster, 1993-1994, City of Barstow et al. v. City of Adelanto et al. Riverside County Superior Court Case No. 208568, Riverside County. February 28.

[7] As stated or implied in multiple annual reports.

[8] However, it should be noted that the cross-sectional area for groundwater flow between the Transition Zone and the Centro Subarea potentially expands and contracts with varying volumes of Transition Zone recharge, which may increase or decrease the assumed 2,000 AFY of Subsurface Flow. Studies to understand the geometry of this potentially dynamic cross-sectional area are warranted but have not yet been undertaken by Watermaster.

[9] As stated or implied in multiple annual reports

[10] The Lower Narrows gage is located at the upstream boundary of the Transition Zone.

[11] Storm Flow is defined in the Judgment as "*That portion of the total surface flow originating from precipitation and runoff without having first percolated to Groundwater storage in the zone of saturation and passing a particular point of reckoning, as determined annually by the Watermaster*."

not always fill the entire width of the channel or may flow in parts of the channel away from the gage. Nevertheless, discharge measurements from these gages are the best available data.

From WY 1931 through WY 2023, Mojave River discharge at the Lower Narrows gage averaged 46,100 AFY. Discharge decreased by an average of 341 AFY over that period. From WY 1994 through WY 2023, Mojave River discharge at the Lower Narrows gage averaged 28,300 AFY. The decrease in average annual discharge over this period increased to 521 AFY.

As noted, there is no active stream gage at or adjacent to the Centro Subarea's upstream boundary. However, there was such a gage from March 1966 through WY 1970: the Wild Crossing gage (**Figure 1**).

DATA ANALYSIS

The Wild Crossing gage was discontinued because of unstable controls and changing stage-discharge relations that did not allow for acceptable discharge records.[12] However, stream discharge measured at the Wild Crossing gage is the best data available that can show the potential change in discharge between the upstream boundary of the Transition Zone and the upstream boundary of the Centro Subarea, despite its shortcomings and relatively short period of record. It should be noted that the Hodge/Hinkley gage was also discontinued two different times since 1932 because of unstable controls and changing stage-discharge relations. However, it was reestablished in 2022, which suggests high-quality data can be gathered at gage locations previously deemed problematic.

Stream Recharge to Groundwater

Figure 2 shows the annual discharge at the Lower Narrows gage, the Wild Crossing gage, and the Barstow gage for the period WY 1966 through WY 1970.[13] For the purposes of this analysis, net stream recharge to groundwater is approximated as the difference in discharge between successive gages.[14] Discharge at the Wild Crossing gage was lower than discharge at the Lower Narrows gage every year during this period. WY 1969 is particularly striking because annual stream discharge at the Wild Crossing gage (156,0000 AF) was 135,000 AF lower than discharge at the Lower Narrows gage (291,000 AF), a decrease of approximately 46 percent.[15]

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[12] Lines, G.C. (1996). Ground-water and surface-water relations along the Mojave River, Southern California: U.S. Geological Survey Water-Resources Investigations Report 95-4189, 43 p.

[13] The Wild Crossing gage was not active until March 1, 1966, thus may underestimate the annual discharge for WY 1966.

[14] This is a reasonable approximation, even though it ignores Base Flow and evapotranspiration, because most of the flow measured at the Wild Crossing gage and the Barstow gage are from episodic storm events. However, evapotranspiration along the stream course may require further evaluation.

[15] WY 1969 represents the largest amount of discharge on record for the Lower Narrows, Wild Crossing, and Barstow gages.

The consistent pattern of lower stream discharge at the Wild Crossing gage compared to the Lower Narrows gage during this period indicates that stream discharge at the Lower Narrows gage was more likely than not significantly greater than stream discharge entering the Centro Subarea. Furthermore, the consistent pattern indicates that significant net stream recharge to groundwater from the Mojave River likely occurred in the Transition Zone.

Figure 3 shows that the average annual stream discharge for WY 1966-1970 decreased substantially between the Lower Narrows and Wild Crossing gages (i.e., by approximately 51,500 AFY). The total average annual net stream recharge between the Lower Narrows gage and the Barstow gage for the WY 1966-1970 period was approximately 59,500 AFY (**Figure 3**). Thus, 86 percent of the total net stream recharge between the Lower Narrows and Barstow gages occurred between the Lower Narrows gage and the Wild Crossing gage, i.e., in the Transition Zone (**Figure 3**). Net stream recharge between the Wild Crossing gage and the Barstow gage (i.e., the Centro Subarea) represents only 14 percent of the total net stream recharge between the Lower Narrows and Barstow gages.

As noted, net stream recharge in the Transition Zone averaged approximately 51,500 AFY for WY 1966-1970. Also as noted, the Judgment specifies that Subsurface Flow into the Centro Subarea from the Transition Zone is 2,000 AFY. Thus, the fate of the Transition Zone net stream recharge is unclear without further analysis, which is discussed below.

Groundwater Extractions

Groundwater extraction data were obtained for 1951-1973 and WY 1994-2022 from the Mojave Water Agency (MWA).[16] Data were analyzed for 1966-1970 and WY 1994-2022 to determine annual groundwater extractions in the Transition Zone. Data from the earlier period were scanned from hard copy and digitized. Data from the later period were provided digitally. **Figures 4** and **5** show the wells for which extractions were reported for the 1966-1970 and WY 1994-2022 periods, respectively. Groundwater extractions were compared to stream recharge to assess if extractions may account for the fate of the Transition Zone stream recharge.

The upper panel of **Figure 6** compares the annual stream recharge in the Transition Zone to the annual reported groundwater extractions. As noted, the WY 1969 stream discharge and recharge were anomalously high. They are statistical outliers, which may cause the average value of stream recharge for WY 1966-1970 to be skewed high when compared to average groundwater extractions, which typically do not have extreme changes year to year.

Rather than comparing average values for this period, the median values of annual stream recharge (33,234 AFY) and annual groundwater extractions (30,287 AFY) for the 1966-1970 period were compared. The median values suggest that most of the Mojave River net stream

[16] Jeff Ruesch, Mojave Water Agency, email communications, July 2023.

recharge to groundwater in the Transition Zone during the 1966-1970 period was extracted by the approximately 260 wells completed in the Transition Zone at that time (**Figures 4** and **6**).

Transition Zone groundwater extractions in the 1966-1970 period may have facilitated higher net stream recharge by sufficiently changing the hydraulic gradient between the River and groundwater enough to induce stream recharge. This could occur even while water levels in key piezometers remain relatively constant. If so, the water-level data may appear to show that the change in groundwater storage in the Transition Zone is zero, when in fact the groundwater flow system is highly dynamic and may include significant net stream recharge.

The lower panel of **Figure 6** shows groundwater extractions in the Transition Zone for the 1966-1970 and WY 1994-2022 periods. The median value for 1966-1970 was 30,287 AFY. The median value for WY 1994-2022 was 11,522 AFY. This is a significant decrease in pumping, likely due to implementation of the Judgment. This decrease may suggest that recent and current net stream recharge in the Transition Zone is minimal compared to the WY 1966-1970 period.

However, a reasonable hypothesis is that significant net stream recharge continued to occur proportionately in the Transition Zone in the recent past and is currently occurring. The analysis described above suggests that groundwater extractions, on average, may remove an equivalent volume of net stream recharge from the Transition Zone. If so, surface water inflow to the Centro Subarea may be overestimated when based on the adjusted stream discharge measured at the Lower Narrows gage, because there may be unaccounted stream losses in the Transition Zone.

Additionally, the occurrence of Transition Zone stream losses and the effect of groundwater extractions and phreatophytes on streamflow losses and stream discharge in the Mojave Basin has been noted in previous reports prepared by others.[17,18] Furthermore, it should be noted that 15,095 AF of treated wastewater was discharged to the Transition Zone downstream of the Lower Narrows stream gage during WY 2022.[19]

OUTLINE OF PROPOSED WORK TO FURTHER EVALUATE THE TRANSITION ZONE WATER BUDGET

Watermaster was directed by the Court in 2022 to re-evaluate the Production Safe Yield (PSY) for each Subarea. **Aquilogic** believes a rigorous reevaluation must include a detailed

[17] Stamos, C.L., Martin, P., Nishikawa, T., and Cox, B.F. (2001). Simulation of ground-water flow in the Mojave River Basin, California. U.S. Geologic Survey Water-Resources Investigations Report 01-4002 Version 1.1.

[18] Todd Engineers (2013). Final report: Conceptual hydrogeologic model and assessment of water supply and demand for the Centro and Baja Management Subareas, Mojave River Groundwater Basin. Prepared by Todd Engineers and Kennedy/Jenks Consultants for the Mojave Water Agency. July.

[19] Watermaster (2023). Twenty-ninth annual report of the Mojave Basin Area Watermaster, water year 2021-2022, City of Barstow et al. v. City of Adelanto et al. Riverside County Superior Court Case No. 208568, Riverside County. May 1.

redetermination of the Transition Zone water budget. Material presented to date by Watermaster does not appear to have included a redetermined Transition Zone water budget.[20]

The analyses performed to date by **aquilogic** and others suggest that groundwater flow dynamics and the Transition Zone water budget are complex. The analyses provide a foundation for deeper evaluation of the Transition Zone water budget and its evolution through time. For example, the **aquilogic** analyses reported here can form components of an overall water budget evaluation. The objective of such an evaluation would be to provide an in-depth analysis of the volume of water that flows into the Centro Subarea annually.

A complete water budget would include all inflows, outflows, and the change of groundwater storage over time. Previous work by others can be leveraged to support development of a complete water budget. For example, the Judgment specifies that 2,000 AFY of groundwater flows into the Centro Subarea from the Transition Zone. This flow rate was specified before in-depth modeling was conducted by the U.S. Geological Survey (USGS) or MWA. A deeper analysis may reveal that this specified flow rate is too low or too high.

Groundwater flow into the Centro Subarea occurs in the Mojave River alluvium, in deeper horizons across the Helendale Fault, and other areas along the Transition Zone-Centro Subarea boundary (**Figure 1**). This flow rate is difficult to assess without using a groundwater flow model. A groundwater model can be used to contribute to a complete water budget evaluation by calculating the transient change in groundwater storage and groundwater flow rates that cannot otherwise be determined due to lack of data in key locations. **Aquilogic** strongly recommends that the current Mojave Basin groundwater flow model used by Watermaster be updated to include the entire basin, as soon as possible. In its current form, it is premature to use the model for any analyses involving the Transition Zone.

The water budget for the Transition Zone should be developed with sufficient detail and rigor to at least meet Sustainable Groundwater Management Act (SGMA) regulations for historic and current water budgets. A preliminary list of tasks to be performed includes, but may not be limited to, the following:

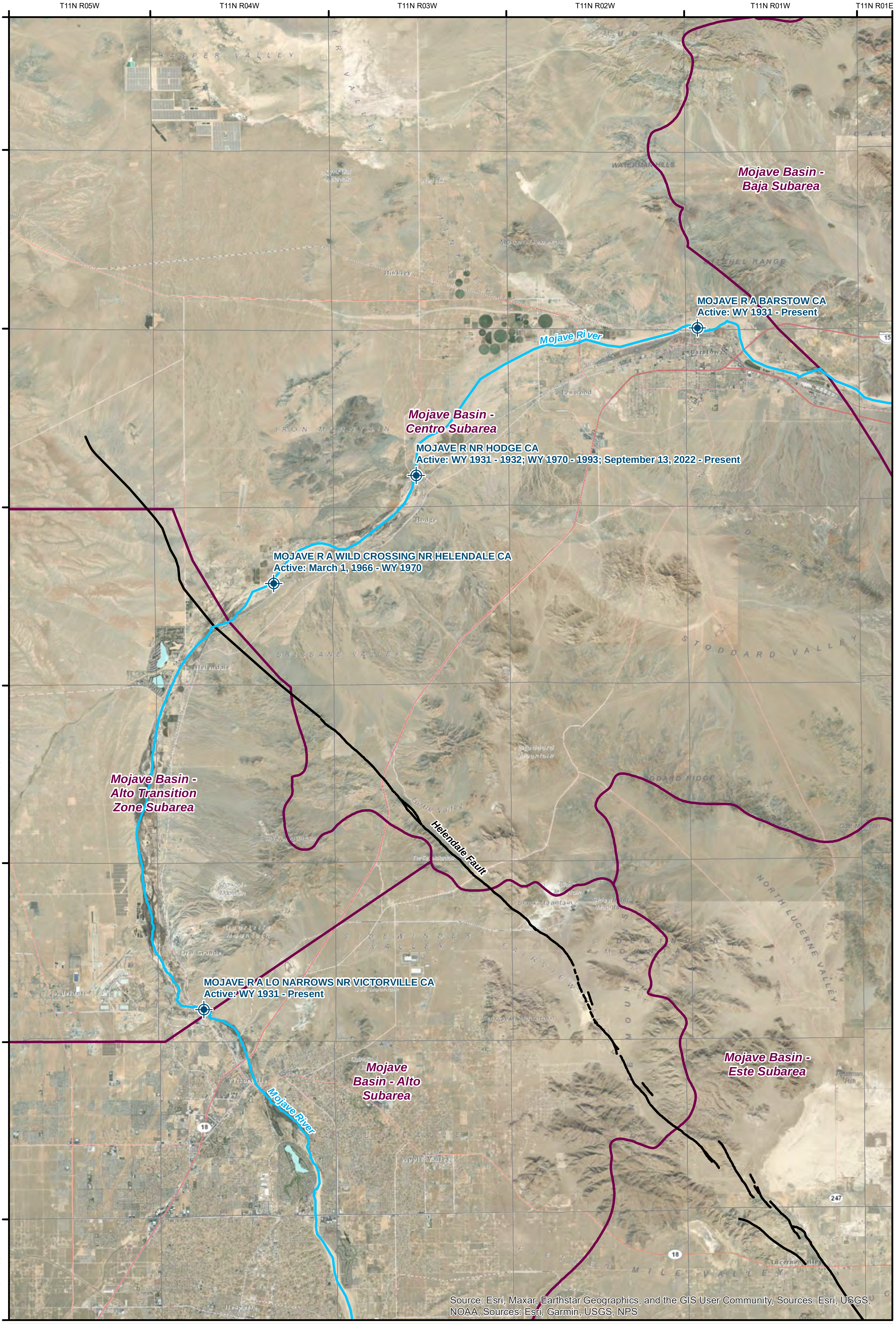
- Compile and review available previous work by others on groundwater flow and water budgets in the Alto and Centro Subareas, including the Transition Zone
- Evaluate the usefulness of the USGS Basin Characterization Model (BCM)[21] and the Parameter-elevation Regressions on Independent Slopes Model (PRISM)[22] dataset for application to the Transition Zone water budget

[20] Watermaster (2024). Groundwater Model and Production Safe Yield Update. Watermaster presentation prepared by Wagner and Bonsignore, Consulting Civil Engineers. Mojave Water Agency / Watermaster Board Meeting, January 24, 2024.

[21] https://ca.water.usgs.gov/projects/reg_hydro/basin-characterization-model.html

[22] https://prism.oregonstate.edu/

- Evaluate groundwater levels in the Transition Zone from WY 1931-present, with particular focus on the WY 1966-1970 and WY 1994-2022 periods to support the analyses described above
    - Estimate evapotranspiration by standard methods, including the use of satellite and areal images, and compare with previous studies
    - Compile all available water level data for the Transition Zone
    - Evaluate the water level data in terms of changes in well hydrographs and spatial water-level distributions over time
    - Determine if groundwater levels increased, decreased, or remained the same during the WY 1966-1970 period
- Use the USGS model and the updated MWA model (if and when available) to further evaluate the WY 1966-1970 period
    - Update the USGS model as needed, including groundwater extractions and potentially extending the model in time
    - Evaluate Transition Zone changes in groundwater storage, stream recharge, effects of evapotranspiration, groundwater extractions, and surface and groundwater flow into the Centro Subarea
- Critically evaluate results and available previous work to determine the best estimate of the Transition Zone water budget
- Identify data gaps and limitations in the analyses
- Effectively communicate the results to stakeholders
- Thoroughly document the analyses and prepare both draft and final reports



Stream Gages
Helendale Fault
Mojave River
Adjudicated Areas
Township/Range

Notes:
All locations approximate.
WY: Water Year

0 3
Miles

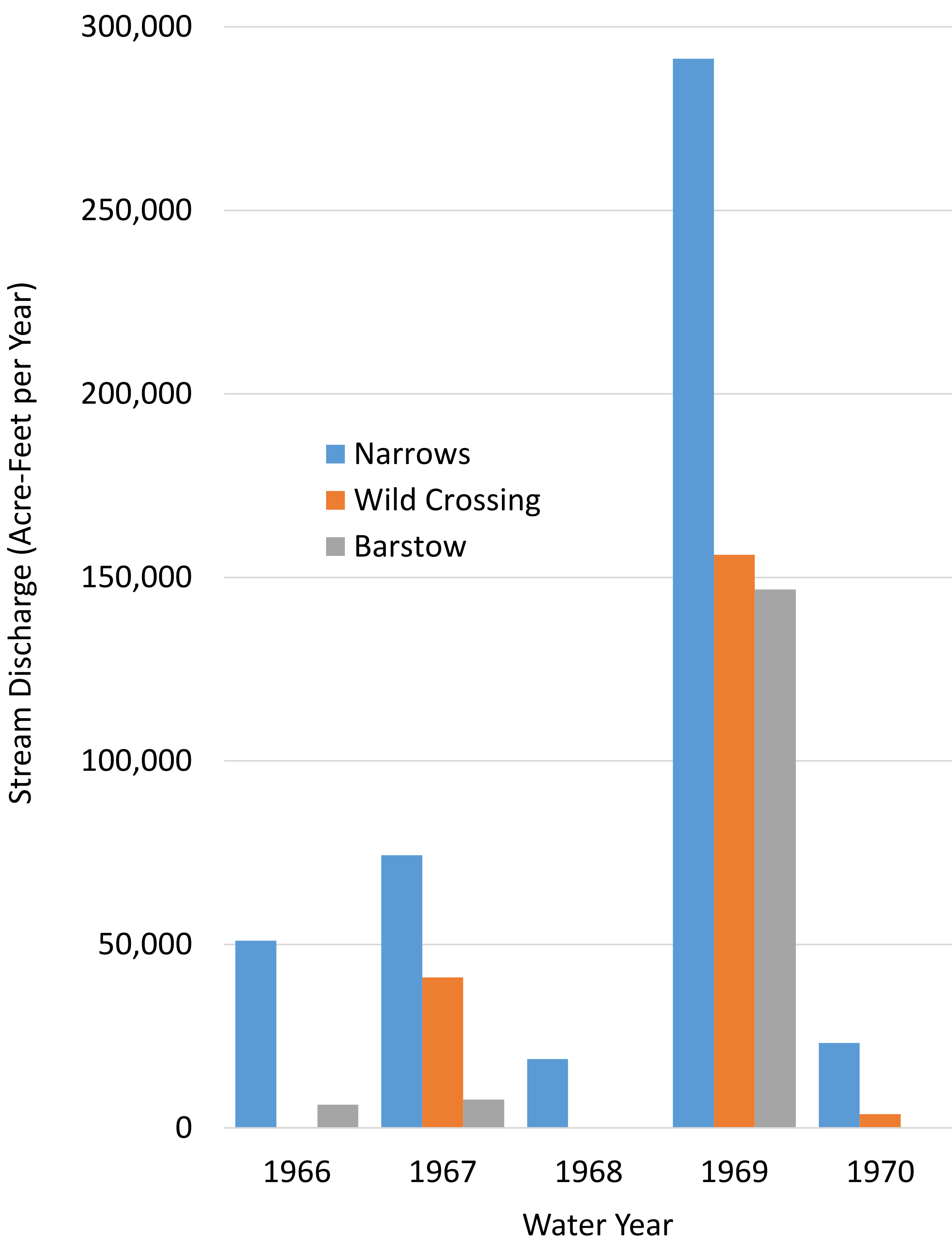
aquilogic, Inc.

BHFS - GSWC Mojave

Key Features in the Mojave Basin

Date: 10/18/2023 | Project #: 018-10 | **Figure 1**

GSWC 0087



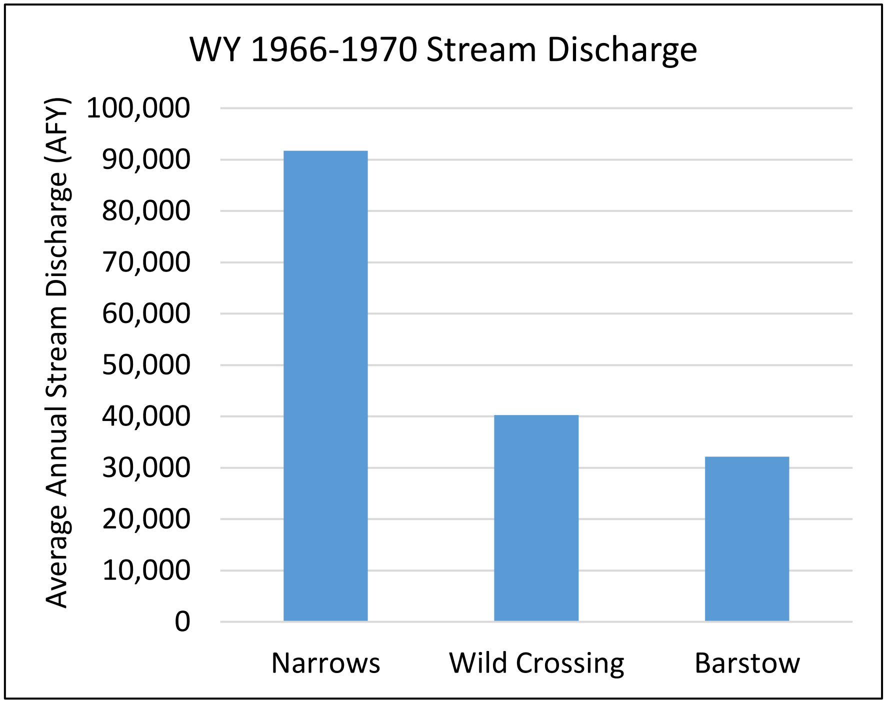
aquilogic, Inc.

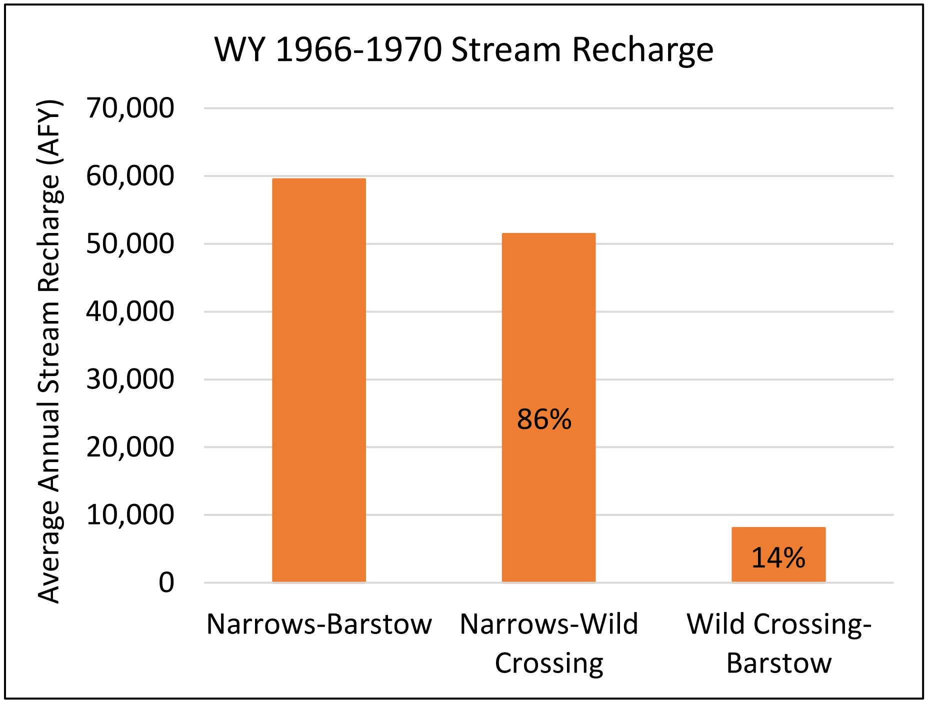
BHFS- GSWC Mojave

Stream Discharge along the Mojave River

Date: 10/25/2023	Project #: 018-10	**Figure 2**

GSWC 0088





AFY: Acre-Feet per Year
WY: Water Year

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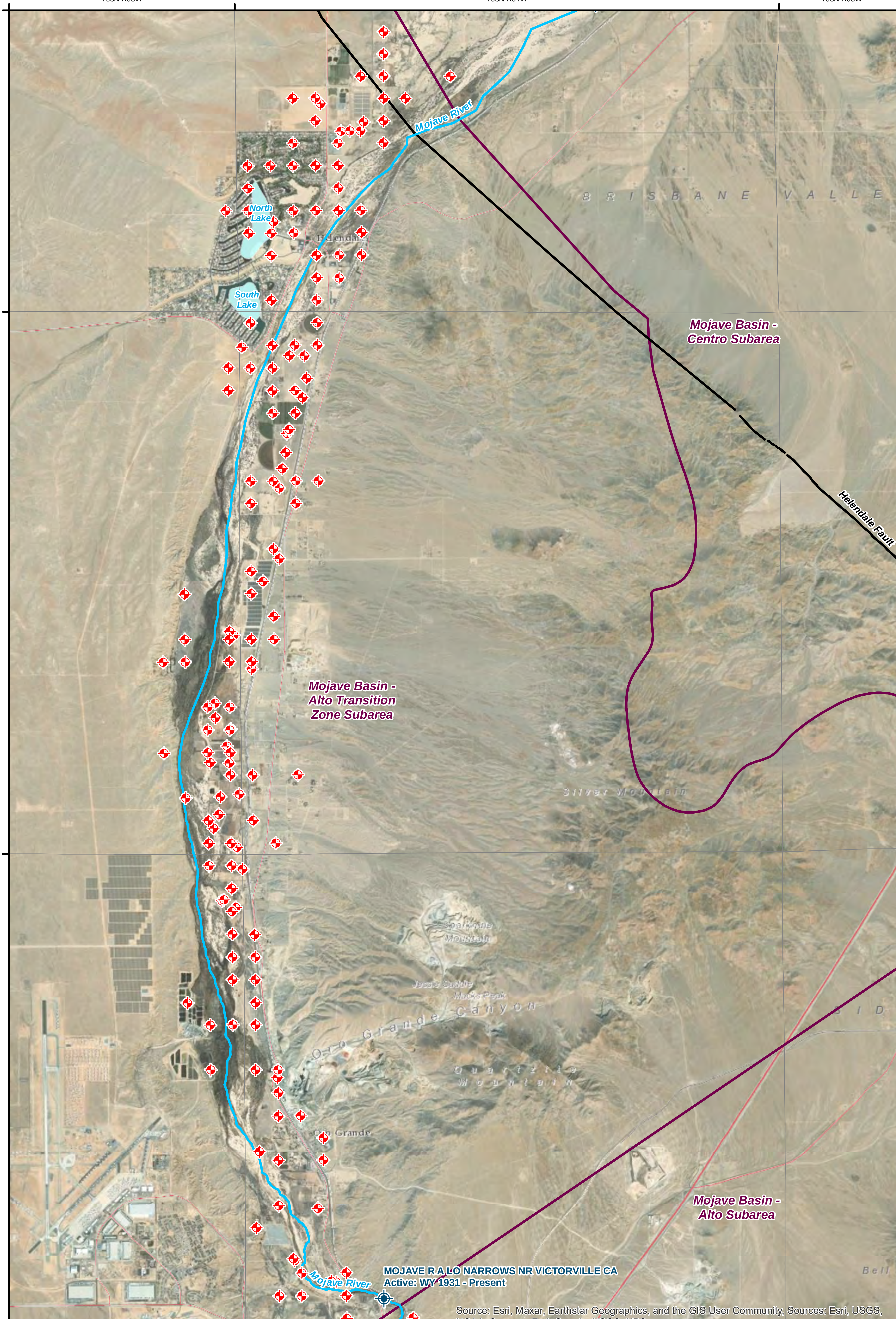
Stream Discharge and Recharge

Date: 2/23/2024	Project #: 018-10	**Figure 3**



Production Well Locations
Stream Gages
Helendale Fault
Mojave River
Adjudicated Areas
Township/Range

Notes:
All locations approximate.

0 — 1 Miles

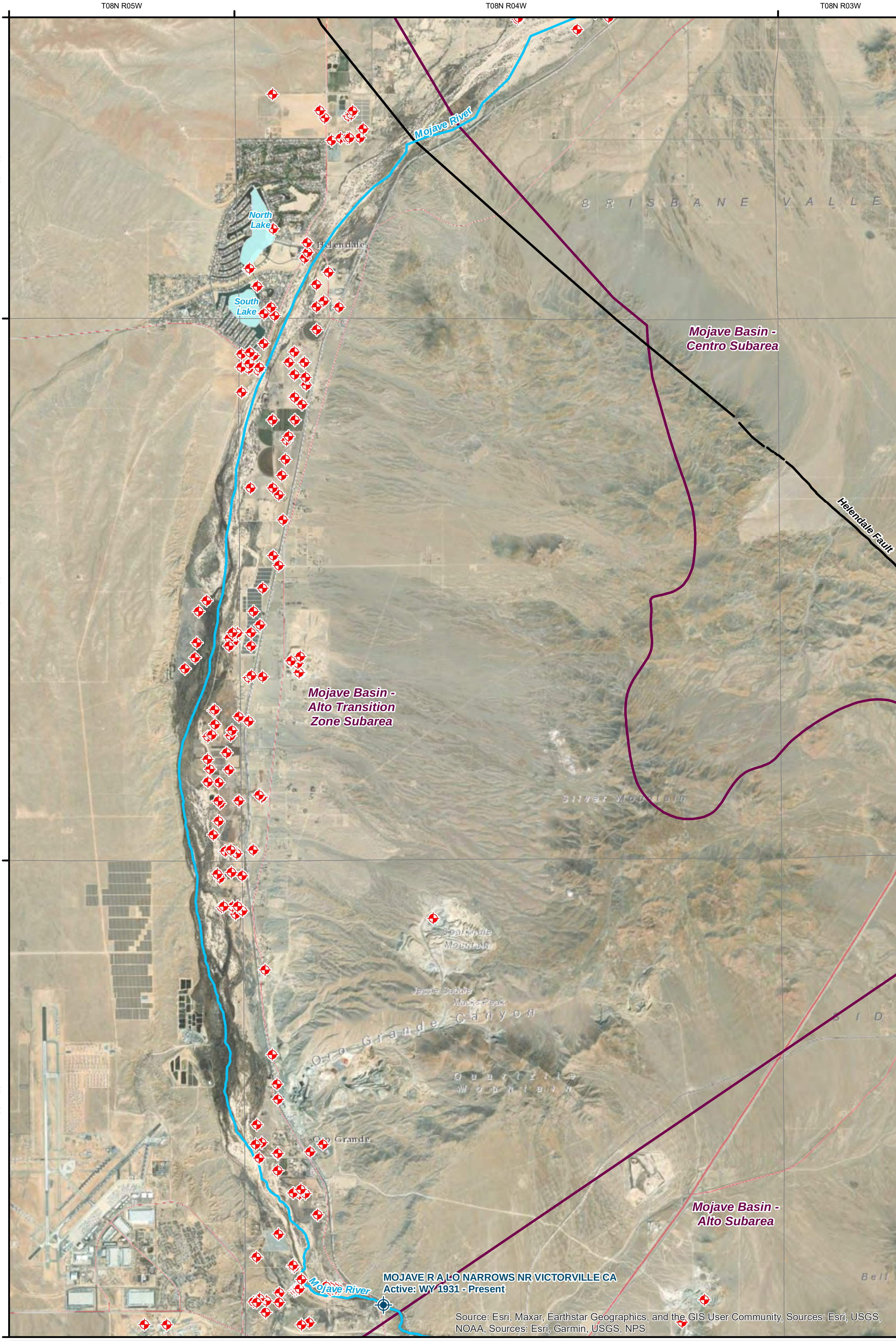
aquilogic, Inc.

BHFS - GSWC Mojave

Transition Zone Production Wells 1966-1970

Date: 10/18/2023	Project #: 018-10	**Figure 4**

GSWC 0090



Production Well Locations
Stream Gages
Helendale Fault
Mojave River
Adjudicated Areas
Township/Range

Notes:
All locations approximate.
WY: Water Year

0 1
Miles

aquilogic, Inc.

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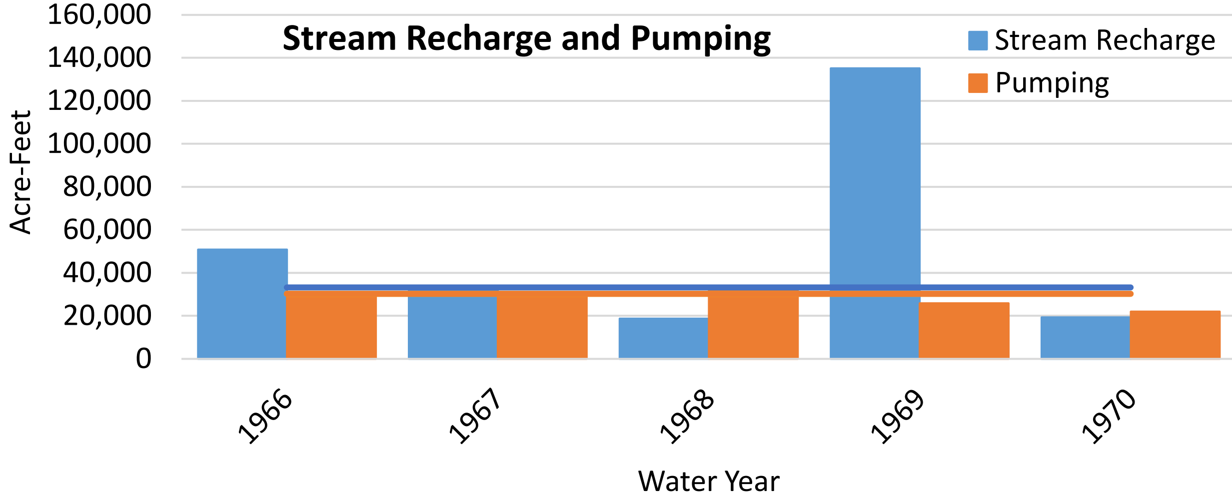
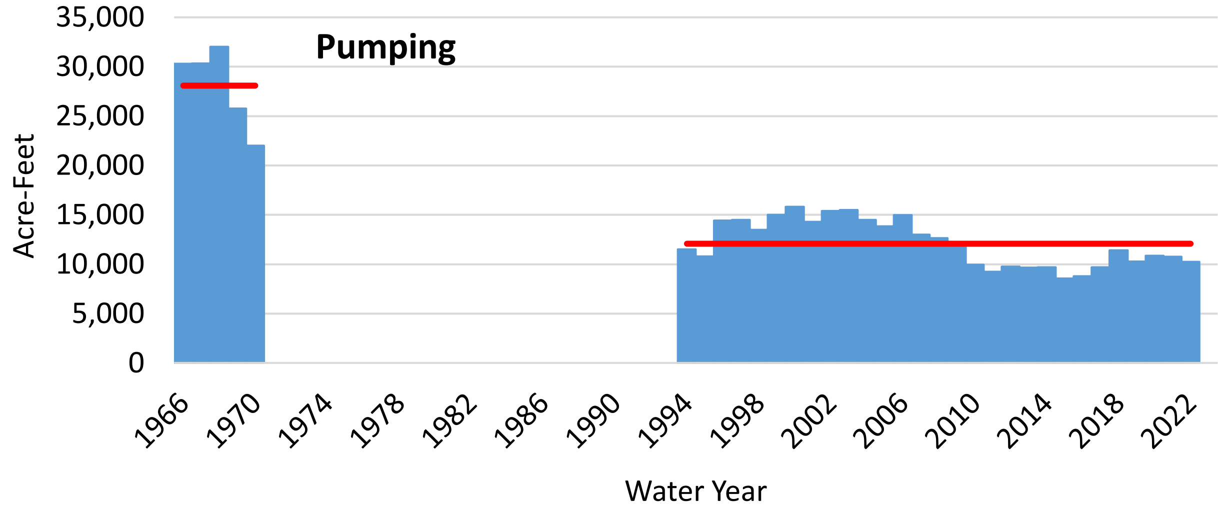
Transition Zone Production Wells
WY 1994 - 2022

Date: 10/18/2023	Project #: 018-10	**Figure 5**

GSWC 0091



1966-1970
Median Stream Recharge = 33,234 AFY
1966-1970
Median Pumping = 30,287 AFY



1966-1970
Median = 30,287 AFY

1994-2022
Median = 11,522 AFY

AFY: Acre-Feet per Year

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Average Annual Stream Transition Zone Recharge and Pumping

Date: 10/25/2023	Project #: 018-10	**Figure 6**

GSWC 0092

APPENDIX B BACKGROUND INFORMATION – MOJAVE GROUNDWATER BASIN SETTING

B1.1. Background Information

Appendix B of this report describes the general setting of the Mojave Basin with a focus on the Alto and Centro Subareas. A map of the Basin is shown in **Figure B-1.**

B1.2. Location and Setting

The Mojave Region ("Region") is a hydrologically diverse area covering over 5,400 square miles of the California High Desert, in San Bernardino County, California. The Mojave River Area, making up the larger of the Region's two major surface water drainage features, drains an area of 3,800 square miles.[1]

For water management purposes, the Basin is separated into five management areas or Subareas: Alto, Baja, Centro, Este, and Oeste. The five Subareas were defined under the Judgment and are referred to in the literature as the "Mojave River Groundwater Basin," "Mojave River Area," or "Mojave Basin Area." The Transition Zone (TZ) was defined in the Judgment to be part of the Alto Subarea (Alto).[2] This report focuses only on the Alto and Centro Subareas.

The Mojave Region lies in the California High Desert, which is part of the Mojave Desert. The High Desert Area is located on the northeastern flanks of the San Bernardino and San Gabriel Mountains, which separate the High Desert from the coastal basins and inland valleys of the greater Los Angeles and Orange counties area. These mountains, which reach elevations of over 10,000 feet above mean sea level (MSL), were uplifted along the San Andreas Fault. The High Desert Area is characterized overall as an alluvial plain. This plain consists of valleys and closed basins composed of water-bearing unconsolidated sediments. Hills and low mountains consisting of non-water-bearing consolidated bedrock separate these valleys and basins. The plain is dissected by a series of northwest-trending geologic faults, resulting in offsets of geologic layering and barriers to groundwater flow. Overall, land surface elevations within the Mojave Region range from 5,500 feet above MSL in the San Bernardino Mountains on the southern boundary to 1,500 feet above MSL near Afton Canyon on the eastern boundary.

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[1] MWA (2014). Mojave Region Integrated Regional Water Management Plan, Kennedy/Jenks Consultants. June. (Page 1-2. https://www.mojavewater.org/wp-content/uploads/2023/12/mojave_irwm-plan_final_626142.pdf)

[2] Riverside (1996). Judgment after Trial, Mojave Basin Area Adjudication. City of Barstow et al. v. City of Adelanto et al. Riverside County Superior Court Case No. 208568. January 10. (Page 13)

B1.3. Climate

The Mojave Water Agency (MWA) maintains a regional network of weather monitoring stations throughout the watershed; some funded by MWA and others maintained by various local and federal government agencies and citizen observer programs. The stations collect various weather data on temperature, precipitation, and evaporation. Rain gauges are mostly located within the Basin and the surrounding mountains.

Rainfall data from eleven climate stations were evaluated to better understand the contribution of runoff from precipitation in the Mojave River headwaters, local mountains, and valley floor.[3] Average annual precipitation in the San Bernardino Mountain headwaters averages 40.53 inches (in), while average annual precipitation on the valley floor averages 4.71 in. Annual precipitation is variable - for the headwater stations, annual precipitation has been as high as 98 inches and as low as 6 inches. Precipitation on the valley floor is low but more consistent. The precise orographic effect of the local mountains on precipitation patterns is uncertain.

Representative precipitation, temperature, and average evapotranspiration (ETo) data are reported in **Table B-1**. Runoff in the upper watershed contributes substantially more to the recharge of the Basin than precipitation falling in the Basin. Average rainfall within the lower lying areas of the Basin and Morongo Area is roughly five to seven inches per year. The large variation in annual rainfall within the surrounding mountains directly affects the annual water supply of the Basin.

B1.4. Land Use

Major existing land use categories within the MWA service area include residential, commercial, industrial, agricultural, and open space public land uses.

Open space is the dominant land use within the MWA service area, the large majority of which is owned and managed by federal and state agencies, primarily the US Department of the Interior (DOI) Bureau of Land Management (BLM). Private (non-government) land is mostly urban, containing residential and commercial development as well as undeveloped acreage. Residential, commercial and industrial land uses are, for the most part, concentrated around the main urban centers including Victor Valley (Victorville, Hesperia, Apple Valley, and Adelanto), Barstow and the Town of Yucca Valley.

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[3] MWA (2013). Final Report Conceptual Hydrogeologic Model and Assessment of Water Supply and Demand for the Centro and Baja Management Subareas Mojave River Groundwater Basin. Prepared by Todd Engineers with Kennedy/Jenks Consultants. July. (Page ES-5, https://www.mojavewater.org/wp-content/uploads/2022/10/FINAL-REPORT-BAJA-CENTRO-BCM-without-Appendices.pdf)

In general, the MWA service area is made up of relatively small urban centers with fairly low population densities. Larger urban centers include the incorporated cities of Victorville, Adelanto, Hesperia, and Barstow, and the towns of Apple Valley and Yucca Valley, all within the County of San Bernardino. The MWA service area had a population of approximately 450,000 in 2014.[4]

The San Bernardino County General Plan identifies the Victor Valley area as one of the fastest growing areas in San Bernardino County.[5] This area includes the cities of Victorville, Hesperia, Adelanto, and the town of Apple Valley, which are all located within the Alto Subarea and all near one another.[6] Land in the vicinity of these cities has steadily been converted to more urban uses to accommodate the population growth experienced in these cities. This supports the premise that the water budgets in Alto should be critically examined to ensure that the components are accurate.

The Barstow area includes the City of Barstow and surrounding unincorporated communities. Most of the future growth in the Barstow area is anticipated to occur within the incorporated City of Barstow and adjacent unincorporated communities.

Besides suburban and residential development, the Region also supports recreational and agricultural uses and contains a few energy generation plants and other large utility pipelines. The Region contains a few state and regional parks including portions of the San Bernardino National Forest, Joshua Tree National Park, and El Mirage, Johnson Valley and Stoddard Valley Off Highway Vehicle Areas. Agricultural uses in the Region occur primarily in the unincorporated areas east of Barstow, in the vicinity of Lucerne Valley and El Mirage, with additional scattered uses along the Mojave River north of Victorville. Wind and solar energy generating plants also dot the Region and electric transmission lines, water, crude oil and natural gas pipelines crisscross the Region.

B1.5. Surface Water Hydrology

The Mojave River is the main surface water drainage feature within the Region. The surface water drainage of the Mojave River covers an area of 3,800 square miles, and is an ephemeral stream fed primarily by storm runoff from the northern slopes of the San Bernardino

[4] MWA (2014). Mojave Region Integrated Regional Water Management Plan, Kennedy/Jenks Consultants. June. (Page 2-20, https://www.mojavewater.org/wp-content/uploads/2023/12/mojave_irwm-plan_final_626142.pdf)

[5] MWA (2014). Mojave Region Integrated Regional Water Management Plan, Kennedy/Jenks Consultants. June (Page 2-3. https://www.mojavewater.org/wp-content/uploads/2023/12/mojave_irwm-plan_final_626142.pdf).

[6] MWA (2014). Mojave Region Integrated Regional Water Management Plan, Kennedy/Jenks Consultants. June (Page 2-3. https://www.mojavewater.org/wp-content/uploads/2023/12/mojave_irwm-plan_final_626142.pdf).

Mountains. Other sources of flow in the river include localized groundwater inflow, direct discharges of treated effluent, and ungauged local storm runoff from ephemeral desert washes.

The Mojave River is formed by the confluence of two smaller streams (West Fork Mojave River and Deep Creek) descending from the mountains at a place called The Forks (**Figure B-1**). From there, the river flows north and then east for about 100 miles through the City of Victorville, north and northeastward through the City of Barstow, and eventually through Afton Canyon. It terminates at Soda and East Cronese Lakes; these lakes pond water only after major storm events. At present, the Mojave River is perennial (continuously flowing) only along a short section downstream of The Forks, in the vicinity of Upper and Lower Narrows and Afton Canyon, and in the section immediately downstream of the Victor Valley Wastewater Reclamation Authority's (VVWRA) treatment plant, about 4 miles downstream of the Lower Narrows. However, during and immediately after storms (principally during the winter), the Mojave River flows along several (sometimes all) of its reaches. Most of the river flow occurs immediately after storms.

The principal factors controlling the frequency and magnitude of downstream flows in the Mojave River are: (1) the frequency, magnitude, and duration of runoff in the San Bernardino Mountains; and (2) the absorption capacity of the river channel. These factors are complex and interrelated. The absorption capacity of the channel is a function of the characteristics of the unsaturated zone sediments along the channel and, at any given time, the depth to the water table, local and regional hydraulic gradients in the shallow aquifer system, and the amount of water held in the unsaturated zone (i.e., from antecedent floods). Consequently, it is difficult to apportion the historical variability in downstream flows to climatic factors versus human-related activities.

The relative impact of upstream production on downstream flows in each Subarea over time has been cursorily evaluated by the United States Geological Survey (USGS) in previous studies (Stamos, et al., 2001). The USGS study concluded that overall, pumping in the Este, Oeste, Alto, and TZ subareas negatively affects the Centro, Harper Lake, Baja, Coyote Lake, and Afton Canyon subareas by decreasing recharge from the Mojave River.

B1.6. Geology

The Mojave Desert was formed in the Tertiary Period from movement along the San Andreas Fault to the south and the Garlock Fault to the north, creating the Mojave structural block. Tectonic activity associated with the Mojave structural block was superimposed onto the previously formed Basin and Range province, which was characterized by normal faulting. The San Andreas and related faults created a horst-like block, uplifting the San Bernardino Mountains south of the Study Area.

The geology of the Region is characterized by sedimentary alluvial basins bordered by igneous and metamorphic mountain ranges and uplands; the uplands dominated by the San Gabriel and San Bernardino Ranges along the Basin's southern border. A typical geologic cross-section depicting the geologic sequence is shown on **Figure B-2**, and the surficial geology in the Basin is shown on **Figure B-3.** The ranges and uplands are composed of pre-Tertiary (greater than 65 million years ago) igneous and metamorphic rocks (labeled as pTb in accompanying figures), and Tertiary (1.64 to 65 million years ago) volcanic and sedimentary rocks (Tv and Ts, respectively). Numerous extensive strike-slip faults trend northwest to southeast across the Basin, causing predominantly horizontal displacement (but also vertical displacement for some faults) in the geologic section.[7]

The alluvial basins are composed of Quaternary (0 to 1.64 million years ago) unconsolidated river, lake, and playa deposits. The river deposits comprise different ages of granitic sand, silt, and gravel laid down by the Mojave River and its predecessor streams – the youngest deposits directly surrounding the current riverbed, with progressively older deposits further from the river or deeper below it.

Other significant sedimentary deposits include lake deposits and aeolian (wind-blown) sand deposits. The lake deposits (thick silts and clays) were formed when the ancestral Mojave River drained into a series of large lakes, including the ancestral Manix Lake in the Baja Subarea (Baja). Within the 270 square mile area once occupied by Lake Manix, the Manix Beds separate the groundwater system into shallow unconfined and deeper confined aquifers and limit recharge to the deeper aquifer system.

Major aeolian deposits occur near Harper (dry) Lake in Centro, along the Mojave River near Barstow, near Coyote Dry Lake and Troy Lake, in central Baja. Anchoring vegetation has been lost because of declining groundwater levels, scouring during flood events, wildfires, and agricultural clearing. As a result of these combined factors, large quantities of exposed sand have been mobilized. In the future, the destabilized dune sands are expected to continue to migrate eastward (downwind), and sandstorms are likely to increase.[8]

Surrounding and underlying the current and ancestral Mojave River alluvium are poorly sorted alluvial deposits from ancestral alluvial fans, braided-streams, lakes or playas.

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[7] MWA (2014). Mojave Region Integrated Regional Water Management Plan, Kennedy/Jenks Consultants. 2014. (Page 2-35)

[8] MWA (2013). Final Report Conceptual Hydrogeologic Model and Assessment of Water Supply and Demand for the Centro and Baja Management Subareas Mojave River Groundwater Basin. Prepared by Todd Engineers with Kennedy/Jenks Consultants. July. (Page ES-5)

B1.7. Hydrogeology (Basin and Subareas)

The Mojave River Groundwater Basin ("Basin") encompasses 1,400 square miles.[9] The Basin is essentially a closed basin, and very little groundwater enters or exits the Basin. However, within the Basin, groundwater moves between the different subareas, and groundwater-surface water and groundwater-atmosphere interchanges also occur. Approximately 80 percent of the Basin's natural recharge is through infiltration from the Mojave River. Other sources of recharge include infiltration of storm runoff from the mountains and recharge from human activities such as irrigation return flows, wastewater discharge, and enhanced recharge with imported water.[10] Over 90 percent of the Basin groundwater recharge originates in the San Gabriel and San Bernardino Mountains. Groundwater is discharged from the Basin primarily by well pumping, evaporation through soil, transpiration by plants, seepage into dry lakes where accumulated water evaporates, and seepage into the Mojave River.

Investigations by MWA, the USGS, and others have resulted in an improved understanding of the geology and hydrogeology of the Basin. Specifically, a more refined examination of the hydro-stratigraphy has allowed for differentiation between the more permeable Floodplain Aquifer that has a limited extent along the Mojave River and the more extensive but less permeable Regional Aquifer.[11] The aerial extent of the Floodplain and Regional aquifers is shown on **Figure B-1**. In the Basin, Alto, Centro, and Baja contain both the Floodplain Aquifer and the Regional Aquifer while Oeste and Este only contain the Regional Aquifer.

B1.7.1. Alto Subarea (Alto)

Faulting, possibly connected with the geologic formation of the Upper Narrows or subsurface structures associated with Shadow Mountains, affects groundwater flow in Alto. Faulting in this area is indicated by steep water-level gradients northwest of Victorville while a relatively flat water-level gradient is maintained between the City of Adelanto and the northern edge of the Southern California Logistics Airport.[12]

Recent alluvium (Qra) fills a smaller channel-shaped incision that generally is inset into the younger alluvium unit; however, at the Upper and Lower Narrows it is inset into granitic bedrock

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[9] MWA (2014). Mojave Region Integrated Regional Water Management Plan, Kennedy/Jenks Consultants. 2014. (Page 2-30)

[10] MWA (2014). Mojave Region Integrated Regional Water Management Plan, Kennedy/Jenks Consultants. 2014 (Page 2-30).

[11] MWA (2014). Mojave Region Integrated Regional Water Management Plan, Kennedy/Jenks Consultants. 2014 (Page 2-30).

[12] Stamos, C.L., Martin, P., Nishikawa, T., and Cox, B.F. (2001). Simulation of Ground-Water Flow in the Mojave River Basin, California. Water-Resources Investigations Report 01-4002 Version 3, US Geological Survey, Sacramento, CA. (Page 27).

(section C-C' **Figure B-4,** locations of Cross Section on **Figure B-3**). In the TZ (section D-D' **Figure B-4**), the recent alluvium is separated from the underlying younger alluvium by a unit of clay or clayey sand. The recent alluvium ranges from about 50 to 70 feet in thickness, recording one or more second-order cycles of stream incision and backfilling that occurred during the past 6,000 years.

Alto is defined in the Judgment to be consistent with the Upper Mojave Subunit identified in DWR Bulletin 84, which was a foundational technical document guiding development of the Judgment.[13] As a result, the boundary between Alto and Centro is placed at the Helendale Fault, where limited stream gaging data existed at the time of the Judgment. Since the Judgment, no stream gaging data has been collected at the Helendale Fault. At the time of the Judgement, the TZ was considered to simply pass Storm Flow from Alto to Centro without interference from pumping within the TZ. It was also assumed that the consumptive use within the TZ could be reasonably determined on an annual basis.

B1.7.1.1. Transition Zone (TZ)

The TZ is defined in the Judgment as the area between the Lower Narrows, Mojave River, and the Helendale Fault (**Figure B-1**) and was also defined by DWR.[14] The Helendale Fault (the boundary between the TZ and Centro) acts as a partial barrier to groundwater flow and causes water to move upward towards the land surface, which helps sustain phreatophytes upstream of the Fault.

Groundwater moves from the TZ to the Centro across the northern extension of the Helendale Fault (**Figure B-5**). Early work by the USGS used water-level data collected from USGS multiple-well monitoring sites and compiled from historical sources to interpret that the Helendale Fault restricts subsurface flow in the Regional Aquifer but not in the overlying Floodplain Aquifer.[15] This assessment is based on seismic refraction, water-level, and water-quality data in addition to hydraulic properties analysis of the Floodplain Aquifer and the Regional Aquifer.[16] On the basis of these data, the USGS estimated flow through the Floodplain Aquifer near, but not necessarily across, the Helendale Fault is between 5,000 to 6,000 Acre-Feet-per-Year (AFY). In the same

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[13] DWR (1967). California Department of Water Resources, 1967, Mojave River Ground Water Basins Investigation: Bulletin 84, 149p. with illustrations. (Pages 7 and 10)

[14] DWR (1967). California Department of Water Resources, 1967, Mojave River Ground Water Basins Investigation: Bulletin 84, 149p. with illustrations. (Pages 7 and 10)

[15] Stamos, C.L., Martin, P., Nishikawa, T., and Cox, B.F. (2001). Simulation of Ground-Water Flow in the Mojave River Basin, California. Water-Resources Investigations Report 01-4002 Version 3, US Geological Survey, Sacramento, CA. (Pages 26-27)

[16] Stamos, C.L., Martin, P., Nishikawa, T., and Cox, B.F. (2001). Simulation of Ground-Water Flow in the Mojave River Basin, California. Water-Resources Investigations Report 01-4002 Version 3, US Geological Survey, Sacramento, CA. (Page 27)

analysis, groundwater flow through the surrounding and underlying Regional Aquifer does not exceed 1,200 AFY but probably is much less because the Helendale Fault is believed to be a barrier to flow in the Regional Aquifer.[17]

The pumping history in the TZ indicates a general decline in pumping since the early 1950s. According to the Watermaster,[18] the decline in pumping as well as a decline in consumptive use has contributed to water level stability in the TZ. The discharge of treated effluent from the VVWRA has contributed to this stability in groundwater levels. Water pumped and used by Producers contributing to sewers, upstream of Lower Narrows, is conveyed, treated and discharged in the TZ. The discharges are part of the basin water supply, contribute to downstream subareas, and support riparian habitat.[19]

B1.7.2. Centro Subarea (Centro)

Centro encompasses 1,242 square miles of surface drainage area traversed by the Mojave River. It is situated generally downstream of Alto and upstream of Baja. Groundwater occurs in a complex geologic setting. Centro generally overlies three DWR basins as defined in the 2003 update of Bulletin No. 118, including the Middle Mojave River Valley (6-41), Harper Valley (6-47), and the western portion of Lower Mojave River Valley (6-40) basins. Also included in Centro are small portions of Cuddeback Valley (6-50) and Superior Valley (6-49) basins; these basins are generally separated from Centro by crystalline bedrock forming the watershed boundary but are included in the MWA service area. For the most part, these latter two basins are covered by the Judgement.

Major geologic structures in Centro include the Helendale, Iron Mountain, Lockhart, Mt. General, and Harper Lake-Camp Rock (Waterman) faults. Previous studies have identified these faults as partial barriers to groundwater flow. As noted, the Helendale Fault (the boundary between Alto and Centro) acts as a partial barrier to groundwater flow and causes water to move upward towards the land surface.

The base of unconsolidated sediments varies from about 200 feet below ground surface (bgs) in the southeast of Centro to more than 600 feet bgs in the northwest. As a result of faulting, the elevation of the base of unconsolidated sediments is highly variable across Centro. For example,

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17 Stamos, C.L., Martin, P., Nishikawa, T., and Cox, B.F. (2001). Simulation of Ground-Water Flow in the Mojave River Basin, California. Water-Resources Investigations Report 01-4002 Version 3, US Geological Survey, Sacramento, CA (Page 27)

18 Wagner and Bonsignore (2024). Watermaster Engineer, Production Safe Yield & Consumptive Use Update. February 28, 2024. Page 22.

19 Wagner and Bonsignore (2024). Watermaster Engineer, Production Safe Yield & Consumptive Use Update. February 28, 2024. Page 22.

the base of unconsolidated sediments varies from more than 600 feet bgs in south Harper Valley to less than 100 feet bgs in the gap between the Lynx Cat Mountain and Iron Mountain. Northeast of Iron Mountain, the alluvial basin thickens dramatically to more than 500 feet and then varies between 200 and 500 feet through the Barstow area. East of Barstow, the alluvial basin thickens again to more than 600 feet, with most of the section represented by older alluvial sediments comprising the Regional Aquifer. The base of unconsolidated sediments is greater than 700 feet bgs in the Kramer Junction area. Accounting for the depth of sediments below the water table (as of 2010) and applying a storativity value (i.e., the volume of water contained in an equal volume of sediments), the estimated volume of groundwater in storage is estimated at 5,429,000 Acre-Feet (AF) for Centro. This value represents the amount of stored groundwater that theoretically could be pumped with wells (albeit without consideration of long-term sustainability, economic or environmental factors).[20]

Groundwater level data from the MWA database indicates that groundwater conditions in 1959 were relatively similar to those in 2010, and that groundwater flow patterns have not changed significantly from 1959 to 2010.[21] Groundwater level declines have been greatest west of Harper Dry Lake, and locally exceeded 50 feet. These declines are associated with historical agricultural pumping; however, since the Judgment, local agricultural land has been gradually converted to industrial land uses, groundwater production has declined, and groundwater levels have recovered slightly.

A water budget for Centro—summarizing groundwater inflows, outflows, and change in storage from 1931 to 1999—was developed by the USGS as part of a groundwater flow model.[22] The USGS water budget indicated that groundwater storage across Centro declined more than 760,000 AF from 1931 to 1999, with most of the storage losses occurring between 1950 and the late 1970s. In contrast, from the late 1970s to roughly 1999, the USGS estimates groundwater inflows and outflows for the entire Centro were generally in balance. The USGS water budgets indicated that groundwater level and storage trends are affected directly by local pumping within the subarea and indirectly by upstream regional pumping. Based on simulations with the USGS model, pumping in Este, Oeste, Alto, and TZ model subareas was the major factor in historical groundwater storage declines in Centro. Since the development of the USGS

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[20] MWA (2013). Final Report Conceptual Hydrogeologic Model and Assessment of Water Supply and Demand for the Centro and Baja Management Subareas Mojave River Groundwater Basin. Prepared by Todd Engineers with Kennedy/Jenks Consultants. July. (Page 4-35)

[21] MWA (2013). Final Report Conceptual Hydrogeologic Model and Assessment of Water Supply and Demand for the Centro and Baja Management Subareas Mojave River Groundwater Basin. Prepared by Todd Engineers with Kennedy/Jenks Consultants. July. (Page 5-11)

[22] Stamos, C.L., Martin, P., Nishikawa, T., and Cox, B.F. (2001). Simulation of Ground-Water Flow in the Mojave River Basin, California. Water-Resources Investigations Report 01-4002 Version 3, US Geological Survey, Sacramento, CA. (Page 91)

numerical model, groundwater use has changed considerably in response to production ramp-down mandated by the Judgment. However, since that time, Golden State production wells have experienced chronic water level declines, despite the overall reduction in pumping in the Centro under the Judgement.

B1.8. Groundwater Production

Groundwater in the Region is pumped from the Floodplain Aquifer and Regional Aquifer for municipal, industrial, and agricultural supply. Pumping increased dramatically in Centro in the 1940s and 1950s and in Baja in the 1950s and 1960s. Total production in the Basin peaked in 1989 at approximately 240,000 AFY, at which time production in Centro was about 52,000 AFY. Since the Judgment, pumping has declined significantly. Total Basin production in WY 2010 (140,000 AF) represents about 60 percent of the historical peak production.[23]

The MWA service area has four sources of water supply: Natural surface water flows; wastewater imports from outside the Region; State Water Project (SWP) imports; and return flows from pumped groundwater not consumptively used. A fifth source, "Agricultural Depletion from Storage," is also shown as a supply. In MWA's demand forecast projection model, natural and SWP supply are expressed as an annual average, although both sources of supply vary significantly from year to year. This reliance on the annual average has led Watermaster to view these fluctuations as relatively unimportant for water supply planning. However, the fluctuations need to be considered to more robustly manage groundwater in the Basin. Almost all the water used within the Region is supplied by pumped groundwater.[24]

Groundwater production in the Floodplain Aquifer (and to a lesser extent in the Regional Aquifer) has induced increased recharge to the groundwater system from the Mojave River where streamflow occurs. Increased recharge along the river in upstream reaches causes depletion in streamflow, thereby reducing the amount of streamflow available for recharge to downstream reaches. The relative impact of upstream production on downstream flows over time was cursorily evaluated by the USGS.[25] As noted previously, evaluation of the groundwater level data and water budgets indicate that groundwater level trends are affected directly by local pumping and indirectly by upstream regional pumping. Overall, the USGS concluded that

[23] MWA (2013). Final Report Conceptual Hydrogeologic Model and Assessment of Water Supply and Demand for the Centro and Baja Management Subareas Mojave River Groundwater Basin. Prepared by Todd Engineers with Kennedy/Jenks Consultants. July. (Page 3-11)

[24] MWA (2014). Mojave Region Integrated Regional Water Management Plan, Kennedy/Jenks Consultants. June. (Page 3-2)

[25] Stamos, C.L., Martin, P., Nishikawa, T., and Cox, B.F. (2001). Simulation of Ground-Water Flow in the Mojave River Basin, California. Water-Resources Investigations Report 01-4002 Version 3, US Geological Survey, Sacramento, CA. (Page 112)

pumping in Centro, Harper Lake, Baja, Coyote Lake, and Afton Canyon model subareas does not negatively affect the Este, Oeste, Alto, and TZ model subareas; however, pumping in the Este, Oeste, Alto, and TZ model subareas negatively affects the Centro, Harper Lake, Baja, Coyote Lake, and Afton Canyon model subareas by decreasing recharge from the Mojave River.

The total verified production from each Subarea for all parties within the Basin for the 2018-19, 2019-20, 2020-21, 2021-22 and 2022-23 Water Years is shown in **Table B-2**. This can be compared to projected water supply requirements in **Table B-3**.

B1.9. Groundwater Recharge

The main sources of recharge of new water to the Basin are surface water percolation and SWP water, and can be characterized as follows:

1. Streamflow losses from the Mojave River represent the primary source of groundwater recharge in the Basin; these have varied over time in response to both physical and human factors.
2. Recharge resulting from the infiltration of storm runoff in ephemeral stream channels from the surrounding mountains and highlands is termed mountain front recharge. The amount of discharge from these ephemeral streams and washes has never been measured directly; therefore, it is uncertain how much water infiltrates their upper reaches to recharge the Regional Aquifer. Estimates of total mountain-front recharge range from about 10,100 to 13,000 AFY with most of the recharge occurring in the Upper Mojave Basin (Oeste, Alto, and Este).[26]
3. MWA imports water from the SWP to recharge the Basin from which local water companies, municipalities, and other well owners pump for beneficial uses. MWA owns and operates two major pipelines (Mojave River Pipeline and Morongo Basin Pipeline) and associated infrastructure that convey imported SWP water to augment local groundwater supplies.[27] The Mojave River Pipeline was completed in 2006 and has a capacity to recharge 45,600 AFY.

Several other sources provide artificial recharge to the Basin, including irrigation return flows, fish hatchery return flows, and treated sewage and septic effluent. Except for septic-tank discharge, these sources discharge directly into, or adjacent to, the Mojave River. The disposal

[26] Stamos, C.L., Martin, P., Nishikawa, T., and Cox, B.F. (2001). Simulation of Ground-Water Flow in the Mojave River Basin, California. Water-Resources Investigations Report 01-4002 Version 3, US Geological Survey, Sacramento, CA. (Page 31)

[27] MWA (2013). Final Report Conceptual Hydrogeologic Model and Assessment of Water Supply and Demand for the Centro and Baja Management Subareas Mojave River Groundwater Basin. Prepared by Todd Engineers with Kennedy/Jenks Consultants. July. (Page 2-5)

of septic wastewater has become a significant source of recharge to the aquifer in Alto where many residences are not connected to a municipal sewer system. These other types of recharge are important for water budgeting. However, because the Mojave River Basin is “closed,” this recharge is not viewed as “new water” that is added to the Basin on an annual basis.

The USGS estimated recharge to the Floodplain Aquifer from infiltration of Mojave River water based on measured streamflow losses between gaging stations and estimates of tributary inflow, base flow, anthropogenic discharges, and evaporation of river water. Recharge to the Floodplain Aquifer was estimated between gages in Alto, the combined TZ and Centro, and the Baja.[28] It was not possible to distinguish separate recharge estimates for the TZ and Centro because there is no gauging station at their boundary. Although Alto, TZ, and Centro receive yearly recharge from Mojave River seepage, such recharge in Baja occurs only during years when flows are very large in magnitude.

The Regional Recharge and Recovery Project (R-Cubed) project delivers SWP water for recharge along the Mojave River (Alto), subsequent recovery through planned MWA-owned production wells, and delivery to retail water agencies. While the project is not within the Centro or Baja, the project provides MWA with increased operational flexibility.

MWA also operates enhanced recharge facilities, including two in Centro (Hodge and Lenwood) and two in Baja (Daggett and Newberry Springs), each of which are supplied by the Mojave River Pipeline.

B1.10. References

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[28] Stamos, C.L., Martin, P., Nishikawa, T., and Cox, B.F. (2001). Simulation of Ground-Water Flow in the Mojave River Basin, California. Water-Resources Investigations Report 01-4002 Version 3, US Geological Survey, Sacramento, CA. (Page 30)

Stamos, C.L., Martin, P., Nishikawa, T., and Cox, B.F. (2001). Simulation of Ground-Water Flow in the Mojave River Basin, California. Water-Resources Investigations Report 01-4002 Version 3, US Geological Survey, Sacramento, CA.

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Table B-1: Climate Data for the Mojave Region

Golden State Water Company - Mojave

Station:	Barstow			Victorville		
	Total ETo (in)	Total Precipitation (in)	Average Air Temperature (F)	Total ETo (in)	Total Precipitation (in)	Average Air Temperature (F)
1997	73.1	11.6	66.1	68.4	6.4	61.4
1998	66	4.7	63	62	11.4	58.3
1999	74	2.6	64.7	67.8	3.2	60
2000	74.9	1.5	66.3	68.4	3.4	61.2
2001	74.8	5.7	66.6	67.3	6.9	61.5
2002	74.6	8.3	65.9	69.6	2.4	61
2003	71.8	4.5	66.6	66.6	12.4	61.5
2004	71.9	8.8	65.3	66.2	13.6	60.6
2005	66.6	13.2	64.7	64.6	13.2	60.6
2006	70.2	2.1	65.6	68.1	4.1	60.8
2007	70.4	1.6	66.4	71.2	3.3	61.5
2008	73.2	2.7	66.1	68.7	3.7	61.3
2009	71	1.5	65.4	66.1	3	58.9
2010	69.2	9.7	65	66.2	18.9	59.9
2011	72.2	1.9	64.1	67.1	12.2	59.3
2012	72.6	2	66.7	70.2	5	62.1
Average	**71.7**	**5.1**	**65.5**	**67.4**	**7.7**	**60.6**

Notes:

Source: MWA, 2014. Mojave Region Integrated Regional Water Management Plan, Kennedy/Jenks Consultants, June 2014 (Table 2-7, Page 2-41).

Source: http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?cavict+sca

Source: https://wrcc.dri.edu/cgi-bin/cliGCStT.pl?ca0521

Source: http://wwwcimis.water.ca.gov/cimis/frontMonthlyEToReport.do

ETo: Evapotranspiration

F: degrees Farenheit

in: inches

Table B-2: Verified Groundwater Production

Golden State Water Company - Mojave

Subarea	2018-19	2019-20	2020-21	2021-22	2022-23
Alto (AF)	69,782	73,441	77,891	74,581	68,751
Baja (AF)	21,162	18,667	12,867	10,521	9,191
Centro (AF)	18,231	16,756	18,132	15.442	14,840
Este (AF)	4,029	4,227	4,304	4,114	3,547
Oeste (AF)	3,380	3,439	3,560	2,893	2,607
Total (AF)	**116,584**	**116,530**	**116,754**	**107,551**	**98,936**

Notes:

Source: MWA, 2024. Appendix L Thirtieth Annual Report of The Mojave Basin Area Watermaster Water Year 2022-23 May 1, 2024. Page III

AF: Acre-Feet

Table B-3: MWA Summary of Current and Planned Water Supplies (AFY)

Golden State Water Company - Mojave

Water Supply Source	2010	2015	2020	2025	2030	2035
Wholesale (Imported)						
SWP	49,680	51,480	53,880	53,880	54,778	54,778
Local Supplies						
Net Natural Supply	54,045	59,973	59,973	59,973	59,973	59,973
Agricultural Depletion from Storage	10,425	12,434	7,348	3,517	942	0
Return Flow	60,393	65,294	65,587	68,602	71,933	75,852
Wastewater Import	4,895	5,274	5,551	5,829	6,107	6,385
Total Existing Supplies	**179,438**	**194,455**	**192,339**	**191,801**	**193,733**	**196,988**
Projected Demands	**145,875**	**159,932**	**159,544**	**164,706**	**170,551**	**177,981**

Notes:

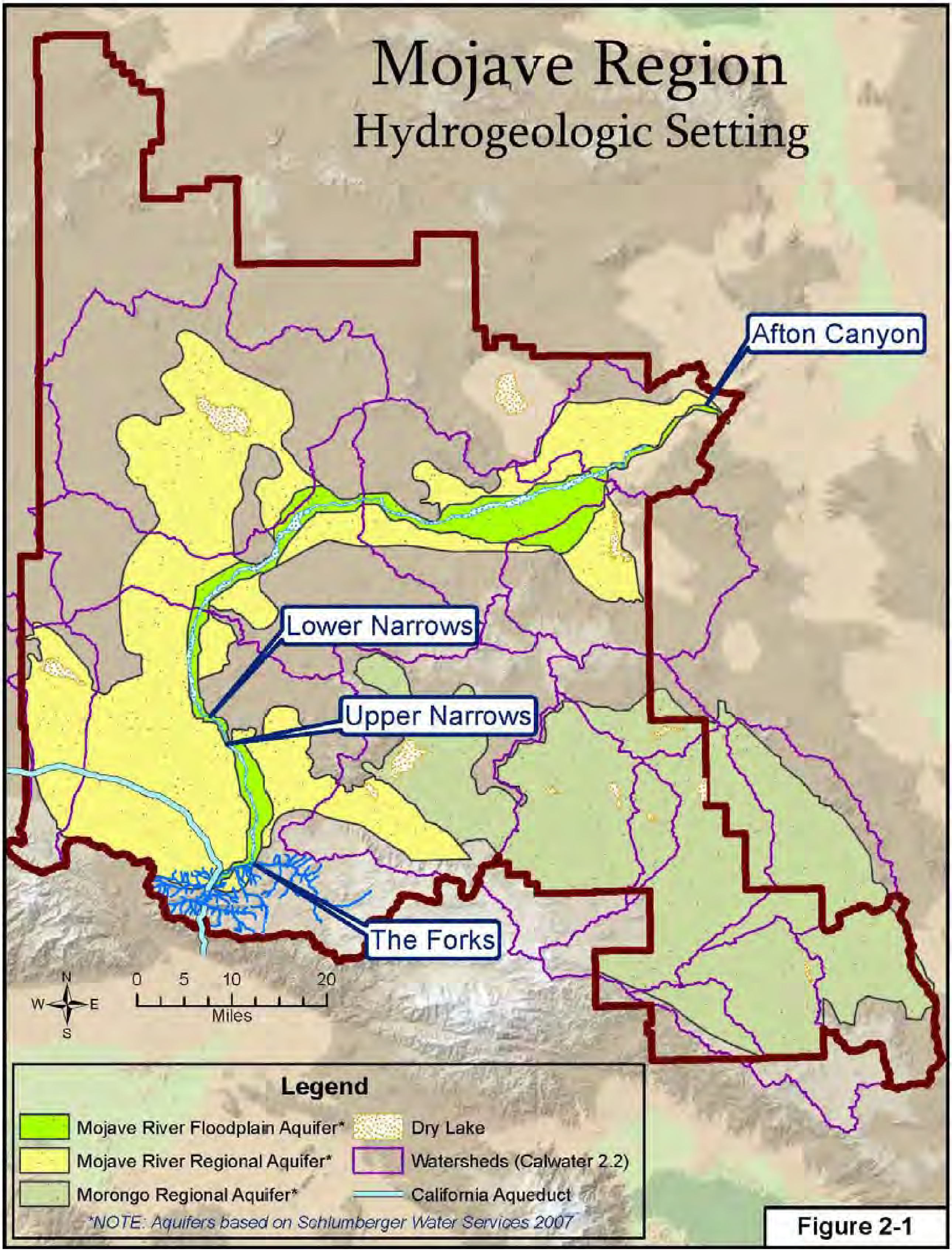
Source: MWA update to its 2010 Urban Water Management Plan (UWMP) demand forecast projection model dated February 26, 2014.

Source: Table 3-1. MWA, 2014. Mojave Region Integrated Regional Water Management Plan, Kennedy/Jenks Consultants, June 2014 (Page 3-1).

AFY: Acre-Feet per Year

MWA: Mojave Water Agency

SWP: State Water Project



Source: Figure 2-1 (page 2-2) of MWA (2014). Mojave Region Integrated Regional Water Management Plan, Prepared by Kennedy/Jenks Consultants, Fig. 2-1 (June 2014)
https://www.mojavewater.org/wp-content/uploads/2023/12/mojave_irwm-plan_final_626142.pdf

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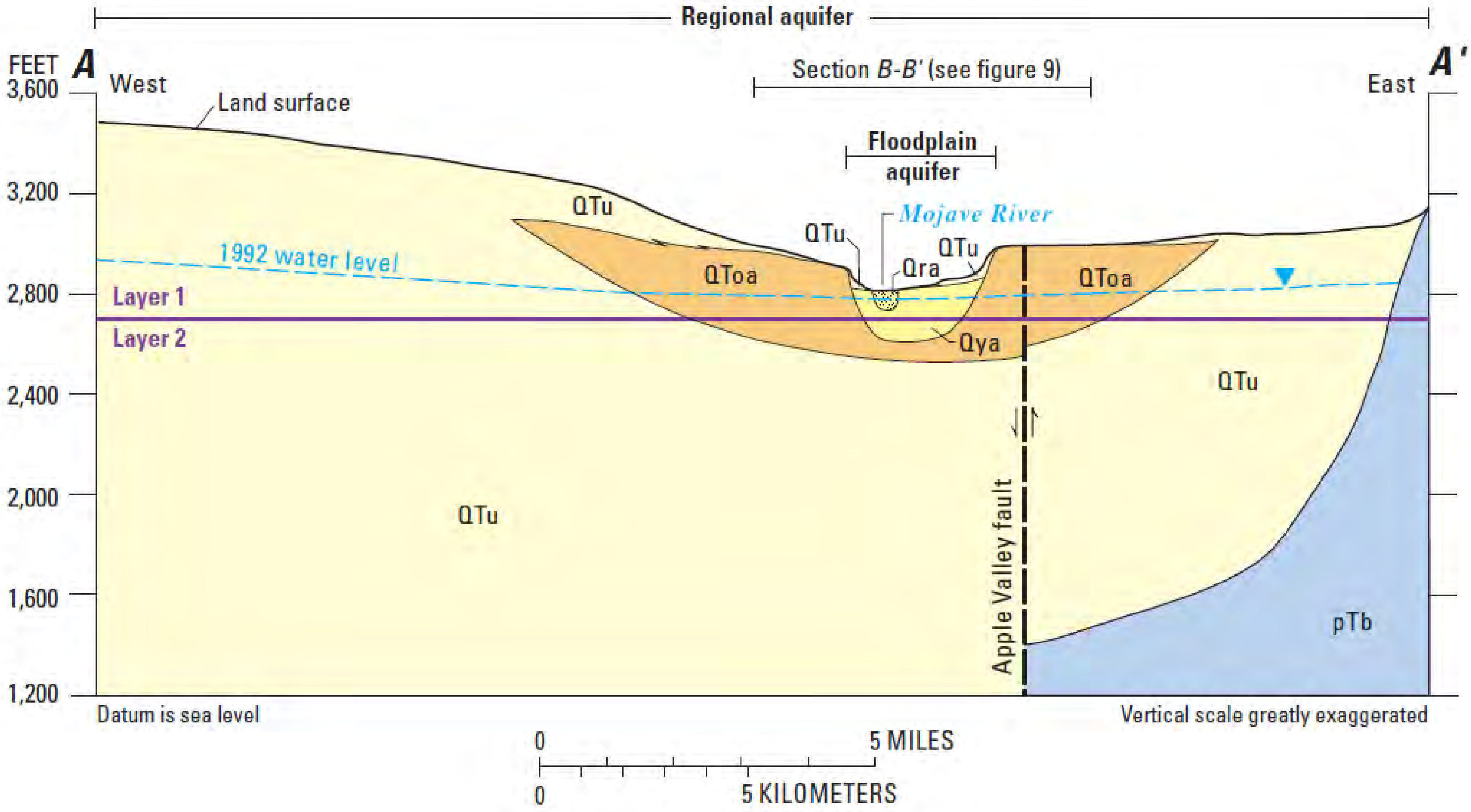
Golden State Water Company - Mojave

Area and Subareas of Mojave Groundwater Basin

Date: 9/4/2024	Project #: 018-10	**Figure B-1**

GSWC 0110



EXPLANATION

Floodplain aquifer

- Qra — **Recent Mojave River alluvium** *Holocene*
- Qya — **Younger Mojave River alluvium** *Holocene to Pleistocene*

Regional aquifer

- QTu — **Undifferentiated alluvium** *Holocene to Pliocene*
- QToa — **Older alluvium of ancestral Mojave River** *Pleistocene to Pliocene*

pTb — **Igneous and metamorphic basement complex** *Pre-Tertiary*

Source: Figure 8 (page 20) Stamos, C.L., Martin, P., Nishikawa, T., and Cox, B.F, Simulation of Ground-Water Flow in the Mojave River Basin, California. Water-Resources Investigations Report 01-4002 Version 3, US Geological Survey, Sacramento, CA, Fig. 8 (2001) https://pubs.usgs.gov/wri/wri014002/.

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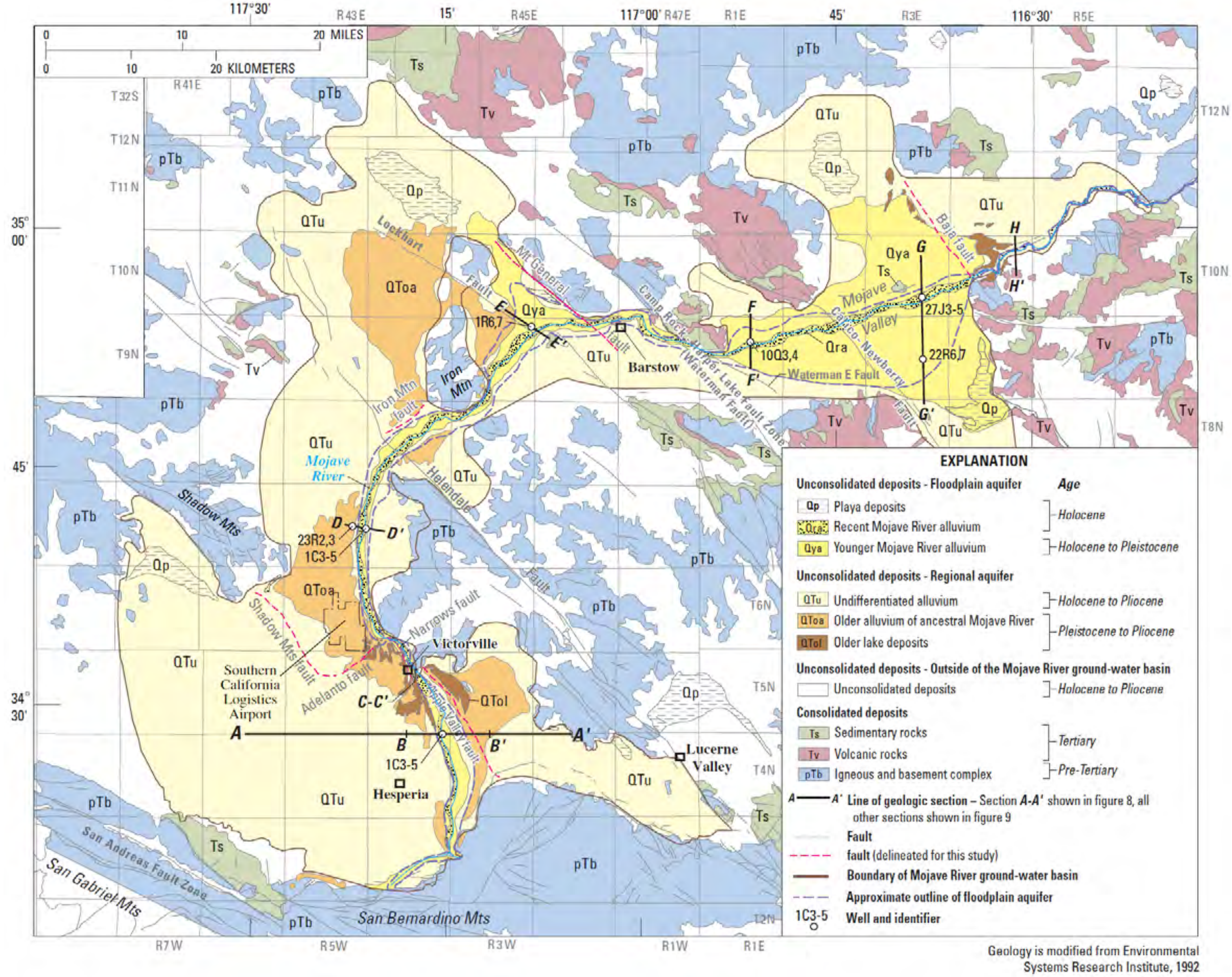
Golden State Water Company - Mojave

Typical Geologic Cross-Section of Mojave River Groundwater Basin

Date: 9/4/2024	Project #: 018-10	**Figure B-2**

GSWC 0111



Source: Stamos, C.L., Martin, P., Nishikawa, T., and Cox, B.F, Simulation of Ground-Water Flow in the Mojave River Basin, California. Water-Resources Investigations Report 01-4002 Version 3, US Geological Survey, Sacramento, CA, Fig. 7 (page 18) (2001) https://pubs.usgs.gov/wri/wri014002/.

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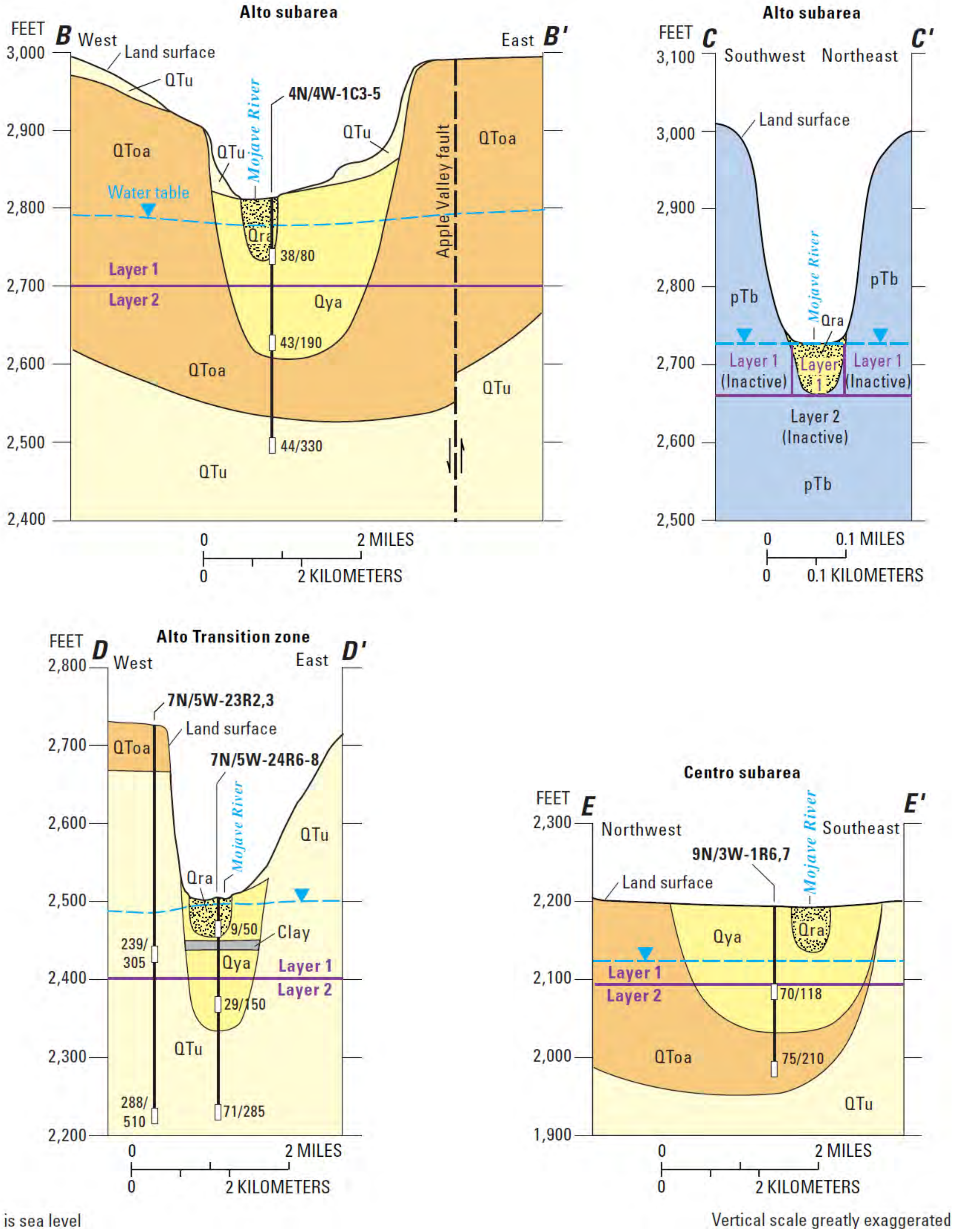
Geology of Mojave River Groundwater Basin

Date: 9/4/2024	Project #: 018-10	**Figure B-3**

GSWC 0112



Source: Stamos, C.L., Martin, P., Nishikawa, T., and Cox, B.F, Simulation of Ground-Water Flow in the Mojave River Basin, California. Water-Resources Investigations Report 01-4002 Version 3, US Geological Survey, Sacramento, CA, Fig. 9 (page 22) (2001) https://pubs.usgs.gov/wri/wri014002/

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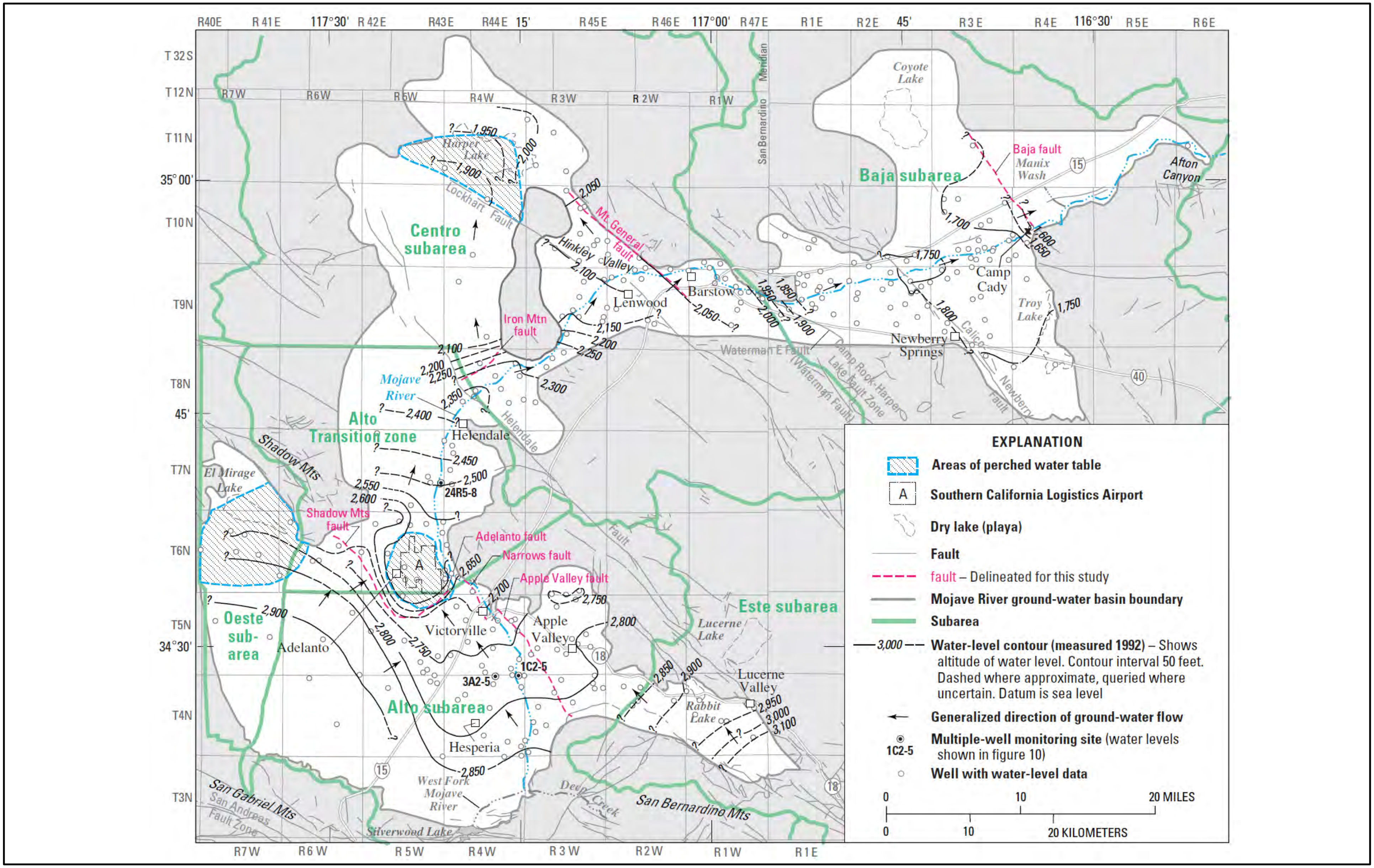
Conceptualization of the ground-water flow system and model layers at various locations along the Mojave River in Alto and Alton Transition areas

Date: 9/4/2024	Project #: 018-10	**Figure B-4**



Source: Stamos, C.L., Martin, P., Nishikawa, T., and Cox, B.F, Simulation of Ground-Water Flow in the Mojave River Basin, California. Water-Resources Investigations Report 01-4002 Version 3, US Geological Survey, Sacramento, CA, Fig. 11 (page 26) (2001) https://pubs.usgs.gov/wri/wri014002/.

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Altitude of water levels and generalized direction of ground-water flow in the Mojave River ground-water basin, southern California, November 1992

Date: 9/4/2024	Project #: 018-10	**Figure B-5**

GSWC 0114

APPENDIX C ANTHONY BROWN CURRICULUM VITAE

aquilogic, Inc.
environment • water • strategy

185 San Leandro Way
San Francisco, CA 94127
Office: +1.714.770.8040
Web: www.aquilogic.com

CURRICULUM VITAE

January 2024

Anthony Brown

he/his/him
Principal Hydrologist

mobile: +1.949.939.7160
email: anthony.brown@aquilogic.com

Disciplines

Hydrology, Hydrogeology, Water Resources, Water Quality, Water Supply, Drinking Water Treatment, Contaminant Source Identification, Contaminant Fate and Transport, Soil and Groundwater Remediation, Environmental Liability Management, Legal and Regulatory Strategy.

Education

M.Sc. Engineering Hydrology, Imperial College London, 1989
D.I.C. Postgraduate diploma in Civil Engineering, Imperial College London, 1988
B.A. Geography, King's College London, 1985

Professional Experience

Anthony is a versatile and proficient professional with over 30 years of experience in hydrology, hydrogeology, water resources, water quality, fate and transport of contaminants, groundwater remediation, regulatory strategy, water resources evaluation, and water supply engineering.

Anthony has conducted and managed numerous groundwater resources projects, including:

- resource evaluation, development, and management
- water balance, storage capacity and safe yield analysis
- water rights disputes and adjudication
- marginal groundwater development (e.g., brackish water)
- aquifer storage and recovery (ASR)
- indirect potable reuse (IPR).

He has also implemented hundreds of hazardous waste site investigations, including sites with multiple potentially responsible parties (PRPs), complex hydrogeology and fate and transport, fractured rock, multiple contaminants, and co-mingled plumes. This work has included detailed Remedial Investigation (RI) or Phase II characterization studies, groundwater flow and solute transport modeling, Preliminary Endangerment Assessments, Human Health Risk Assessments, and remedial feasibility studies (FS), remedial system design and implementation. Anthony has been involved in the design, testing, and permitting of drinking water treatment systems for impaired (contaminated) water sources.

Anthony has provided expert services to many prominent water and environmental law firms, the Attorneys General of California, New Jersey, Pennsylvania, Maryland, Ohio, North Carolina, and Puerto Rico, several County District Attorneys, and numerous City Attorneys' Offices.

Through his work for water utilities impacted by gasoline constituents (e.g. MTBE), chlorinated solvents (e.g. PCE, TCE), solvent stabilizers (e.g. 1,4-dioxane), soil fumigants (e.g. 1,2,3-TCP), chlorofluorocarbons (e.g. Freon 11, 12 and 113), perfluorinated compounds (i.e., PFAS), the rocket propellants perchlorate and NDMA, and hexavalent chromium, arsenic and other metals, Anthony has become a recognized expert in the fate, transport, and remediation of these compounds, and the protection of source waters from contamination by such recalcitrant chemicals.

Amongst other technical areas of expertise, he has also provided expert advice related to:

- groundwater resource development
- groundwater basin management
- California Sustainable Groundwater Management Act (SGMA)
- water rights and the development of physical solutions
- groundwater discharges and the Clean Water Act
- compliance with the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) and National Contingency Plan (NCP)
- cleanup under the Resource Conservation and Recovery Act (RCRA)
- the environmental impact of oil field contaminants and their mitigation
- source identification and mitigation of bacteria and fecal contamination in coastal waters
- source identification and persistence of microplastics in coastal waters.

Through his extensive experience on "high-profile" projects, Anthony has developed an excellent working relationship with private and public sector clients, Federal, State, and local elected officials and government agency staff, the legal community, professional organizations, non-profit environmental organizations, and his colleagues in the environmental and water resources professions.

Anthony has also testified before the U.S. Senate and briefed White House staff, federal, State, and local elected officials and regulators, independent commissions, professional groups, academic institutions, and the news media (including CBS 60 Minutes, National Public Radio [NPR] and local newspapers) on groundwater issues.

Beyond his US experience, Anthony has worked on projects in the United Kingdom, Ireland, Canada, Mexico, Costa Rica, Columbia, Ecuador, Yemen, Egypt, and Nepal.

U.S. Senate Testimony and Briefings for Elected Officials

- Testimony before the U.S. Senate Committee on Environment and Public Works on "the Appropriate Role of States and the Federal Government in Protecting Groundwater", on April 18, 2018.
- Briefing for White House Officials and the Council on Environmental Quality on "the Impact of MTBE on Water Resources of the United States", in October 1997.
- Briefing for U.S. Senators Feinstein and Boxer on "MTBE Contamination of the City of Santa Monica Water Supply", in October 1997.
- Briefing for Assistant Administrators and other leadership at the US Environmental Protection Agency (EPA) on "the Impact of MTBE on Water Resources of the United States", in October 1997.
- Briefing of State Senator Sheila Kuehl, several Assembly members, leadership at the California Environmental Protection Agency (CalEPA) and State Water Resources Control Board (SWRCB) on "MTBE Contamination of the City of Santa Monica Water Supply", in 1997-1998

Anthony has also briefed the following on the impact of fuel oxygenates, chlorinated solvents, rocket propellants, metals, oil field activities, and bacteria on water quality:

- USEPA staff (Region IX)
- State Senators and Assembly Members
- State regulators
- Local officials (Mayors, council and board members, City attorneys, etc.)
- Independent Commissions
- Professional bodies (ABA, ACS, ACWA, AEHS, AGWA, NGWA, GRA, etc.)
- Academic institutions and many other organizations
- Media outlets (NPR, CBS 60 Minutes, local TV stations)

Expert Consulting and Witness Services

Anthony is a respected, credible, and highly effective expert witness. He has testified at trial (blue text) on 14 occasions, including three times in Federal court. Anthony is currently scheduled to testify in another five trials during the next 18 months. Overall, he has been retained as an expert in over 80 matters related to water rights, water resources management, and water pollution (including representing hundreds of parties in multi-district litigation [MDL]). Anthony has provided deposition testimony (red text) on 40 occasions and these depositions have lasted from one to 32 days in length.

Active:

- Multiple water utility plaintiffs vs. Fluorotelomer defendants et al. (Trial sites in Phase 2 of multi-district litigation [MDL] for impact on water supplies by PFAS) – US District Court, District of South Carolina (discovery)
- State of Wisconsin vs. Johnson Controls Inc. and Tyco Fire Products et al. (PFAS contamination of soil, sediment, surface water, groundwater, and drinking water from a fire training facility in northern Wisconsin) – Wisconsin Superior Court (expert report, deposition scheduled)
- Kern River Water Association vs. Sandridge Partners (Dispute over the transfer and beneficial use of groundwater in the San Joaquin Valley) - California Superior Court, Kern County (discovery)
- Separate matters for several (5+) confidential State clients vs. 3M et al. (Contamination of natural resources [soil, surface water, groundwater, State-owned lands] by Per- and Polyfluoroalkyl substances [PFAS]) – Various State Superior Courts (various stages ranging from discovery through settlement, including expert reports for two states so far)
- Environmental NGO vs. Confidential California County et al (Public trust action related to discharges of groundwater that support stream flows and ecological habitat) – California Superior Court (discovery)
- 12909 Cordary LLC vs. Hussein Berry, Excaliber Fuels, et al (MTBE and benzene contamination associated with a gasoline service station extending beneath an apartment complex) - California Superior Court, Orange County (expert report, trial scheduled)
- Separate matters for numerous municipal and county water utilities and water management districts vs. DuPont er al. (Impact of PFAS on water supplies) – Various State Superior Courts (discovery)
- Confidential California City vs. Confidential Defendant (Impact of releases of perchlorate, chlorinated solvents, 1,2,3-trichlorpropane [TCP], and PFAS at an aerospace facility on municipal water supply wells) – California Superior Court, Los Angeles County (discovery)
- Confidential Alabama community vs. Major landfill owner/operator (Soil, sediment, surface water, groundwater, and drinking water contamination associated with an active landfill) – Alabama Superior Court
- Landowner group vs. Confidential county water district (Pending adjudication of groundwater rights in several groundwater subbasins in Central California) – California Superior Court (pre-discovery)
- Andorra vs. Fabricure et al (Contamination of groundwater and soil gas beneath a large apartment complex associated with releases at an adjacent dry cleaners) – US District Court, Central District of California (discovery)

- Confidential Southern California City vs. Confidential Defendant (Impact of releases of perchlorate, 1,2,3-TCP, and solvents at an aerospace research and testing facility on municipal water supply wells) – California Superior Court, Los Angeles County (discovery)
- Confidential State client vs. Paint Manufacturer (Restoration of soil, sediment, groundwater, and surface water contaminated by discharges at a former paint manufacturing facility) – US District Court (discovery)
- Grimmway and Bolthouse Farms vs. numerous water right holders (water rights adjudication in the Cuyama Valley) – California Superior Court, Los Angeles County (discovery, expert reports, deposition, trial scheduled)
- Mobile Baykeeper vs. Alabama Power (Contamination of groundwater and surface water by coal combustion residual [CCRs] placed in a coal ash lagoon) – US District Court, Southern District of Alabama (discovery)
- Lanier Parkway Associates vs. Hercules Chemical (Ashland) (the impact of benzene and chlorobenzene contamination from a chemical facility on an adjacent commercial property) – Superior Court of Glynn County, Georgia (expert affidavit)
- College Park East vs. Midway City Sanitary District et al (groundwater contamination by chlorinated solvents at a former dry cleaner) - US District Court, Central District of California (discovery)
- Mojave Pistachios et al vs. Indian Wells Valley Groundwater Authority (IWVGA) (challenge to the Groundwater Sustainability Plan [GSP] and associated pumping fees in a groundwater basin in eastern Kern County) – California Superior Court, Kern County (discovery)
- James J. Kim vs. L. Tarnol et al (chlorinated solvent contamination at a former dry cleaner in Glendale) – California Superior Court, Los Angeles County (discovery, expert affidavit)
- Oxnard Pleasant Valley Landowner Group v. Fox Canyon Groundwater Management Agency (water rights dispute) – California Superior Court, Los Angeles County (discovery)
- Stoll vs. Ewing et al (chlorinated solvent contamination at a former dry cleaner in Pleasanton) - US District Court, Northern District of California (discovery)
- San Luis Obispo Coastkeeper et al vs. Santa Maria Valley Water Conservation District et al (dispute over surface water flows to enhance steelhead habitat in the Santa Maria River watershed, Santa Barbara County) – US District Court, Central District of California (discovery)
- Mojave Pistachios vs. Indian Wells Valley Water District (IWVWD) et al (water rights dispute in eastern Kern County between agricultural interests and public water purveyors) – California Superior Court, Kern County (discovery)
- Santa Barbara Channel-keeper et al vs. City of San Buenaventura et al (adjudication of surface water and groundwater rights in the Ventura River watershed, Ventura County) – California Superior Court, Los Angeles (expert report, deposition)
- Commonwealth of Pennsylvania vs. ExxonMobil, et al (State-wide assessment of impact and damages associated with MTBE and TBA releases) – US Federal Court, Southern District of New York (expert reports, deposition [22 days])

- State of Maryland vs. ExxonMobil et al (State-wide assessment of impact and damages associated with MTBE and TBA releases in Maryland) – US Federal Court, Southern District of New York (discovery)
- Steinbeck Winery et al vs. City of Paso Robles et al (Quiet title action brought by a group of wineries against the public water agencies to adjudicate water rights) - California Superior Court, San Jose (deposition, Phase 2 and Phase 3 trial testimony, Phase 4 pending)
- Various individuals vs. San Luis Obispo County et al (Trichloroethene [TCE] contamination in groundwater and water supply wells in a community adjacent to a County-operated airport) – California Superior Court, San Luis Obispo (litigation stayed)
- Commonwealth of Puerto Rico vs. Shell Oil Co., et al (Island-wide assessment of impact and damages associated with MTBE and TBA releases in Puerto Rico) – US Federal Court, Southern District of New York (expert reports, deposition [10 days])
- New Jersey Department of Environmental Protection (NJDEP) vs. Sunoco et al (State-wide assessment of impact and damages associated with MTBE and TBA releases in New Jersey) – US Federal Court, Southern District of New York (expert reports, deposition [17 days], hearing testimony)
- Orange County Water District (OCWD) vs. Sabic Innovative Plastics et al (Chlorinated solvent, 1,4-dioxane and perchlorate contamination of groundwater resources from various sites in Orange County, California) – California Superior Court, Orange County (expert reports, deposition [32 days], trial testimony)
- City of Modesto vs. Vulcan Chemical et al (perchloroethylene [PCE] releases from numerous dry cleaners contaminating drinking water wells and groundwater resources) – California Superior Court, San Francisco (expert reports, deposition [25 days], trial testimony [twice])

Past:

- Town of Ayer, MA vs. 3M et al. (Trial site in Phase 1 of MDL for over 200 cases related to the impact on water supplies by PFAS) – US District Court, District of South Carolina (expert report, deposition, $13 B settlement)
- City of Lincoln vs. Placer County (CERCLA cost recovery action for contamination at a former landfill) – US District Court, Eastern District of California (expert report, deposition, settled)
- TC Rich et al vs. Shaikh et al (chlorinated solvent contamination at a former small batch chemical distributor in Los Angeles) - US District Court, Central District of California (expert report, deposition, settled)
- City of Stuart, FL vs. 3M et al. (Trial site in Phase 1 of MDL for over 200 cases related to the impact on water supplies by PFAS) – US District Court, District of South Carolina (expert report, deposition, $13 B settlement)
- Las Posas Valley Water Rights Coalition et al vs. Fox Canyon Groundwater Management Agency et al (adjudication of water rights in the Las Posas Groundwater Basin, Ventura County) – California Superior Court, Santa Barbara County (expert reports, deposition, Phase 2

and Phase 3 trial testimony, favorable final statement of decision in which my expert reports were cited 33 times as a basis for the decision)

- City of Sioux Falls, SD vs. 3M et al. (Trial site in Phase 1 of MDL for over 200 cases related to the impact on water supplies by PFAS) – US District Court, District of South Carolina (expert report, deposition, $13 B settlement)
- City of Fresno vs. Shell Chemical et al (1,2,3-TCP contamination of groundwater resources and water supply wells) – California Superior Court (settled)
- Goleta Water District vs. Slippery Rock Ranch (water rights dispute in central California between an avocado ranch adjacent to an adjudicated groundwater basin) – California Superior Court, Santa Barbara (expert reports, deposition, settled)
- Friends of Riverside Airport vs. Department of the Army et al (CERCLA cost recovery action for poly-chlorinated biphenyl [PCB] contamination at a former wastewater treatment plant in Riverside, California) US District Court, Central District of California (expert report, deposition, case dismissed on summary judgment)
- City of Corona vs. Dow Chemical et al (1,2,3-TCP contamination of groundwater resources and water supply wells) – US District Court, Southern District of California (settled)
- Black Warrior Riverkeeper et al vs. Drummond Coal (acid mine drainage from a former coal mine impacting a tributary of the Black Warrior River, Alabama) – US Federal Court, Middle District of Alabama, Birmingham (expert report, deposition, settled)
- City of Riverside vs. Goodrich et al (perchlorate contamination of groundwater resources and water supply wells) - California Superior Court (expert declaration, deposition)
- Bakman Water Company vs. Dow Chemical et al (1,2,3-TCP contamination of groundwater resources and water supply wells) – US District Court, Central District of California (settled)
- Borrego Water District (water rights dispute and physical solution) – California Superior Court, San Diego (stipulated adjudication)
- Charleston Waterkeeper and South Carolina Coastal Conservation League vs. Frontier Logistics (lawsuit over polyethylene nurdle pollution in and around Charleston Harbor) - US District Court, Charleston District of South Carolina (expert report, settled)
- City of Arcadia vs. Dow Chemical et al (1,2,3-TCP contamination of groundwater resources and water supply wells) – US District Court, Central District of California (expert report, settled)
- City of Upland vs. Dow Chemical et al (1,2,3-TCP contamination of groundwater resources and water supply wells) – US District Court, Central District of California (expert report, settled)
- San Miguel Electric Cooperative vs. Peeler Ranch (contamination of soil, surface water and groundwater beneath a ranch from a lignite mine and coal-fired power plant) – Texas Superior Court, 218th District (expert report, deposition, hearing testimony, settled)
- Sunnyslope Water Company vs. Dow Chemical et al (1,2,3-TCP contamination of groundwater resources and water supply wells) – US Federal Court, Southern District of California (expert report, settled)

- City of Hemet vs. Dow Chemical et al (1,2,3-TCP contamination of groundwater resources and water supply wells) – US Federal Court, Southern District of California (expert report, settled)
- Sierra Club et al vs. Dominion Energy (contamination of groundwater and surface water resources by coal combustion residuals [CCRs] from ash ponds) – US Federal Court, Eastern District of Virginia (expert report, deposition, trial testimony)
- Sunny Slope Water Company vs. Dow Chemical et al (1,2,3-TCP contamination of groundwater resources and water supply wells) – California Superior Court, Los Angeles County (settled)
- Greenfield et al vs. Ametek Aerospace et al (solvent contamination in groundwater beneath three mobile home parks) – US Federal Court, Southern District of California, San Diego (expert report, deposition, settled)
- Golden State Water Company vs. Dow Chemical et al (1,2,3-TCP contamination of groundwater resources and water supply wells in Nipomo and Claremont) – US Federal Court, Southern District of California (expert report, settled)
- National Association for the Advancement of Colored People (NAACP) vs. Duke Energy (coal ash contamination of groundwater, sediments, and surface waters at the Belews Creek coal-fired power plant) – US Federal Court, Middle District of North Carolina (expert report, settled)
- City of Atwater vs. Shell Chemical et al (1,2,3-TCP contamination of groundwater resources and water supply wells) – California Superior Court (expert report, deposition, trial testimony)
- State of Vermont vs. ExxonMobil et al (State-wide assessment of impact and damages associated with MTBE and TBA releases in Vermont) – US Federal Court, Southern District of New York (settled)
- Trujillo et al vs. Ametek Aerospace et al (solvent contamination in groundwater beneath an elementary school) – US Federal Court, Southern District of California, San Diego (expert report, deposition, settled)
- Roanoke River Basin Association vs. Duke Energy (coal ash contamination of groundwater, sediments, and surface waters at two coal-fired power plants: Mayo and Roxboro) – US Federal Court, Middle District of North Carolina (expert report, deposition, settled)
- OCWD vs. Unocal et al (MTBE and TBA contamination of groundwater resources from service station sites in Orange County, California) – US Federal Court, Southern District of New York (expert reports, deposition [12 days], settled)
- State of North Carolina vs. Duke Energy (administrative hearing related to coal ash contamination at six power plants) – North Carolina Superior Court (settled)
- City of Clovis vs. Dow Chemical et al (1,2,3-TCP contamination of groundwater resources and water supply wells) – California Superior Court (expert report, deposition, trial testimony)
- San Juan Hills Golf Course vs. City of San Juan Capistrano et al (suit filed over groundwater pumping in the San Juan Basin) – California Superior Court, Orange County (settled)
- City of Tulare vs. Dow Chemical et al (1,2,3-TCP contamination of groundwater resources and water supply wells) – California Superior Court (settled)

- State of California vs. Columbia Casualty Company et al (perchlorate and solvent contamination at the Stringfellow Acid Waste disposal pits in Glen Avon) – California Superior Court (expert report, settled)
- City of Delano vs. Crop Production Services (CPS) et al (Nitrate contamination of water supply wells) - California Superior Court (settled)
- Laborers' International Union of North America Local Union No. 783 v. Santa Margarita Water District et al. (Review of the groundwater hydrology of the Cadiz project, San Bernardino County) - California Superior Court, Orange County (independent expert report, settled)
- Southern California Water Company vs. Aerojet General Corp. (TCE, perchlorate and NDMA contamination of drinking water supplies in Rancho Cordova, California) – California Superior Court, Sacramento District (expert report, deposition, settled)
- The City of Stockton Redevelopment Agency (RDA) vs. Conoco-Phillips et al (petroleum hydrocarbon contamination at former oil terminals) – California Superior Court (deposition, settled)
- PK Investments vs. Barry Avenue Plating (hexavalent chromium and solvent contamination of soil and groundwater) - California Superior Court, Los Angeles District (deposition, settled)
- City of Santa Monica, California vs. Shell et al (MTBE contamination of drinking water supplies) – California Superior Court, Orange County District (expert report, deposition, settled)
- State of California vs. Joint Underwriters (perchlorate and solvent contamination at the Stringfellow Acid Waste disposal pits in Glen Avon) – California Superior Court (expert report, deposition, settled)
- Community of Broad Creek, North Carolina vs. BP Amoco et al (MTBE, benzene and 1,2-DCA contamination of private water supply wells) – North Carolina Superior Court (deposition, settled)
- South Tahoe Public Utility District, California vs. ARCO et al (MTBE contamination of drinking water supplies) - California Superior Court, San Francisco (expert report, deposition [13 days], trial testimony)
- Private well owners in 18 reformulated gasoline (RFG) states vs. various oil companies (class action related to MTBE) - US Federal Court, New York District (deposition, class certification hearing)
- Individual plaintiffs vs. Lockheed Corporation (TCE and perchlorate contamination of drinking water supplies in Redlands, California) – California Superior Court, Los Angeles District (deposition, settled)
- City of Norwalk vs. Five Point U-Serve et al (1.2-DCA contamination of a municipal drinking water well) – California Superior Court (deposition, case dismissed)
- Forest City Corp. vs. Prudential Real Estate (PCE contamination of soil and groundwater) – California Superior Court, Los Angeles District (deposition, trial testimony)

- Huhtamaki vs. Ameripride (chlorinated solvent contamination at a commercial dry cleaner/ laundry facility) – California Superior Court, Sacramento District (expert report, deposition, settled)
- Consolidated Electrical Distributors (CED) vs. Hebdon Electronics et al (chlorinated solvent contamination in fractured granite) - California Superior Court, North San Diego District (expert report, deposition, trial testimony)
- Southern California Water Company vs. various parties (water rights petition and adjudication for the American River, Sacramento, California) – State Water Resources Control Board, Sacramento
- The City of Santa Monica, California vs. ExxonMobil Corporation (MTBE contamination of drinking water supplies) – California Superior Court (designated, settled, retained as consultant to both parties for remedy implementation)
- The town of Glenville, California vs. various parties (MTBE contamination of drinking water supplies in Kern County, California) - California Superior Court (designated, settled)
- Great Oaks Water Company vs. Chevron and Tosco (MTBE contamination of drinking water supplies in San Jose, California) - California Superior Court (designated, settled)
- Orange County District Attorney's Office vs. ARCO et al (Underground Storage Tank [UST] violations, and MTBE contamination of soil and groundwater) - California Superior Court (designated, settled)
- Cambria Community Services District (CCSD) vs. Chevron et al (MTBE impact to drinking water supplies) in San Luis Obispo County, California - California Superior Court (designated, settled)
- Los Osos Community Services District (CCSD) vs. Chevron et al (MTBE impact to drinking water supplies) in San Luis Obispo County, California - California Superior Court (designated, settled)
- The town of East Alton, Illinois vs. various parties (MTBE contamination of drinking water supplies) – Illinois Superior Court, Jefferson County (designated, settled)
- The City of Dinuba vs. Tosco et al (MTBE contamination of groundwater resources) - California Superior Court (expert report, settled during deposition)
- Stella Stephens vs. Bazz-Houston et al (chlorinated solvent contamination at an active metal finishing facility in Garden Grove, California) - California Superior Court (designated, settled)
- Communities for a Better Environment (CBE) vs. Chrome Crankshaft (hexavalent chromium and TCE contamination beneath a chrome plating facility and adjacent school) - California Superior Court (designated, settled)
- California Attorney General's Office vs. Unocal (Natural Resource Damage Assessment [NRDA] at a former oil field in the central coast of California) - California Superior Court (designated, settled)
- Phillips Petroleum Corporation vs. private property owner (contamination from a former oil well in Signal Hill, California) - California Superior Court (designated, settled)
- Mobil Oil Corporation vs. private property owner (contamination from a former bulk fuel plant in the Bay Delta area) – California Superior Court (designated, settled)

- Mobil Oil Corporation vs. terminal operator (contamination from a former bulk fuel plant in Monterey area) – California Superior Court (designated, settled)

General Project Experience

Anthony has acted as the Principal in Charge, Project Manager (PM), Quality Assurance (QA) Manager and/or Principal Review for the following ongoing or recently completed projects:

Current Water Resources Projects

- Analysis of the transfer and beneficial use of groundwater within a defined watershed and groundwater sustainability agency (GSA) - Sandridge Partners
- Assessment of groundwater discharges that support stream flows and aquatic habitat in northern California – Confidential Client
- Evaluation of Hydrologic Conditions, Safe Yield, and Management Actions in the Cuyama Basin – Confidential Client
- Evaluation of groundwater conditions, including groundwater in storage and safe yield, and management actions in a basin subject to SGMA – Confidential Client
- Assessment of Water Source Reliability, Both Yield and Quality, for a Large Water Supply Project in South Florida – Confidential Client
- Analysis of Basin Hydrology, Recharge, Water Budgets, and Inter-Basin Flows in the Mojave River Basin – Confidential Client
- Review of the Effect of Releases from a Reservoir on Surface Water Flows Intended to Enhance California Steelhead Habitat, and the Potential Impact on Groundwater Recharge – City of Santa Maria, Golden State Water Company
- Evaluation of the Effects of Aquifer Connectivity and Well Bore Leakage on Saltwater Intrusion in the Upper Salinas Basin – Confidential Client
- An Investigation of the Hydrology of Perennial Spring in the Mojave Desert, as it Relates to Potential Impact from a Groundwater Resource Development Project - Three Valleys Municipal Water District
- Consulting Support Related to the Implementation of SGMA in the Pleasant Valley and Oxnard Plain Groundwater Basins, Pleasant Valley County Water District, Guadalasca Mutual Water Company.
- Consulting Support for a Surface Water and Groundwater Rights Dispute in the Ventura River Watershed – Group of Confidential Landowners
- Support Related to a New Car Manufacturing Plant in Huntsville, Alabama, and potential impact on habitat for an endangered species of fish – Center for Biological Diversity
- Review of the Groundwater Monitoring, Management, and Mitigation Plan (GMMMP) for the Cadiz Water Conservation Project – Three Valleys Municipal Water District
- Groundwater Consulting Support to an Agricultural Business in southeast Kern County Located within a Partially Adjudicated Basin – SunSelect

- Strategic Groundwater Consulting Support to a Large Golf Resort Located in a Desert Groundwater Basin Subject to Critical Overdraft under SGMA – Rams Hill GC
- Assessment of Water Resources at Oil Fields Throughout California and the Development of Produced Waters as an Alternate Water Supply – California Resources Corporation (CRC)
- Support Related to SGMA, Possible Adjudication, and Overall Groundwater Management Strategy for a Municipality in Southern California – Confidential Municipal Client
- Consulting Support for a Groundwater Rights Adjudication in the Las Posas Groundwater Basin, Ventura County – Group of Large Landowners
- Support Related to SGMA, Salinity Management, Alternate Water Sources, and Overall Groundwater Management Strategy for a Grower in the Bay-Delta – Wonderful Orchards
- Evaluation of the Feasibility of Using Brackish Groundwater and Oilfield Produced Water as an Alternate Water Supply for a Basin in Critical Overdraft – Northwest Kern Brackish and Oilfield (BOF) Water Study Group
- Support Related to SGMA, Possible Adjudication, and Overall Groundwater Management Strategy for a Large Water District in the Central Valley – Confidential Water District Client
- Water Rights Dispute Between a Water District and an Avocado Ranch in Central California – Slippery Rock Ranch
- Evaluation of the Feasibility of Using Brackish Groundwater as an Alternate Water Supply for a Closed Desert Basin in Critical Overdraft – Indian Wells Valley Brackish Water Study Group
- Development of a Plan for an Adjudication of Water Rights in a Desert Basin and the Principles of a Groundwater Management Plan (i.e., Physical Solution) – Confidential Water District Client
- Support Related to SGMA for Water Districts on the West Side of Kern County, Including the Creation of Defined Groundwater Management Areas – Westside District Water Authority
- Support to Agricultural Interests in the "White Areas" in Madera County with Respect to the Implementation of the California Sustainable Groundwater Management ACT (SGMA) – Madera County Farm Bureau
- Evaluation of Water Supply Options, Including New Water Supply Wells, for a Major Oilfield in West Fresno County – CRC
- Development of a Water Budget for a Baseline Period, and Evaluation of Native Safe Yield, Annual Operating Safe Yield, Historical Pumping, and Conditions of Overdraft as Part of a Water Rights Dispute in the Central Coast of California – City of Paso Robles
- Design and Permitting of an Aquifer Storage and Recovery (ASR) Project for Indirect Potable Reuse (IPR) of Tertiary Treated Municipal and Industrial Wastewater – City of Fresno
- Assessment of Increased Pumping at a Data Center and the Impact on Nearby Municipal Water Supply Wells in Charleston, South Carolina – Southern Environmental Law Center (SELC)
- Litigation Support and Development of Groundwater Management Approaches as an Alternative to Compliance with the Sustainable Groundwater Management Act – Confidential Water District Client, Southern California

- Groundwater Management Support to a Very Large Agribusiness with Over 170,000 Acres of Almonds, Pistachios, Mandarins, Pomegranates, and Grapes in the San Joaquin Valley - Wonderful Orchards
- Evaluation of Groundwater Conditions and Quality, and The Degree of Hydraulic Connection Between Groundwater Basins, as Part of a Water Rights Dispute in the Central Coast of California – City of Paso Robles
- Development of a Water Supply Well Drilling Ordinance and Valuation of Water Rights for a Confidential Municipality in Southern California
- Support for a Major Agricultural Interest with Holdings in Four Separate Groundwater Basins in Relation to the Implementation of SGMA – RTS Agribusiness
- Development of a New Water Supply Well Field, Including Compliance with California Division of Drinking Water (DDW) Policy 97-005 (Impaired Source Policy), and Evaluation of Groundwater Contamination at a Nearby Aerospace Facility – City of Torrance
- Evaluation of Aquifer Characteristics and Groundwater Conditions Related to the Reinjection of Oil Field Produced Water and Development of a Strategy to Obtain an Aquifer Exemption – Confidential Oil Company
- Development of a recycled water program (including possible aquifer storage and recovery [ASR]/salt-water intrusion program) using advanced treatment of a blend of brackish groundwater and urban storm-water – City of Santa Monica
- Membership of the Technical Advisory Committee (TAC) of a Cooperative Groundwater Group that will Become a Groundwater Sustainability Agency (GSA) – Indian Wells Valley
- Evaluation of Basin Hydrogeology, Groundwater Conditions, Water Quality, and Well Production in a Riparian Coastal Basin in Southern California – City of San Juan Capistrano
- Investigation and Development of Alternate Groundwater Supplies for an Agricultural Interest with Land Holdings in an Arid California Valley – Mojave Pistachios
- Development of a 50,000 acre-foot per year (AFY) ASR Project in the Eastern Portion of a Large Agricultural Valley in Southeast California – Confidential Client
- Review of the Groundwater Hydrology of the Cadiz Project – an independent expert report prepared for Orange County Superior Court in re: Laborers' International Union of North America Local Union No. 783 v. Santa Margarita Water District et al.

Petroleum Hydrocarbons

- Assessment of the Impact of MTBE/TBA Contamination of Water Resources in the State of Vermont, Including Contamination at Release Sites, Public Water Supply Wells, and Private Domestic Wells – State of Vermont
- Contamination of soil vapor and groundwater beneath an apartment complex associated with releases of oxygenated fuels and solvents at an active gasoline service station – Confidential Client

- Evaluation of Produced Water Management Options for Two Active Oil Fields in Southern California, including Treatment and Beneficial Use - CRC
- Assessment of the Impact of MTBE/TBA Contamination of Groundwater Resources in the State of Maryland, and Development of Costs to Address the Contamination at Release Sites, Public Water Supply Wells, and Private Domestic Wells – State of Maryland
- Investigation of Petroleum Hydrocarbon Contamination Related to Releases at a Pipeline that Crosses a Large Ranch in the Central Coast of California – Twin Oaks Ranch
- Assessment of Petroleum Contamination from a Large Pipeline Release that is Discharging to Two Streams and a Wetland in Belton, South Carolina – Southern Environmental Law Center (SELC)
- Evaluation of Contamination by Petroleum Hydrocarbons from a Pipeline Release at a Large Ranch/Winery in the Central Coast of California, and Development of a Conceptual Remedial Program and Costs to Implement – Santa Margarita Ranch, California
- Assessment of the Impact of MTBE/TBA Contamination of Groundwater Resources in the State of Pennsylvania, and Development of Costs to Address the Contamination at Release Sites, Public Water Supply Wells, and Private Domestic Wells – Commonwealth of Pennsylvania
- Investigation and Remediation of MTBE/TBA and Petroleum Hydrocarbon Contamination (using surfactant enhanced product recovery) at a Maintenance Facility in Hawthorne, California – Golden State Water Company
- Assessment of the Effectiveness of Site Investigation and Remediation Activities, Investigation of Off-Site Groundwater Contamination by MTBE/TBA, and Development of Remedial Programs (and Costs) at "Bellwether" Trial Sites - Orange County Water District
- Evaluation of Contaminant Conditions and Prior Site Investigation and Remediation Activity, Implementation of Off-site Investigations, and Development of Remedial Programs and Associated Costs to Address MTBE/TBA Contamination at Trial Sites in Puerto Rico – Commonwealth of Puerto Rico
- Assessment of Site Investigation and Remediation Activities, Investigation of Off-Site Groundwater MTBE/TBA Contamination, and Development of Remedial Programs (and Costs) at Trial Sites – New Jersey Department of Environmental Protection (NJDEP)
- Environmental Impact Report (EIR) and Baseline Environmental Assessment at a Proposed Oil Field Redevelopment Project, Southern Iraq - Confidential Client
- Development of a Remediation Approach and Costs for Soil and Groundwater Contamination at Two Former Petroleum Terminals – Stockton Redevelopment Agency
- Assessment of the Nature of Contamination and the Costs to Address this Contamination at a Former Municipal Landfill in San Diego County – Confidential Client
- Evaluation of Contaminant Sources, and the Fate and Transport of MTBE, 1,2-DCA and Benzene to Numerous Private Water Supply Wells in the Community of Broad Creek, North Carolina

- Assessment of the Effectiveness of Site Investigation and Remediation Activities to Address MTBE/TBA/Benzene Contamination at ARCO and Thrifty Service Stations Throughout Orange County, California - Orange County District Attorney's Office
- Evaluation of Contaminant Sources, Fate, Transport, and Impact of MTBE and TBA to Public Water Supplies, and the Costs to Treat these Contaminants, in the town of East Alton, Illinois
- Court Appointed Consultant to Develop Site Investigation Programs for MTBE/TBA/Benzene Contamination at 35 Thrifty Service Stations in Orange County
- Impact and Mitigation of Oil Field Contaminants at the Belmont Learning Center – Los Angeles Unified School District (LAUSD) - Belmont Commission
- Investigation, PRP Identification, Remediation and Restoration of Municipal Well Fields Impacted by MTBE Contamination – City of Santa Monica (Charnock Well Field), South Lake Tahoe Public Utility District (STPUD), Santa Clara Valley Water District (SCVWD), Great Oaks Water Company
- Oversight of Oil Company Investigation and Remediation Programs in Honolulu Harbor, Hawaii – US Environmental Protection Agency (USEPA)
- Assessment of Oil Field Contaminants in Relation to High Incidences of Leukemia and non-Hodgkins Lymphoma at a High School in Southern California – Confidential Client
- Evaluation of Fuel Releases and Their Impact upon Groundwater Resources at Service Stations, Bulk Plants, Fuel Terminals and Refineries Throughout California – Confidential Client
- Complete Restoration of Municipal Water Supply Wells Contaminated with MTBE – City of Santa Monica (Arcadia Well Field) and ExxonMobil Corporation
- Preliminary Environmental Assessment (PEA) at the Hull Middle School - located on a former oil field and landfill - Torrance Unified School District (TUSD), California
- Oversight of Investigation and Remediation Activities for a MTBE Release at a Service Station and the Potential Impact on a City's Water Distribution System – City of Oxnard, California
- Investigation of MTBE Contamination of Water Supply Wells and Other Petroleum Hydrocarbon Contamination at a Marine Fueling Depot on Catalina Island – Southern California Edison
- Impact of MTBE Releases at Service Stations and a Bulk Fuel Terminal on Drinking Water Wells and Groundwater Resources - City of Dinuba, California
- Oversight of a Court-ordered MTBE/TBA Plume Delineation Program at Gasoline Service Stations in Orange County, California – OCDA, California
- Oversight and Investigation of Remediation of MTBE Contamination Impacting Drinking Water Supplies in the Towns of Cambria and Los Osos/Baywood Park, California – Cambria Community Services District (CCSD), Los Osos Community Services district (LOCSD), Cal-cities Water Company
- Assessment of the Impact of an MTBE Release on Water Supply Wells, Sewers, and a Wastewater Treatment Plant – City of Morro Bay, California

- Investigation and Remediation of an MTBE Release in the Immediate Vicinity of a Drinking Water Supply Well - City of Cerritos, California
- Assessment of the Impact of Petroleum Hydrocarbon Contamination from a Wolverine Pipeline Release in Jackson, Michigan – Private Property Owner
- Investigation of Fuel Oil LNAPL and Hexavalent Chromium Contamination at a Former Clay Products Manufacturing Facility in Fremont, California – Mission Clay Products
- Assessment of the Impact of MTBE Releases on Water Supply Wells, and Oversight of Responsible Party (RP) Investigation and Remediation Activities - Soquel Creek Water District, California
- MTBE Contamination of Private Drinking Water Supplies and Development of Water Supply Treatment and Replacement Alternatives – Glenville, California
- Assessment of the Impact of MTBE on Drinking Water Supply Wells in Santa Clara County, California – Great Oaks Water Company (GOWC)
- Assessment of Data Gaps and Research Needs Regarding MTBE Impact to Water Resources – UK Environment Agency
- Investigation and Mitigation of the Impact of Oil Field Contaminants on a Large Apartment Complex in Marina del Rey, Los Angeles, California – Confidential Client
- Investigation and Remediation of Methane and Hydrogen Sulfide as Part of the Redevelopment of a Former Oil Field in Carson, California - Dominguez Energy/Carson Companies
- Assessment of Methane and Petroleum Hydrocarbon Contamination at a Former Oil Field in Santa Fe Springs, California – General Petroleum
- Natural Resource Damage Assessment (NRDA) at the Guadalupe Oil Field, California - State of California (Department of Fish and Game [DFG], Oil Spill Prevention and Response [OSPR], Attorney General and Regional Water Quality Control Board [RWQCB])
- Assessment of the Impact of Oil Field Activities on Surface Water and Groundwater Resources in the Central Coast of California – State of California
- Groundwater Investigation and Remediation at Four Petroleum Terminals in Wilmington, Carson, and San Pedro, California - GATX
- Research into Technologies for Treatment of MTBE in Water - Association of California Water Agencies (ACWA) / Western States Petroleum Association (WSPA) / Oxygenated Fuels Association (OFA)
- Characterization and Remediation of a Hydrocarbon Release (including MTBE) from a Refined Product Pipeline in Fractured Bedrock in Illinois – Shell
- Investigation and Remediation of Petroleum Hydrocarbon Contamination Beneath a City Maintenance Yard and City Bus Yard – City of Santa Monica, California
- Investigation and Remediation of a Gasoline Release (including MTBE) in Fractured Bedrock Resulting from a Catastrophic Tank Failure – Intrawest Ski Resorts, California

- Assessment of LNAPL, Aromatic Hydrocarbon, and Chlorinated Solvent Contamination Beneath a Former Waste Disposal Facility in Santa Fe Springs, California – Confidential Client
- Investigation of Soil and Groundwater Contamination at a Fueling Facility at a Municipal Airport – City of Santa Monica, California
- Pipeline Leak Investigation and Remedial Design - Mobil Pipeline, Ft. Tejon, California
- Investigation of a Petroleum Release in Fractured Bedrock - Chevron, Julian, California
- Contribution of Multiple Sources to Groundwater Contamination – Mobil Oil Corporation, La Palma, California
- Forensic Assessment of a Gasoline Release – Mobil Oil Corporation, Santa Monica, California
- Investigation of a Diesel Fuel Release – General Petroleum, Point Hueneme, California
- Service Station Investigations and Remediation (> 60 sites) - Mobil Oil Corporation, World Oil, Los Angeles County Metropolitan Transportation Authority (LACMTA), and Others
- Assessment of a Crude Release from a Former Pipeline - Mobil Oil, Gorman, California
- Remediation of 2,000,000-gallon (7,560 m^3) LNAPL Spill - Gulf Strachan Gas Plant, Alberta

Chlorinated Compounds

- Evaluation of PFAS Contaminant Sources, Extent of Contamination, Fate and Transport, Persistence of Impact at Water Supply Wells, and Selection of Remedial Actions for Release Sites – Confidential Municipal Client, Florida
- Evaluation of soil vapor and groundwater contamination beneath a large apartment complex associated with releases at an adjacent dry cleaner – Confidential Client
- Determination of Damages Associated with PFAS, including Remediation of Soil and Groundwater Contamination, for Several Confidential State Attorneys General
- Assessment of Contaminant Sources, Release Location and Timing, Soil and Groundwater Contamination, and Remedial Actions at a Dry Cleaners in Pleasanton, California – Confidential Property Owner
- Investigation of Numerous PFAS Contaminant Sources, Extent of Contamination, Fate and Transport, and Persistence of Impact at Two Separate Water Supply Well Fields – Confidential Municipal Client, Massachusetts
- Evaluation of Groundwater Contamination at an Aerospace Facility in El Cajon, the Threat to Water Supply Wells, and Vapor Intrusion Concerns at Overlying Properties – Confidential Client
- Investigation of Chlorinated Solvent Contamination of Soil and Groundwater at a Dry Cleaners in Orange County, California – Midway City Sanitation District
- Assessment of PFAS Contaminant Sources, Extent of Contamination, Fate and Transport, Persistence of Impact at Water Supply Wells, and Selection of Remedial Actions for Release Sites – Confidential Municipal Client, South Dakota

- Analysis of Site Operating Records and Soil and Groundwater Contaminant Data to Identify Contaminant Release Locations, Fate and Transport of Contamination, and Remedial Options at a Dry Cleaners in Glendale, California – Confidential Property Owner
- Investigation of Groundwater Contamination and Potential Sources for TCE Contamination in Groundwater and Water Supply Wells in a Community Adjacent to a County-Operated Airport – Confidential Client
- Evaluation of Poly-Chlorinated Biphenyls (PCBs) in Storm Water and the Impact on Groundwater Resources and the Use of Treated Storm Water for Aquifer Recharge and Saline Intrusion Barriers – Confidential Municipal Clients
- Investigation of Chlorinated Solvent Contamination and Implementation of an Extended Remediation Pilot Study at a Chemical Distribution Facility in Los Angeles, California – Pacifica Chemical Corporation
- Assessment of the Effectiveness of Site Investigation and Remediation Activities, Investigation of Off-Site Groundwater Contamination, and Development of Remedial Programs (and Costs) at Solvent "Source Sites" in the South Basin Groundwater Protection Project (SBGPP) - Orange County Water District
- Consulting Support to a Community Adjacent to the Santa Susana Field Laboratory (SSFL), a Facility Previously Used to Test Rockets – Bell Canyon Homeowners Association
- Investigation of Groundwater Contamination by Perfluorinated Compounds (e.g., PFOA, PFOS) and its Impact on Public Water Supplies in Southeastern North Carolina – Confidential Client
- Investigation of Chlorinated Solvent and Petroleum Hydrocarbon Contamination and Implementation of an Extended Remediation Pilot Study at a Small-Batch Chemical Distribution Facility in Santa Fe Springs, California – Angeles Chemical Corporation
- Evaluation of Contaminant Distribution and Fate, and Development of a Remedial Approach and Costs, for Chlorinated Solvent Contamination in Groundwater at a Light Industrial Facility in Northridge, California – Confidential Client
- Project Management Consultant (PMC) for the Hazardous Substances Account Act (HSAA) Program (i.e., State-CERCLA) as part of the SBGPP – Orange County Water District
- Assessment of Conceptual Hydrogeology and the Sources of 1,2-DCA and PCE Contamination of a Large Public Water Supply Well – Confidential Client
- Investigation and Remediation of Chlorinated Solvent Contamination in Soil and Groundwater Beneath a Metal Finishing Facility in Inglewood, California – Bodycote Hinterliter and Joseph Collins Estate.
- Investigation and Remediation of Soil and Groundwater Contamination at a Former Wood Treating Facility – Port of Los Angeles
- Assessment of the Nature of PCE Releases from Dry Cleaning Facilities, the Impact Upon Groundwater Resources, and the Cost of Remediation – City of Modesto, California

- Investigation of Chlorinated Solvent Contamination in Soil, Groundwater and Drinking Water Supplies Beneath Various Facilities in Lodi, California – Confidential Client
- Investigation of TCE and Hexavalent Chromium Contamination at the Suva School in Montebello, California – Communities for a Better Environment
- Remediation of Chlorinated Solvents, Including Vinyl Chloride, in Soil and Groundwater Beneath a Former Aerospace Facility in West Los Angeles, California – Playa Vista Capital
- Assessment of Chlorinated Solvent and Hexavalent Chromium Contamination at an Active Metal Finishing Facility in the City of Garden Grove, California – Confidential Client
- Investigation and Remediation of Hexavalent Chromium and TCE Contamination at an Active Plating Facility in West Los Angeles – confidential client
- Contamination of Drinking Water Supplies by TCE and Perchlorate from an Aerospace Manufacturing Facility in Redlands, California – Individual Plaintiffs
- Investigation and Remediation of Hexavalent Chromium, TCE, and Gasoline LNAPL Contamination at an Active Plating Facility in Santa Fe Springs, California – Confidential Client
- Investigation and Remediation of Hexavalent Chrome and TCE Contamination at the Los Angeles Academy (formerly Jefferson) Middle School, Los Angeles, California – Jefferson Site PRP Group
- Evaluation of Groundwater and Contaminant Conditions at an Active Municipal Landfill in Los Angeles County, California – Browning Ferris Industries (BFI)
- Investigation of Chlorinated Solvent Contamination in Groundwater Beneath a Municipal Airport – City of Santa Monica, California
- Resource Conservation and Recovery Act (RCRA) Facility Assessment and Closure for a Large Aerospace Facility in Hawthorne, California – Northrop Grumman Corporation
- Characterization of Complex Hydrogeology and Contaminant Fate and Transport (with Poly-chlorinated Biphenyls [PCBs] and Chlorinated Solvents) in Karstic Bedrock at a Site on the National Priority List (NPL) in Missouri – MEW PRP Steering Committee
- Design of a Groundwater Remediation Program for Chlorinated Solvent, Perchlorate and Other Contaminants Utilizing Existing Drinking Water Wells – San Gabriel Valley Water Company (SGVWC)
- Investigation of a Chlorinated Solvent Release in Fractured Bedrock – Consolidated Electrical Distributors, San Diego, California
- Contamination of Drinking Water Supplies by TCE from an Aerospace Manufacturing Facility in Redlands, California – Individual Plaintiffs
- Investigation of a Chlorinated Solvent Release at an Active Chemical Terminal - GATX, San Pedro, California
- Technical and Regulatory Assistance, and RP Oversight and Review, Chlorinated Solvent Contamination Beneath a Former Aerospace Facility – City of Burbank, California
- Investigation and Remedial Design for a Chlorinated Solvent Release at an Active Machine Shop – Mighty USA, Los Angeles, California

- Remediation of Chlorinated Solvents in Groundwater as Part of a Rail Freight Transfer Terminal Development - Port of Los Angeles, California
- Remedial Evaluation of PCE Contamination at a Former Scientific Instruments Manufacturing Facility – Forest City, Irvine, California
- Evaluation of a Chlorinated Solvent Release at a Dry Cleaners - Los Angeles City Attorney, West Los Angeles, California
- Assessment of a Chlorinated Solvent Release from Former Dry Cleaners – DeLoretto Plaza, Santa Barbara, California
- Characterization and Remediation of LNAPL at an Active Chemical Refinery - ICI, Teeside, UK

Perchlorate

- Assessment of contaminant sources and extent, fate, and persistence of groundwater contamination associated with releases of perchlorate, 1,2,3-TCP, and solvents at an aerospace research and testing facility – Confidential City Client
- Investigation of Regional Perchlorate Contamination of Groundwater Resources in the Central Basin of Los Angeles – Water Replenishment District of Southern California (WRD)
- Investigation of regional groundwater contamination by perchlorate in the Rialto-Colton, Bunker Hill, and North Riverside Basins, and impact to water supply wells – City of Riverside
- Assessment of the Effectiveness of Site Investigation and Remediation Activities, Investigation of Off-Site Groundwater Contamination, and Development of Remedial Programs (and Costs) at Perchlorate Release Sites in the South Basin Groundwater Protection Project (SBGPP) - Orange County Water District
- Hydrogeologic Investigation, Source Identification, Water Supply Well Impact Assessment, and Drinking Water Treatment for Perchlorate – City of Morgan Hill, California
- Evaluation of the Fate and Transport of Perchlorate and NDMA Contamination and its Impact on Water Supplies in Rancho Cordova, California – Southern California Water Company
- Hydrogeologic Investigation, Water Supply Well Impact Assessment, Regulatory Assistance, and Responsible Party (RP) Oversight for Perchlorate Contamination – City of Gilroy, California
- Regulatory and Technical Assistance, RP Oversight and Review, Water Resource Impact Assessment for Perchlorate Contamination – City of Santa Clarita, California
- Design of a Groundwater Remediation Program for Chlorinated Solvent, Perchlorate and Other Contaminants Utilizing Existing Drinking Water Wells – San Gabriel Valley Water Company (SGVWC), San Gabriel Valley Superfund Site, California
- Evaluation of the Off-site Migration of Perchlorate and TCE Contamination from a Rocket Testing Facility in Simi Hills, California – City of Calabasas, County of Los Angeles
- Investigation of Potential Perchlorate Source Sites, Source Contribution, Contaminant Pathway Assessment, and Drinking Water Treatment – Fontana Water Company, West Valley Water District, Fontana, California

- Evaluation of Previous Environmental Investigations, Contaminant Transport and Remediation Options for Perchlorate and Solvent Contamination at the Stringfellow Acid Waste Disposal Pits in Glen Avon, California – Joint Underwriters

Hexavalent Chromium

- Investigation and Remediation of Hexavalent Chrome and TCE Contamination at the Los Angeles Academy (formerly Jefferson) Middle School, Los Angeles – Jefferson Site PRP Group
- Investigation and Remediation of Hexavalent Chromium and TCE Contamination at an Active Plating Facility in West Los Angeles – Confidential Client
- Hydrogeologic Investigation of Hexavalent Chromium Contamination in the Northern Area of the Central Basin in Los Angeles County – Water Replenishment (WRD)
- Investigation of TCE and Hexavalent Chrome Contamination at the Suva School in Montebello, California – Communities for a Better Environment
- Investigation of Fuel Oil LNAPL and Hexavalent Chromium Contamination at a Former Clay Products Manufacturing Facility in Fremont, California – Mission Clay Products
- Investigation and Remediation of Hexavalent Chromium, TCE, and Gasoline LNAPL Contamination at an Active Plating Facility in Santa Fe Springs California – Confidential Client

Other Projects

- Evaluation of Contaminant Conditions at a Municipal Landfill, the Presence of CERCLA Hazardous Substances, Compliance with CERCLA/NCP, and Contribution to Contamination – Placer County
- Determination of Compliance with the Coal Combustion Residual (CCR) Rule at an Operating Coal-Fired Power Plant in Alabama – Southern Environmental Law Center (SELC)
- Investigation of the Source, Magnitude, Extent and Fate of Polyethylene Nurdle Pollution in and Around Charleston Harbor – Charleston Waterkeeper and South Carolina Coastal Conservation League
- Assessment of the Impact of 1,2,3-TCP Contamination from Soil Fumigant Applications on Municipal Water Supplies – City of Corona
- Review and Critique of Proposed Coal Ash Pond Closure at the Tennessee Valley Authority (TVA) Gallatin Power Plant - SELC
- Evaluation of Surface Water and Groundwater Pollution by Boron and Other Metals and Salts Associated with Coal Ash at Georgia Power's Plant Scherer Generating Station - SELC
- Assessment of the Impact of 1,2,3-TCP Contamination from Soil Fumigant Applications on Municipal Water Supplies – City of Arcadia
- Investigation of PCB Contamination at a Former Wastewater Treatment Plant at a Former US Army Camp – City of Riverside
- Investigation of the Fate, Transport, and Persistence of 1,2,3-TCP Contamination of Groundwater and Municipal Water Supply Wells – City of Upland

- Assessment of Sediment, Surface Water, and Groundwater Contamination Associated with Coal Ash at the Belews Creek Coal-Fired Power Plants in North Carolina, and an Evaluation of Closure Options for Coal Ash Basins – NAACP
- Assessment of the Impact of 1,2,3-TCP Contamination from Soil Fumigant Applications on Municipal Water Supplies – Sunny Slope Water Company
- Investigation of Sources and Fate and Transport of 1,2,3-TCP Contamination in Groundwater and its Impact on Potable Water Supply Wells in and around the City of Claremont – Golden State Water Company
- Evaluation of disposal and/or treatment options for produced waters at three active oil fields in Kern County – California Resources Corporation
- Assessment of 1,2,3-TCP Contamination of Groundwater and Potable Water Supply Wells in the Nipomo Area of Central California – Golden State Water Company
- Evaluation of potential water resources impacts from a proposed coal ash landfill located within a flood plain near Laredo Texas – confidential ranch owner
- Investigation of the Fate, Transport, and Persistence of 1,2,3-TCP Contamination of Groundwater and Municipal Water Supply Wells – City of Hemet
- Investigation of elevated concentrations total dissolved solids (TDS) and dissolved metals in surface water and groundwater related to an active lignite mine and coal-fired power plant at a large ranch in southeast Texas – Peeler Ranch
- Assessment of soil, groundwater, and surface water contamination associated with a Former Manufactured Gas Plant (MGP) in South Carolina – Southern Environmental Law Center (SELC)
- Evaluation of Contaminated Groundwater and Surface Waters by 1,4-dioxane, Perfluorinated Compounds [PFCs], and Gen-X at a Chemical Manufacturing Facility in North Carolina – Cape Fear Riverkeeper
- Investigation of 1,2,3-TCP Contamination of Groundwater and Municipal Water Supply Wells – City of Fresno
- Evaluation of Surface Water, Sediment, and Groundwater Contamination and Assessment of Remedial Actions at a Former Manufactured Gas Plant in South Carolina – Confidential Client
- Evaluation of Flow Conditions and Water Quality in Surface Water and Groundwater at an Active Coal-Fired Power Plant in North Carolina, including Three-Dimensional Groundwater Flow and Solute Transport Modeling – Sierra Club
- Assessment of 1,2,3-TCP Contamination of Groundwater Resources and Water Supply Wells in Clovis, California, and Development of Well-head Treatment Programs and Associated Costs - City of Clovis
- Investigation of Surface Water and Groundwater Impacted by Acid Mine Drainage (AMD) from a Former Coal Mine in Alabama, Including Geophysical Mapping, Piezometer Installation, and Soil, Sediment, and Surface Water Sampling – Black Warrior Riverkeeper
- Evaluation of Groundwater and Surface Water Contamination by Coal Combustion Residuals (CCRs) from Ash Ponds at Power Generation Facilities in Eastern Virginia – Sierra Club

- Investigation of 1,2,3-TCP Contamination of Groundwater and Municipal Water Supply Wells – City of Atwater
- Evaluation of Contaminant Sources and Hydrogeologic Pathways for 1,2,3-TCP Contamination of Water Supply Wells - City of Tulare
- Identification of Potential Sources of Nitrate Contamination at a Municipal Water Supply Well – Water Replenishment District of Southern California (WRD)
- Assessment of Sediment, Surface Water, and Groundwater Contamination Associated with Coal Ash at Two Coal-Fired Power Plants in North Carolina, and an Evaluation of Closure Options for Coal Ash Basins – Roanoke River Basin Association
- Assessment of the Volume and Quality of Storm Water and Shallow Groundwater (from Dewatering) at a Large Condominium Complex, as part of a City's MS-4 Storm Water Permitting – Coronado
- Investigation of Nitrate Contamination of Groundwater Resources and Water Supply Wells in Delano, California, and Development of Well-head Treatment Programs and Associated Costs - City of Delano
- Evaluation of Contaminant Conditions and Closure Plans for Coal Ash Basins at Two Coal-Fired Power Plants in Virginia – Sierra Club
- Evaluation of Groundwater and Surface Water Contamination by CCRs from Ash Ponds at a Former Power Generation Facility in Central Virginia – Sierra Club and Potomac Riverkeeper
- Negotiation of Private Agreements Between Water Utilities and RPs – City of Santa Monica, STPUD, City of Morro Bay, SGVWC, GOWC, City of Oxnard, OCDA
- Evaluation of Power Plant Intake and Outfall Structures on Fecal Coliform Plume Dynamics and Resulting Beach Closures, Huntington Beach, California – California Energy Commission
- Investigation of Bacteria and Fecal Contamination in Groundwater Beneath the Downtown Area of Huntington Beach, California – City of Huntington Beach
- Investigation of the Source(s) and Transport of Enterococcus and Fecal Bacteria to the Near Shore Waters of Huntington Beach, California – City of Huntington Beach, County of Orange, Orange County Sanitation District (OCSD)
- Characterization and Remediation, Former Town Gas Sites - British Gas Properties, U.K.
- Aquifer Characterization, Contaminant Assessment, Slurry Wall Design and Installation, Soil Excavation and Water Treatment System Design - Port of Los Angeles, California

Professional History

aquilogic, Inc., Founder, Chief Executive Officer (CEO), and Principal Hydrologist, 2011 to present.
Ridgewood Infrastructure, Senior Advisor, 2019 to present.
exp, Executive Vice-President, Chief Business Development Officer, 2010 to 2011
WorleyParsons, Senior VP, Strategy & Development, 2006 to 2010.
Komex Environmental Ltd., Founder, CEO, Principal Shareholder, Director, 1992 to 2005.
Remedial Action Corporation, Project Manager and Geohydrologist, 1989 to 1992.

Lanco Engineering, Project Manager, 1985 to 1987, and 1988.
Royal Geographical Society, Kosi Hills Resource Conservation Project, Nepal: Project Director, 1983 to 1985

Teaching

Anthony has recently taught the following classes:

- Environmental Aspects of Soil Engineering and Geology - a ten-week course at the University of California, Irvine
- Site Characterization and Remediation of Environmental Pollutants - two lectures as part of the course at Imperial College London
- Methyl Tertiary Butyl Ether: Implications for European Groundwater - a one day seminar for the UK Environment Agency (UKEA)
- Successful Remediation Strategies – a two-day course for the NGWA
- Understanding Environmental Contamination in Real Estate, and one day class for the International Right-of-Way Association (IRWA)
- Project Development and the Environmental Process, a one-day class for the IRWA
- Environmental Awareness, a one-day class for the IRWA
- Regional Fuels Management Workshop, a two-day workshop for the USEPA.

Publications

In addition to his teaching experience, Anthony has prepared over 1000 written project reports, and has written, presented and published many articles regarding the following:

- The implementation of the SGMA in California
- Groundwater law in California
- The development of alternate water supplies, notably brackish groundwater
- Aquifer storage and recovery and other groundwater augmentation actions
- The Clean Water Act and groundwater contamination
- Contamination of groundwater and drinking water supplies by fuel oxygenates, chlorinated solvents, rocket propellants, PFCs, and metals
- Contaminant fate and transport in fractured or heterogeneous media
- The impact of oil field activities on the environment
- Source water assessment and protection
- Public health and toxicology
- Risk analysis and assessment
- Environmental economics
- General water resources and environmental issues

The following is a list of publications and presentations:

Brown, A., 2022. Are PFAS A Bigger Issue Than Other Emerging Contaminants – Implications For Water Utilities. 23rd Annual American Groundwater Trust (AGWT) – Association of Groundwater Agencies (AGWA), March 2022.

Brown, A., 2021. Science in the Court Room: Expert Witness Testimony in Contamination Cases. American Groundwater Trust California PFAS Webinar, March 2021.

Brown, A., 2021. Sources of 1,2,3-TCP and its Persistence in California Groundwater. American Groundwater Trust 1,2,3-TCP Webinar, February 2021.

Brown, A., 2020. Groundwater and the Clean Water Act. American Groundwater Trust California Groundwater Conference, Ontario, February 2020.

Brown, A., and T. Watson, 2020. Produced Water – A New California Resource. Produced Water Society Annual Seminar, Houston, February 2020.

Brown, A., 2019. Perspectives on the Future of the Water Business. Environmental Business International, Industry Summit, San Diego, March 2019.

Brown, A., 2019. Paso Robles – The First Jury Trial over Water Rights in California. American Groundwater Trust California Groundwater Conference, Ontario, February 2019.

Brown, A., 2018. Emerging Contaminants – Where Do They Come From? American Groundwater Trust Conference on Emerging Contaminants, Chino Basin, March 2018.

Brown, A., 2017. Contaminated Groundwater as a Resource. State Bar of California Environmental Law Conference, Yosemite, October 2017.

Stone A. and A. **Brown**, 2017 (organizers). Groundwater Law – An American Groundwater Trust Conference. UC Hastings Law School, San Francisco, May 18, 2017

Brown, A. 2016. The SGMA Cookbook – Implementing the Sustainable Groundwater Management Act. Association of California Water Agencies (ACWA), Spring Conference, Monterey, CA, April 2016.

Stone A. and A. **Brown**, 2016 (organizers). Groundwater Law – An American Groundwater Trust Conference. Loyola Law School, Los Angeles, April 26, 2016

Stone A. and A. **Brown**, 2015 (organizers). Groundwater Law – An American Groundwater Trust Conference. Doubletree San Francisco Airport, May 15, 2015

Brown, A., 2015. Challenges Implementing the California Sustainable Groundwater Management Act (SGMA). Bar Association of San Diego County, May 5, 2015.

Brown, A., 2015. Technical and Other Issues Implementing the California Sustainable Groundwater Management Act (SGMA). Ventura Association of Water Agencies, March 19, 2015.

Brown, A., 2015. Outlook for Environmental Services in the Global Energy and Resources Sectors. Environmental Business Journal, Environmental Industry Summit, San Diego, March 11-13, 2015.

Brown, A., 2015. The Effect of $50 Oil on the Environmental Services Sector. Environmental Business Journal Conference, San Diego, March 11-13, 2015.

Brown, A. 2014. Hydrology and the Law: The Role of Science in the Resolution of Legal Issues for Water Quality and Damages Issues. Law Seminars International, Santa Monica, CA. October 2014

Stone A. and A. **Brown**, 2014 (organizers). Groundwater Law – An American Groundwater Trust Conference. Marriott Marina del Rey, May 20-21, 2014

Brown, A. 2014. Environmental Issues with Hydraulic Fracturing. Los Angeles County Bar Association (LACBA), Spring Symposium, Los Angeles, CA. April 2014.

Brown, A. 2014. Environmental Services in the Global Energy & Resources Sectors. Environmental Business Journal, Environmental Industry Summit, San Diego, March 2014.

Brown, A. 2013. Dealing with Emerging Groundwater Contaminants. Association of California Water Agencies (ACWA), Fall Conference, Los Angeles, November 2013.

Brown, A., 2013. Outlook for Environmental Services in the Global Energy and Resources Sectors. Environmental Business Journal, Environmental Industry Summit, San Diego, March 2013.

Brown, A., Colopy, J, and Johnson, T, 2007. Groundwater Science in the Courtroom: Observations from the Expert Witness Chair. Groundwater Resource Association of California (GRAC), Groundwater Law Conference, San Francisco, June 2007.

Brown, A. 2005. Emerging Water Contaminants. California Special Districts Association (CSDA), Annual Conference, Palm Springs, May 2005.

Brown, A. 2005. The Interplay of Science and Policy at Contaminated Sites. Los Angeles County Bar Association (LACBA), Spring Symposium, Los Angeles, CA. April 2005.

Brown, A., M. Trudell, G. Steensma, and J. Dottridge, 2005. European Experiences with Artificial Aquifer Recharge. Groundwater Resource Association of California (GRAC), Aquifer Storage Conference, Sacramento, March 2005.

Brown, A. 2004. Viagra, Estrogen, Prozac, and Other Emerging Contaminants: have you checked your groundwater lately? American Groundwater Trust (AGWT), Legal Issues Conference, Los Angeles, November 2004.

Brown, A. 2004. The Use of Groundwater Models in Complex Litigation. American Groundwater Trust (AGWT), Groundwater Models in the Courtroom Symposium, May 2004.

Brown, A. 2004. Emerging Groundwater Contaminants: MTBE as a Case Study. Association of California Water Agencies (ACWA), Spring Conference, Los Angeles, May 2004.

Rohrer, J., A. **Brown**, S. Ross, 2004. MTBE and Perchlorate, Lessons Learned from Recent Groundwater Contaminants. California Special Districts Association (CSDA), Annual Conference, Palm Springs, May 2004.

Hagemann, M., A. **Brown**, and J. Klein, 2002. An Estimate of Costs to Address MTBE Releases from Underground Storage Tanks and to Treat Drinking Water Supplies Impacted by MTBE. NGWA, Conference on MTBE: Assessment, Remediation, and Public Policy, Orange, CA. June 2002

Hagemann, M., A. **Brown**, and J. Klein, 2002. From Tank to Tap: A Chronology of MTBE in Groundwater. NGWA, Conference on Litigation Ethics, and Public Awareness, Washington, D.C., August 2002

Major, W., A. **Brown**, S. Roberts, L. Paprocki, and A. Jones, 2001. The Effects of Leaking Sanitary Sewer Infrastructure on Groundwater and Near Shore Ocean Water Quality in Huntington Beach, California. California Shore and Beach Preservation Association and California Coastal Coalition – Restoring the Beach: Science, Policy, and Funding Conference. San Diego, California, November 8-10, 2001.

Ross, S.D., A. Gray, and A. **Brown,** 2001. Remediation of Ether Oxygenates at Drinking Water Supplies and Release Sites. Can-Am 6th Annual Conference of National Groundwater Association Banff, Alberta, Canada. July 2001.

Gray, A.L. and A. **Brown**, 2000. The Fate, Transport, and Remediation of Tertiary-Butyl-Alcohol (TBA) in Ground Water. Proceedings of the NGWA/API 2000 Petroleum Hydrocarbons and Organic Chemicals in Groundwater: Prevention, Detection, and Remediation. Anaheim, November 14-17, 2000.

Hardisty, P.E., J. Dottridge and A. **Brown**, 2000. MTBE in Ground Water in the United Kingdom and Europe. Proceedings of the NGWA/API 2000 Petroleum Hydrocarbons and Organic Chemicals in Groundwater: Prevention, Detection, and Remediation. Anaheim, November 14-17, 2000.

Brown, A., B. Eisen, W. Major, and A. Zawadzki, 2000. Geophysical, Hydrogeological and Sediment Investigations of Bacterial Contamination in Huntington Beach, California. California Shore and Beach Preservation Association – Preserving Coastal Environments Conference. Monterey, California, November 2-4, 2000.

Hardisty, P.E., G.M. Hall, A. **Brown** and H.S. Wheater, 2000. Natural Attenuation of MTBE in Fractured Media. 2nd National Conference on Natural Attenuation in Contaminated Land and Groundwater. Sheffield, U.K., June 2000.

Brown, A., 2000. Treatment of Drinking Water Impacted with MTBE. Mealey's MTBE Conference. Marina del Rey, California. May 11-12, 2000.

Brown, A., 2000. Other Fuel Oxygenates in Groundwater. Mealey's MTBE Conference. Marina del Rey, California. May 11-12, 2000.

Brown, A., 2000. The Fate, Transport and Remediation of TBA in Groundwater. Mealey's MTBE Conference. Marina del Rey, California. May 11-12, 2000.

Brown, A., 2000. MTBE Contamination of the City of Santa Monica Water Supply: Recap. Mealey's MTBE Conference. Marina del Rey, California. May 11-12, 2000.

Mooder, R.B., M.D. Trudell, and A. **Brown**, 2000. A Theoretical Analysis of MTBE Leaching from Reformulated Gasoline in Contact with Groundwater. American Chemical Society, Div. of Environmental Chemistry, 219th ACS National Meeting. San Francisco, March 26-30, 2000.

Trudell, M.R., K.D. Mitchell, R.B. Mooder, and A. **Brown**, 2000. Modeling MTBE Transport for Evaluation of Migration Pathways in Groundwater. American Chemical Society, Div. of Environmental Chemistry, 219th ACS National Meeting. San Francisco, March 26-30, 2000.

Brown, A., 1999. How LUST Policy Led to the Current MTBE Problem. Submitted for the Government Conference on the Environment. Anaheim, CA. August 1999.

Trudell, M.R., K.D. Mitchell, R.B. Mooder and, A. **Brown**, 1999. Modeling MTBE transport for evaluation of migration pathway scenarios. In proceedings, 6th International Petroleum Environmental Conference, Houston TX, November 16-19, 1999. Integrated Petroleum Environmental Consortium, University of Tulsa, OK.

Gray, A.L., A. **Brown**, R.A. Rodriguez, 1999. Treatment of Groundwater Impacted with MTBE By-Products**.** In proceedings, 6th International Petroleum Environmental Conference, Houston TX, November 16-19, 1999. Integrated Petroleum Environmental Consortium, University of Tulsa, OK.

Gray, A.L., A. **Brown**, M.M. Nainan, and R.A. Rodriguez, 1999. Restoring a Public Drinking Water Supply Contaminated with MTBE. In proceedings, 6th International Petroleum Environmental Conference, Houston TX, November 16-19, 1999. Integrated Petroleum Environmental Consortium, University of Tulsa, OK.

Ausburn M.P., A. **Brown**, D. A. Reid, and S.D. Ross, 1999. Environmental Aspects of Crude Oil Releases to the Subsurface. In proceedings, 6th International Petroleum Environmental Conference, Houston TX, November 16-19, 1999. Integrated Petroleum Environmental Consortium, University of Tulsa, OK.

Hardisty, P.E., A. **Brown**, and H. Wheater, 1999. Using Economic Analysis to Support Remedial Goal Setting and Remediation Technology Selection. In proceedings, 6th International Petroleum Environmental Conference, Houston TX, November 16-19, 1999. Integrated Petroleum Environmental Consortium, University of Tulsa, OK.

Brown, A., and J.J. Clark, 1999. MTBE: Air Today, Gone Tomorrow! California Environmental Law and Remediation Reporter. Argent Communications Group. Foresthill, CA. Volume 9 (2): pp 21 - 30.

Brown, A., P.E. Hardisty, and H. Wheater, 1999. The Impact of Fuel Oxygenates on Water Resources. A one-day course for the UK Environment Agency. London, UK. June 1999

Brown, A., K.D. Mitchell, C. Mendoza and M.R. Trudell, 1999. Modeling MTBE transport and remediation strategies for contaminated municipal wells. Battelle In-Situ and On-Site Bioremediation, Fifth International Symposium, San Diego, CA. April 19-22, 1999.

Brown, A., 1999. LUST Policy and Its Part in the MTBE Problem. USEPA National Underground Storage Tank Conference. Daytona Beach, FL. March 15-17, 1999.

Brown, A., T.E. Browne, and R.A. Rodriguez, 1999. Restoration Program for MTBE Contamination of the City of Santa Monica Arcadia Well Field. Ninth Annual Conference on Soil and Groundwater Contamination, Oxnard, CA. March 1999.

Brown, A., 1999. Moderator of a Panel Session - Judging Oil Spill Response Performance: The Challenge of Competing Perspectives. International Oil Spill Conference. Seattle, WA. March 8-11, 1999.

Brown, A., 1999. MTBE: Asleep at the Wheel! Editorial in the Newsletter of the Los Angeles County Bar Association, Environmental Section. February 1999.

Brown, A., J.S. Devinny, T.E. Browne and R.A. Rodriguez, 1998. Restoration of a Public Drinking Water Supply Impacted by Methyl *tertiary* Butyl Ether (MTBE) Contamination. Proceedings of the NGWA/API 1998 Petroleum Hydrocarbons and Organic Chemicals in Groundwater: Prevention, Detection, and Remediation, November 11-13, 1998, Houston, TX.

Brown, A., 1998. Petroleum and the Environment: A Consultants Perspective. USEPA Regional Fuels Management Workshop, November 3-4, 1998, Shell Beach, CA.

Brown, A., 1998. How Much Does Remediation Really Cost? Presented at the Southern California Chapter of the Appraisal Institute, Summer Seminar Spectacular: Damages, Diminution and Mitigation. Anaheim, California, August 13, 1998.

Brown, A., J.S. Devinny, A.L. Gray and R.A. Rodriguez, 1998. A Review of Potential Technologies for the Remediation of Methyl *tertiary* Butyl Ether (MTBE) In Groundwater. International Petroleum and the Environment Conference, Albuquerque, NM. October 1998.

Brown, A., A.L. Gray, and T.E. Browne, 1998. Remediation of MTBE at Leaking Underground Storage Tank (LUST) Sites. The UST Clean-up Fund Conference, Austin, TX. June 22, 1998.

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APPENDIX D ROBERT ABRAMS CURRICULUM VITAE

aquilogic, Inc.
environment • water • strategy

245 Fischer Avenue, Suite D-2
Costa Mesa, CA 92626, USA
Tel. +1.714.770.8040
Web: www.aquilogic.com

CURRICULUM VITAE
May 2024

Robert H. Abrams, PhD, PG, CHg

Senior Principal Hydrogeologist

mobile: +1.650.743.0594
email: bob.abrams@aquilogic.com

Disciplines
Hydrogeology, Water Resources, Geology, Geostatistics, Analytical and Numerical Modeling, Water Quality, Groundwater and Vadose Zone Fluid Flow, Contaminant Fate and Transport.

Education
Ph.D. Hydrogeology, Stanford University, 1999
M.S. Hydrogeology, Stanford University, 1996
B.S. Geology, San Francisco University, 1991

Professional Registrations
Professional Geologist, California (No. 8703)
Certified Hydrogeologist, California (No. 931)
Licensed Geologist, North Carolina (No. 2639)

Professional Experience
Bob has over 25 years of professional experience in groundwater resource development, groundwater sustainability, groundwater banking, groundwater quality, and model design and evaluation. He has worked for the California Geological Survey, the United States Geological Survey (USGS), Stanford University, San Francisco State University, consulting firms, and as an independent consultant to public and private clients. Recent projects have included evaluation of seawater intrusion impacts to water supply wells; vadose zone characterization and modeling; vadose zone and groundwater persistence of per- and polyfluoroalkyl substances (PFAS) and other contaminants; technical review and investigation of hydrogeological concepts and processes in multiple groundwater basins; evaluation of subsidence investigations; development and evaluation of water budgets, development and review of integrated groundwater/surface water hydrologic models; and preparation and review of California Sustainable Groundwater Management Act (SGMA) Groundwater Sustainability Plans (GSPs). Bob currently serves on seven Technical Advisory Committees (TACs) in four California Department of Water Resources Bulletin 118 groundwater basins/subbasins.

Project Experience

Summary of Selected Recent Projects

- Ongoing evaluation of hydrogeology, groundwater flows, and water budgets in the Mojave Basin – *Golden State Water Company/Brownstein Hyatt Farber Schreck, LLP*.
- Ongoing evaluation of hydrogeology, groundwater flows, water budgets, and basin boundaries in the Cuyama Basin – *Best Best & Krieger LLP*.
- Participating member of the Cuyama Basin Groundwater Sustainability Agency Technical Forum – *Best Best & Krieger LLP*.
- Consultant to a large group of Salinas Valley growers regarding multiple hydrogeological concerns related to GSPs and other water supply issues – *Salinas Basin Water Alliance/Brownstein Hyatt Farber Schreck, LLP*.
- Participating member of the Groundwater TAC (GTAC) for the Salinas Valley Basin. The GTAC provides advice and guidance on a range of ongoing groundwater issues and projects, including model development, seawater intrusion, and other hydrogeological issues – *Salinas Basin Groundwater Sustainability Agency, Salinas, California, representing the Salinas Basin Water Alliance*.
- Participating member of the Sustainable Management Criteria TAC (SMC TAC) for the Salinas Valley Basin, Upper Valley and Forebay Subbasins. The SMC TAC provides advice and guidance regarding implementation of projects and management actions – *Salinas Basin Groundwater Sustainability Agency, Salinas, California, representing the Salinas Basin Water Alliance*.
- Participating member of the Drought TAC (DTAC) for the Salinas Valley Basin. The DTAC is charged with developing standards and guiding principles for determining reservoir release schedules and operations of Nacimiento and San Antonio Reservoirs during multiyear droughts, as well as developing the release schedules during such droughts – *Monterey County Water Resources Agency, Salinas, California, representing Grower-Shipper Association of Central California.*
- Participating member of the Habitat Conservation Plan TAC (HCP TAC) for the Salinas Valley Basin. The HCP TAC provides advice and guidance regarding scenarios to be evaluated during development of the HCP, as well as related HCP matters – *Monterey County Water Resources Agency, Salinas, California, representing the Salinas Basin Water Alliance.*
- Participant of the Borrego Springs Watermaster TAC (BSW TAC). The BSW TAC provides consensus advice and guidance to the Borrego Springs Watermaster regarding implementation of the Stipulated Judgment – *T2 Borrego LLC*.
- Voting member of the Las Posas Valley Basin Watermaster TAC (LPV TAC). The LPV TAC provides advice and guidance regarding implementation of the LPV Adjudication Judgment – *LPV Watermaster*, *West Constituency Groups*.

- Evaluated the performance of an aquifer storage and recovery (ASR) project in the Las Posas Valley Basin and conducted other hydrogeological analyses – *Large Landowners Group, an interested party in the Las Posas Valley Basin adjudication process*.
- Designed and implemented custom computer programs to construct and test a facsimile of the USGS Central Valley Hydrologic Model (CVHM), which runs in Groundwater Vistas (GV), a graphical user interface. The computer programs generate input data for the facsimile model from CVHM output and CVHM MODFLOW packages that are not supported by GV. The facsimile model produces results that are nearly identical to CVHM – *Confidential Client*.
- Developed a methodology to combine vadose zone and groundwater flow and transport modeling to estimate the persistence in the subsurface of dissolved 1,2,3-trichloropropane from multiple fertilizer application areas using custom computer programs using HYDRUS, MODFLOW, and MODPATH. Four regions in California were successfully analyzed with this methodology (settlements and jury awards). For the Central Valley region, the CVHM facsimile model (described above) was used – *Miller and Axline; SL Environmental Law Group.*
- Developed and applied an enhanced version of the methodology described above to evaluate the subsurface persistence of PFAS at multidistrict litigation bellwether sites and other sites – *multiple law firms*.
- Co-wrote the Chapter Groundwater Sustainability Plan for the Westside Water Authority in Kern County. Used extremely sparse data and modeling results from C2VSimFG-Kern to estimate current and future water budgets and groundwater availability – *Westside Water Authority*.
- Conducted environmental impact assessment simulations using the CVHM facsimile model described above to evaluate drawdown and subsidence caused by a proposed brackish groundwater water treatment project in Kern County – *Westside Water Authority*.
- Critically evaluated subsidence estimates along the Tule Subbasin portion of the Friant-Kern Canal (FKC) by reviewing historical USGS reports, InSAR data, geomechanical modeling, and the Tule Subbasin Groundwater Flow Model – *Confidential Client*.
- Critically evaluated groundwater flow and solute transport models for three coal ash disposal sites in North Carolina to determine if the models simulated flow and transport properly and sufficiently to allow the sites' owner to claim no offsite groundwater quality impacts above water quality standards – *Southern Environmental Law Center*.
- Invited to participate in the Deep Aquifer Roundtable, a formal meeting attended by Salinas Valley hydrogeology experts to discuss approaches to monitoring and protecting the deepest portions of the Salinas Valley aquifer system – *Monterey County Water Resources Agency, Salinas, California*.
- Served on the TAC for the development of the Salinas Valley Integrated Hydrologic Model, a new MODFLOW model constructed by Monterey County and the U.S. Geological Survey – *Monterey County Water Resources Agency, Salinas, California representing Grower-Shipper Association of Central California*.

Summary of Other Selected Water Supply Projects

- Developed a new Integrated Water Flow Model (IWFM) groundwater-surface water model, based on the Central-Valley-wide C2VSim model, for Stanislaus County to assess impacts in terms of foreseeable land-use changes and installation of new wells – *Stanislaus County, Regional Groundwater-Surface Water Model for PEIR, Modesto, California.*
- Assisted Stanislaus County with evaluation of new major well permit applications based on a then-recently passed groundwater ordinance requiring evaluation under CEQA for potential pumping-induced impacts to the groundwater basin, such as lowered water levels in existing wells, land subsidence, and significant groundwater or surface water depletion – *Stanislaus County, Well Permit CEQA Analysis, Modesto, California*.
- Evaluated well efficiency test results for multiple years and multiple wells for a Salinas Valley grower and food processor. Quantitative and statistical analyses were used to assess well performance and make recommendations for potential well maintenance and repair activities – *Nunes Vegetables, Salinas, California*.
- Reviewed and analyzed published reports and data from international and national seawater intrusion mitigation efforts to assess the feasibility, level of effort required, volumes of water required, and costs of implementation in the Salinas Valley of a seawater intrusion injection barrier using recycled water – *Tanimura & Antle, Salinas, California*.
- Conducted a technical evaluation and provided detailed comments regarding the hydrologic analysis undertaken for the draft environmental impact report/environmental impact statement for the proposed Monterey Peninsula Water Supply Project (MPWSP) - *Third-Party Evaluation of Hydrologic Analysis Conducted for Monterey Peninsula Water Supply Project, City of Marina, California*.
- Developed two local-scale groundwater flow (MODFLOW) and solute transport models (MT3DMS) for subregions within the USGS regional Antelope Valley MODFLOW model domain to evaluate the performance of a new groundwater bank. Updated geologic characterization was based on recent investigations by the USGS and sparse well logs – *Antelope Valley-East Kern Water Agency (AVEK), Groundwater Banking and Blending Study, Palmdale, California.*
- Developed and calibrated groundwater flow (MODFLOW) and solute transport models (MT3DMS) to assess water sources for a new 20 MGD water treatment plant using a new detailed geologic model. Assessed the extent of the deep target aquifer; evaluated the risk of groundwater contamination from an overlying heavy industrial area; evaluated proposed well locations and long-term performance; defined the wellhead protection area; and optimized wellfield performance – *City of Longview, Design and Construction of a New Groundwater Source and Treatment Facility, Longview, Washington.*

- Developed and implemented groundwater flow models (MODFLOW) to evaluate the impact on nearby wells of compressed air injection into a depleted natural-gas reservoir – *Pacific Gas and Electric (subcontractor to Jacobson James and Associates), Compressed Air Energy Storage Pilot Project, San Joaquin County, California.*
- Evaluated (with SEAWAT) the degree to which irrigation wells were drawing seawater inland and if groundwater withdrawals contributed to anoxic conditions in certain reaches of a river hydraulically connected to the aquifer – *El Sur Ranch, Seawater Intrusion and Impact of Irrigation Wells, Monterey County, California*.
- Developed a hydrostratigraphic model of the Mesquite Lake groundwater subbasin from existing well logs and nearby USGS studies for input to a new groundwater flow model (MODFLOW), which was used to assess the volume of water available for a new municipal water treatment plant – *Twentynine Palms Water District, Groundwater Study for the Mesquite Lake Subbasin, Twentynine Palms, California.*
- Developed a calibrated, steady-state analytical groundwater flow model for the Rialto-Colton Basin to delineate source areas for two impacted production wells for a CDPH 97-005 permit application – *West Valley Water District, Wellhead Treatment Project, Rialto, California.*
- Analyzed the results of aquifer tests of multiple water supply wells completed in a fractured-rock aquifer – *Lake Don Pedro Community Services District, California (subcontractor to SGI The Source Group)*.
- Analyzed the results of a complex aquifer-test dataset to determine aquifer properties and assess groundwater availability, characterized groundwater quality, and assessed regional impact of developing a new water supply – *Silver Oak Cellars (subcontractor to Taber Consultants), Aquifer Test Analysis and Groundwater Availability Study, Sonoma County, California.*
- Evaluated a well and a spring in terms of water quality, influence of surface water, source area, and zone of influence for a license application to operate a new private water supply – *Buster's on the Mountain (subcontractor to Taber Consultants), Hydrogeology Report for New Private Water Supply, Napa County, California*.
- Reviewed and critiqued for accuracy and completeness groundwater flow modeling, aquifer test results, and qualitative hydrogeological analyses to assess the feasibility of gravel mining adjacent to the upper reaches of a major river in Los Angeles and Ventura counties. In the second phase of the project, developed a new MODFLOW model to assess groundwater-surface water interactions – *Confidential Client (subcontractor to Todd Engineers), Groundwater Pumping Impacts on Streamflow, Los Angeles County, California.*
- Developed a complex geologic model in the fold-thrust terrane of the Las Posas Valley Basin in eastern Ventura County, which formed the foundation for preliminary wellfield design and estimation of available groundwater for desalter operations in a strictly managed aquifer – *Calleguas Municipal Water District, Somis Desalter Feasibility Study, Las Posas Basin, Ventura County, California*.

- Evaluated geologic, hydrologic, and hydrogeologic data to assess the suitability for establishing a groundwater banking operation and provided recommendations on further field-based and modeling studies deemed necessary to address data and knowledge gaps – *Los Angeles Department of Water and Power, Evaluation of Proposed Water Storage/Transfer Potential in Fremont Valley Basin, Fremont Valley, California.*
- Evaluated the groundwater component of an existing water-budget model; implemented changes to include the effects on water levels from climate and distant municipal pumping in deeper parts of the aquifer, to design an engineered wetland that used stormwater runoff and groundwater pumping to maintain lake levels – *San Francisco Public Utilities Commission, Lake Merced Water-Budget Model, San Francisco, California.*

Summary of Other Selected Water Quality Projects

- Determined the factors influencing nitrate concentrations in well-water from approximately 60 wells on 40 ranches and developed an enhanced groundwater monitoring program; analyzed diverse and complex data sets statistically and qualitatively to understand the geologic, hydrologic, and anthropogenic factors that variably influence well-water concentrations over short- and long-term timeframes; developed specific recommendations for wellhead protection – *Costa Farms, Analysis of Observed Nitrate Concentration Trends in Irrigation Wells, Soledad, California*.
- Statistically evaluated publicly available groundwater quality data from a set of regularly sampled water-supply wells to develop an alternative to installation of new monitoring wells for a land application area that received wastewater from a food processing plant – *Dole Fresh Vegetables, Salinas, California*.
- Conducted Monte Carlo hydraulic gradient analysis and stochastic 1D and 2D solute transport simulations (analytical solutions) based on regional groundwater maps and 13 years of monthly groundwater levels from dozens of production wells to determine the most likely methyl tert-butyl ether (MTBE) source areas; developed a customized GIS framework to evaluate source-area probability – *Monterey County Water Resources Agency, Salinas MTBE Investigation, Salinas, California.*
- Developed three-dimensional, variably saturated flow and reactive transport models (MODFLOW-SURFACT) to assess the groundwater impact from arsenic and boron in artificially recharged, partially treated oilfield produced water – *Cawelo Water District, Groundwater Banking Waste Discharge Requirements Support, Central Valley, California*.
- Developed, calibrated, and evaluated a calibrated transient model (MODFLOW and MT3DMS) of groundwater flow and solute transport to compare estimated timeframes to achieve remedial action objectives (RAOs) for three remedial alternatives at a land application site – *Hilmar Cheese Company, Groundwater Modeling for Cleanup and Abatement Order, Central Valley, California.*

- Reviewed the results of two modeling efforts to reassess contributions from responsible parties; developed a new metric, the Responsibility Factor (RF), and applied to existing input data; used the RFs to estimate relative contributions to the MEW Superfund site regional plume from several responsible parties – *Confidential Client (subcontractor to Montclair Environmental Management), Reassessment of Contributions to the MEW Superfund Site Regional Plume, Santa Clara County, California.*
- Conducted and compared mass flux calculations for TCE and PCE on behalf of a multi-PRP (potentially responsible part) group; compared calculations of mass flux through time upgradient and downgradient of several sites within the Omega Superfund site regional plume to estimate the contribution from each individual site for cost allocation among PRPs – *Confidential Client, Mass Flux Calculations for Cost Allocation, Omega Superfund Site, Santa Fe Springs, California.*
- Developed and calibrated a three-dimensional model (MODLFOW-SURFACT) of unsaturated zone and saturated zone flow and solute transport based on sparse discharge records and well observations to assess the fate of a legacy of contaminated soil water being mobilized by increased discharge to the subsurface – *California Dairies, Incorporated, Report of Waste Discharge, Central Valley, California.*
- Conceptualized, implemented, and calibrated a transient groundwater flow model (MODFLOW) for a major oil refinery; used linear programming to quantitatively minimize groundwater pumping and qualitatively optimize well placement for containment of subsurface LNAPL and BTEX-contaminated groundwater; analyzed multiple capture zones of various sizes for control of LNAPL hotspots and site-wide containment scenarios – *Sun Oil Company, Pumping-Rate Optimization and Capture Zone Analysis, Tulsa County, Oklahoma.*
- Developed a groundwater flow and reactive solute transport model (MODFLOW and RT3D) to evaluate the efficacy of a permeable reactive barrier using simulated sequential decay and transport of TCE and its daughter products – *Mohawk Laboratories, Analysis of Permeable Reactive Barrier, Sunnyvale, California.*
- Determined regional-scale risk to groundwater from potentially contaminating activities (PCA) in the Santa Clara Valley, Coyote, and Llagas subbasins, as part of a multifaceted effort; developed a regional-scale PCA-risk map and combined with intrinsic aquifer sensitivity to generate a groundwater vulnerability map, which formed the basis of a web-based GIS tool for evaluating development projects and land-use changes – *Santa Clara Valley Water District, Groundwater Vulnerability Study, Santa Clara, California.*
- Prepared a Remedial Investigation (RI) Summary report under CERCLA guidelines, which included development of a conceptual model that incorporated regional and local hydrostratigraphy, source-area history, details of previous remedial investigations, and characterization of the basin-wide perchlorate and TCE groundwater contamination – *West Valley Water District, NCP Compliance Documents, Rialto, California.*

- Estimated the volume of LNAPLs beneath a refinery by modifying analytical solutions for LNAPL recovery presented within API Publications 4682 and 4729, utilizing the van Genuchten relations for porous media to design a LNAPL recovery system – *Sun Oil Company, LNAPL Spatial Distribution, Tulsa County, Oklahoma.*
- Developed internal White Paper on DNAPL assessment techniques describing techniques and thresholds for assessing DNAPL mobility at a fueling facility – *BNSF, Remediation Design Support, Park County, Montana*.
- Developed and implemented groundwater flow and particle tracking models to evaluate well placement designs and optimize pumping rates for an in-situ groundwater recirculation and volatile organic compound (VOC) treatment zone – *BNSF, Remediation Design Support, Park County, Montana.*
- Analyzed slug test data for multiple tests using several techniques to assess parameter uncertainty for a bedrock aquifer, for submission to Montana Department of Environmental Quality – *BNSF, Site Characterization for Remedial Investigation, Park County, Montana.*
- Prepared report of waste discharge and request for waste discharge requirements for land application of onsite waste and storm water – *Confidential Client, Report of Waste Discharge, Los Angeles County, California.*
- Developed an unsaturated zone flow and transport model to assess the impact to groundwater of VOCs and metals present in the soil at a facility; developed a future 100-year scenario based on climate data from the past 100 years – *SMTEK, Former Chemical Facility, Orange County, California.*

Summary of Other Selected Litigation Support Projects

- Implemented detailed regional, three-dimensional conceptual model for a 35-year period (MODFLOW and MT3DMS). Geologic data, crop-based time-variant DBCP application rates, pumping, recharge basins, and flow and transport in the unsaturated and saturated zones were used to evaluate whether label-recommended use of DBCP caused contamination in municipal wells and to establish likely source areas for high-concentration hot spots – *Sedgwick, Detert, Moran, and Arnold, Regional-Scale Pesticide Contamination Litigation Support, Fresno, California.*
- Designed and implemented three-dimensional models (LEACHM, MODFLOW, and MT3DMS) of unsaturated and saturated fluid flow and solute transport for periods of up to 150-years using soils and geologic data, rainfall records, pumping, and plant operational history to assess whether off-site groundwater contamination was caused by unanticipated releases of coal tar at numerous sites in the Midwest – *Jones, Day, Reavis, and Pogue, Former Manufactured-Gas Plant Sites, Litigation Support, Los Angeles, California.*
- Evaluated the impact of different rainfall data disaggregation techniques on the results of fluid flow and solute transport simulations in the unsaturated zone. Various disaggregation strategies were applied to simulations of contaminant fate at three former manufactured-gas

plants – *Northern Indiana Public Service Company, Impact of Rainfall Data Disaggregation Techniques, Merrillville, Indiana.*

- Evaluated expert reports and thoroughly evaluated and verified a detailed water budget model. Assisted in preparation of expert report related to the application of the model – *Confidential Client, Water Budget Model Litigation Support, Pinal County, Arizona*.
- Evaluated expert reports and critiqued a detailed MODFLOW groundwater flow model for litigation of damages and fatalities from a landslide. Assisted in preparation of expert report – *Confidential Client, Landslide Initiation Litigation Support, British Columbia.*

Professional History

aquilogic, Inc., Senior Principal Hydrogeologist, October 2020 to present.
aquilogic, Inc., Senior Hydrogeologist, February 2018 to October 2020.
Jacobson James & Associates, Inc., Principal Hydrogeologist, October 2015 to December 2017.
Independent Consultant, December 2012 to September 2015.
Kennedy/Jenks Consultants, Associate Hydrogeologist, March 2009 to November 2012.
Independent Consultant, July 2005 to February 2009.
San Francisco State University, Lecturer/Adjunct Professor, September 2003 to February 2009.
SGI The Source Group, Inc., Senior Hydrogeologist, August 2002 to June 2005.
Stanford University, Research Associate, September 2000 to July 2002
Independent Consultant/Graduate Student, October 1995 to July 2000.
U.S. Geological Survey/Graduate Student, Hydrologist, June 1992 to September 1995.

Research

- Designed and implemented a new protocol and computer code to simulate the development of redox zones in contaminated aquifers. Simulated transport of dissolved constituents coupled to complex interactions between organic and inorganic compounds with consideration of reaction energetics, reaction-rate limitations, and advection and dispersion – *Stanford University/United States Geological Survey, Development and Fate of Redox Zones in Contaminated Aquifers, Falmouth, Massachusetts*.
- Evaluated interactions between surface water, soil-water, and groundwater with a three-dimensional model of coupled saturated-unsaturated subsurface and surface fluid flow. Incorporated detailed rainfall data into the model to determine the relative importance of different stormflow generation mechanisms – *Stanford University, Stormflow Generation, Chickasha, Oklahoma*.
- Conducted basin-scale modeling analysis of subsurface fluid flow in the Illinois Basin to evaluate the role of paleogroundwater flow versus fluid density in long-range, deep-basin petroleum migration – *United States Geological Survey, Basin-scale Analysis of Subsurface Fluid Flow, Illinois Basin*.
- Developed reactive solute transport models to evaluate zinc transport in a geochemically complex aquifer in Falmouth, MA. Coupled solute transport/geochemical modeling,

laboratory experiments, and a two-site surface complexation model were used to represent the pH-dependent adsorption of dissolved zinc on aquifer sediments – *United States Geological Survey, Zinc Transport in a Geochemically Complex Aquifer, Falmouth, Massachusetts*.

Peer-Reviewed Publications

Abrams, R.H. and K. Loague. 2000. A compartmentalized solute transport model for redox zones in contaminated aquifers, 2, Field-scale simulations. Water Resources Research 36, 2015-2029.

Abrams, R.H. and K. Loague. 2000. A compartmentalized solute transport model for redox zones in contaminated aquifers, 1, Theory and development. Water Resources Research 36, 2001-2013.

Abrams, R.H., K. Loague, and D.B. Kent. 1998. Development and testing of a compartmentalized reaction network model for redox zones in contaminated aquifers. Water Resources Research 34, 1531-1541.

Abrams, R.H. and K. Loague. 2000. Legacies from three former manufactured-gas plants: Impacts on groundwater quality. Hydrogeology Journal 8, 594-607.

Kent, D.B., R.H. Abrams, J.A. Davis, J.A. Coston, and D.R. LeBlanc. 2000. Modeling the influence of variable pH on the transport of zinc in a contaminated aquifer using semi-empirical surface complexation models. Water Resources Research 36, 3411-3425.

Kent, D.B., R.H. Abrams, J.A. Davis, and J.A. Coston. 1999. Modeling the influence of adsorption on the fate and transport of metals in shallow ground water--Zinc contamination in the sewage plume on Cape Cod, MA. Morganwalp, D.W., and Buxton, H.T., eds., USGS WRI Report 99-4018C, 361-370.

Loague, K., R.H. Abrams, S.N. Davis, A. Nguyen, and I.T. Stewart. 1998. A case study simulation of DBCP groundwater contamination in Fresno County, California: 2. Transport in the saturated subsurface. Journal of Contaminant Hydrology 29, 137-163.

Loague, K., D. Lloyd, A. Nguyen, S.N. Davis, and R.H. Abrams. 1998. A case study simulation of DBCP groundwater contamination in Fresno County, California: 1. Leaching through the unsaturated subsurface. Journal of Contaminant Hydrology 29, 109-136.

Loague, K. and R.H. Abrams. 1999. DBCP contaminated groundwater in Fresno County: Hot Spots and nonpoint sources. Journal of Environmental Quality 28, 429-445.

Coston, J. A., R. H. Abrams, and D. B. Kent. 1998. Selected inorganic solutes, in water quality data and methods of analysis for samples collected near a plume of sewage-contaminated ground water, Ashumet Valley, Cape Cod, Massachusetts, 1993-1994. USGS WRI Report 97-4269.

Loague, K., C.S. Heppner, R.H. Abrams, A.E. Carr, J.E. VanderKwaak, and B.A. Ebel. 2005. Further testing of the Integrated Hydrology Model (InHM): Event-based simulations for a small rangeland catchment located near Chickasha, Oklahoma. Hydrological Processes 19, 1373–1398.

Loague, K. and R.H. Abrams. 2001. Stochastic-conceptual analysis of near-surface hydrologic response. Hydrological Processes 15, 2715-2728.

Loague, K., G.A. Gander, J.E. VanderKwaak, R.H. Abrams, and P.C. Kyriakidis. 2000. Technical Addendum for "Simulating hydrologic response for the R-5 catchment: A never-ending story". Floodplain Management 2, 57-64.

Loague, K., G.A. Gander, J.E. VanderKwaak, R.H. Abrams, and P.C. Kyriakidis. 2000. Simulating hydrologic response for the R-5 catchment: A never-ending story. Floodplain Management 1, 57-83.

Grose, T.L.T. and R.H. Abrams, 1992. Geologic map of the Grasshopper Valley 15' quadrangle, Lassen County, California. California Department of Conservation, Division of Mines & Geology Open-File Report 93-07.

Grose, T.L.T. and R.H. Abrams. 1991. Geologic map of the Karlo 15' quadrangle, Lassen County, California. California Department of Conservation, Division of Mines & Geology Open-File Report 91-23.

APPENDIX E KEY TERMS IN THE JUDGMENT

Base Annual Production (BAP) is defined in the Judgment as, "The verified maximum Year Production, in acre-feet, for each Producer for the five Year Period 1986-1990 as set forth in Table B-1 of Exhibit 'B', except where otherwise noted therein. The maximum Year Production for each Producer was verified based on one or more of the following: flow meter readings, electrical power or diesel usage records or estimated applied water duty. The Base Annual Production for recreational lakes in the Baja Subarea and for Aquaculture shall be equal either to the area of water surface multiplied by seven feet or to verified Production, whichever is less. The five Year period 1986-1990 shall also be the time period for which Base Annual Production calculated."

Base Flow is defined in the Judgment as, "That portion of the total surface flow measured Annually at Lower Narrows which remains after subtracting Storm Flow."

Consumption or Consumptive Use is defined in the Judgment as, "The permanent removal of water from the Mojave Basin Area through evaporation or evapotranspiration. The Consumptive Use rates resulting from particular types of water use are identified in Paragraph 2 of Exhibit 'F'."

Free Production Allowance (FPA) is defined in the Judgment as, "The total amount of water, and any Producer's share thereof, that may be Produced from a Subarea each Year free of any Replacement Obligation."

Makeup Water is defined in Judgement as, "Water needed to satisfy a Minimum Subarea Obligation."

Minimal Producer is defined in Judgement as, "Any Person whose Base Annual Production, as verified by MWA is not greater than ten (10) acre-feet. A Person designated as a Minimal Producer whose Annual Production exceeds ten (10) acre-feet in any Year following the date of entry of Judgment is no longer a Minimal Producer."

Minimum Subarea Obligation is defined in Judgement as, "The minimum Annual amount of water a Subarea is obligated to provide to an adjoining downstream Subarea or the Transition Zone or, in the case of the Baja Subarea, the minimum Annual Subsurface Flow at the MWA eastern boundary toward Afton in any Year, as set forth in Exhibit 'G'."

Producer(s) is defined in Judgement as, "A Person, other than a Minimal Producer, who Produces water."

Production Safe Yield (PSY) is defined in the Judgment as, "The highest average Annual Amount of water that can be produced from a Subarea: (1) over a sequence of years that is representative of long-term average annual natural water supply to the Subarea net of long-term average annual natural outflow from the Subarea, (2) under given patterns of Production, applied water, return flows and Consumptive Use, and (3) without resulting in a long-term net reduction of groundwater in storage in the Subarea."

Replacement Water is defined in the Judgment as, "Water purchased by Watermaster or otherwise provided to satisfy a Replacement Obligation."

Storm Flow is defined in the Judgment as, "That portion of the total surface flow originating from precipitation and runoff without having first percolated to Groundwater storage in the zone of saturation and passing a particular point of reckoning, as determined annually by the Watermaster."

Subarea Obligation is defined in the Judgment as, "The average Annual amount of water that a Subarea is obligated to provide to an adjoining downstream Subarea or the Transition Zone or, in the case of the Baja Subarea, the average Annual Subsurface Flow toward Afton at the MWA eastern boundary as set forth in Exhibit "G".

Subsurface Flow is defined in the Judgment as, "Groundwater which flows beneath the earth's surface."

EXHIBIT 2

William J. Brunick, Esq. [SB No. 46289]
Leland P. McElhaney, Esq. [SB No. 39257]
BRUNICK, McELHANEY& KENNEDY PLC
1839 Commercenter West
P.O. Box 13130
San Bernardino, California 92423-3130

Telephone: (909) 889-8301
Facsimile: (909) 388-1889
E-Mail: bbrunick@bmklawplc.com

Attorneys for Defendant\Cross-Complainant,
MOJAVE WATER AGENCY

Exempt from filing fee pursuant to Gov't. Code Section 6103

SUPERIOR COURT OF THE STATE OF CALIFORNIA

IN AND FOR THE COUNTY OF RIVERSIDE

CITY OF BARSTOW, et al Plaintiff, v. CITY OF ADELANTO, et al Defendant. AND RELATED CROSS ACTIONS	CASE NO.: CIV 208568 **NOTICE OF SERVING THE COURT'S SEPTEMBER 16, 2022 ORDER (1) DISCHARGING ORDER TO SHOW CAUSE WHY THE FPA OF ALTO SHOULD NOT BE REDUCED BY ANOTHER 4.5% OF BAP (2) REDUCING THE FPA IN ALTO BY ANOTHER 0.1% OF BAP and (3) DIRECTING THE WATERMASTER TO RE-EVALUATE PSY FOR THE ENTIRE BASIN, AND PROOF OF SERVICE THEREON** Assigned for All Purposes to: Hon. Craig G. Riemer, Judge Presiding Dept. 1

PLEASE TAKE NOTICE THAT pursuant to the Court's direction, defendant/cross-complainant, Mojave Water Agency in its role as Watermaster, hereby serves the Court's Order (1) Discharging Order to Show Cause Why the FPA of Alto Should Not Be Reduced by another 4.5% of BAP, (2) Reducing the FPA in Alto by an additional 0.1% of BAP, and (3) Directing the Watermaster to Re-Evaluate PSY for the Entire Basin.

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A copy of the Court's September 16, 2022 Order is attached hereto as Exhibit A.

Dated: September 19, 2022

BRUNICK, MCELHANEY & KENNEDY PLC

By: ______________________________

William J. Brunick
Leland P. McElhaney
Attorneys for Defendant/Cross-complainant,
MOJAVE WATER AGENCY

EXHIBIT "A"

SUPERIOR COURT OF THE STATE OF CALIFORNIA, COUNTY OF RIVERSIDE

FILED
SUPERIOR COURT OF CALIFORNIA
COUNTY OF RIVERSIDE
SEP 16 2022
L. Howell

CASE TITLE: City of Barstow v. City of Adelanto	Department 1	
CASE NO.: CIV208568		
DATE: September 16, 2022		

PROCEEDING: Order (1) Discharging Order to Show Cause Why the FPA of Alto Should Not Be Reduced by Another 4.5% of BAP, (2) Reducing the FPA in Alto by Another 0.1% of BAP, and (3) Directing the Watermaster to Re-Evaluate PSY for the Entire Basin

Background:

In its order filed 6-3-22, the Court reduced the FPA in the Alto Subarea from 55% to 54.5, a reduction of 0.5%. In addition, the Court ordered all interested parties "to appear on August 25, 2022, at 1:30 P.M. in Department 1 and show cause, if any exists, why the Free Production Allowance for Alto should not be reduced by another 4.5% for Water Year 2022-2023." That return date was later continued to September 16 2022.

Responses to the that OSC were filed by the Watermaster (on 6-28-22), the California Department of Fish and Wildlife (on 8-4-22), Mitsubishi Cement Corporation (on 8-4-22), the Silver Lakes Association (on 8-5-22), and the CalPortland Company (on 9-6-22). In addition, the Watermaster filed a reply to the DF&W's response (on 8-5-22). After considering the arguments raised in those responses, the Court issued a tentative ruling substantially the same as this order. No oral arguments, objections, or opposition was offered at the hearing on the OSC.

Order:

Accordingly, the Court rules as follows:

The order to show cause is discharged.

The free production allowance for all producers in the Alto Subarea is reduced by an additional 0.1 percent, for a total reduction of 0.6 percent, to 54.4 percent of BAP for Water Year 2022-2023.

The Watermaster shall re-evaluate the PSY for each of the five subareas in the basin. If possible, that new formulation shall be the foundation of the recommendations for adjustments to FPA for the Water Year 2023-2024. If that re-evaluation cannot be completed soon enough to be used for that purpose, it shall be completed as soon as possible and the Court's approval shall be sought as soon as possible thereafter.

Analysis:

<u>There Is No Procedural Impediment to a Reduction of FPA Below PSY</u>

The judgment requires the Watermaster to make annual recommendations to the court to adjust FPA "if needed." (¶ 24(o).) In determining whether an adjustment is needed, the

Watermaster must "be guided by the factors set forth in Exhibit 'C' . . . ." (¶ 24(o).) The scope of those factors is broad. They include "all pertinent hydrologic data and estimates," changes in storage, changes in the factors listed in Table C-1, and the factors listed in ¶ 2.a of Exhibit H. (Exhibit C, ¶ A.)

Beyond necessity, there are only two restrictions on placed on the Watermaster when deciding upon its recommendations to the Court. First, paragraph 24(o) provides that the Watermaster cannot recommend a reduction in FPA for a Subarea in an amount that would "exceed five percent of the aggregate Base Annual Production of that Subarea." Second, paragraph 2.a. of Exhibit H provides that the Watermaster must "compare the Free Production Allowance with the estimated Production Safe Yield. In the event the Free Production Allowance exceeds the estimated Production Safe Yield by five percent or more, Watermaster shall recommend a reduction of the Free Production Allowance equal to a full five percent of the aggregate Subarea Base Annual Production."

The restrictions placed upon the Court when ruling on those recommendations are few. If the Watermaster recommends a change, the Court must "conduct a hearing, after notice given by Watermaster according to paragraph 36, upon Watermaster's recommendations and may order such changes in Subarea Free Production Allowance." (*Ibid.*)

However, the judgment contemplates annual recommendations to the Court by the Watermaster. (¶ 24(o).) So do the Watermaster's own rules. (Rule 15.) Moreover, those rules require the Watermaster to give notice of its preliminary recommendation, conduct a public hearing concerning that preliminary recommendation, and then make a final recommendation to the Court, all by prescribed dates. The Watermaster did not, in either its preliminary or final recommendation, recommend that the FPA for Alto be reduced below PSY. Indeed, it did not recommend any reduction for Alto whatsoever. Because it did not recommend a reduction by the prescribed deadlines, and because therefore no notice was given of any such potential reduction, the Watermaster asserts that the Court cannot reduce the FPA below PSY at this procedural juncture.

Two premises appear to underlie that conclusion. One is that, unless the Watermaster first makes a recommendation concerning a subarea's FPA, the Court cannot adjust the FPA. The Court agrees. (¶ 24(o).)

The second premise appears to be that, when considering what adjustment should be made, the Court is somehow limited by the Watermaster's recommendation. Specifically, the Watermaster opines: "Subsection (o) does not authorize a reduction in FPA where, as here, the Watermaster has not recommended a further reduction in FPA." (Reply to DF&W, p. 2.) With that premise, the Court does not agree.

The Court's role is not simply to approve or veto the Watermaster's recommendation. To the contrary, the judgment provides that "[t]he Court's review shall be de novo and the Watermaster['s] decision or action shall have no evidentiary weight in such proceeding." (¶ 36(d).) In other words, the Court is not bound by the recommendation of the Watermaster as to what changes are or are not necessary. Instead, the Court is charged with drawing its own conclusions from the evidence, which may differ from the Watermaster's conclusions.

In short, while the Court cannot act until the Watermaster has submitted its recommendations, and while the Court must conduct a noticed hearing on those recommendations, the Court thereafter can make whatever adjustment is called for by the Court's interpretation of the evidence, limited only by the 5%-per-annum maximum reduction.

The Court has implicitly applied that interpretation of the judgment repeatedly when ruling on the last four annual adjustment motions, regarding both Alto and other subareas.

- In 2019, the Watermaster recommended that the FPA for agricultural producers in Alto remain at 80%. The Court instead reduced it to 75%. In the same motion, the Watermaster recommended that the FPA for both Centro and Este remain at 80%. The Court rejected those recommendations and reduced both to 75%.
- In 2020, the Watermaster recommended that the FPA for agricultural producers in Alto be reduced to 70%. The Court instead reduced it to 65%. At the same time, the Watermaster recommended that Oeste be reduced to 70%. Instead, the Court reduced it to 65%, and abolished the differential rampdowns between agricultural producers and M&I producers in Oeste.
- In 2021, contrary to the recommendation of the Watermaster regarding Alto, the Court eliminated the differential between agricultural producers and M&I producers, and imposed a reduction to 55%. In the same order, the Court rejected the recommendation that Baja be reduced to 20%, and instead reduced it to 22.5%.
- In 2022, the Watermaster recommended that Baja stay at 22.5%. Instead, the Court reduced its FPA to 20%.

Thus, over the last four water years, the Court has sometimes adopted the Watermaster's recommendations, sometimes imposed a lesser reduction than recommended, and sometimes imposed a greater reduction. Occasionally, it also restructured the rampdowns by eliminating pre-existing differentials between different types of users, without any recommendation by the Watermaster to do so. Were the Watermaster's interpretation of the judgment correct, then the Court acted beyond its authority every time that its order varied from the Watermaster's recommendation. Neither the Watermaster nor any other party has ever questioned the Court's authority to order reductions in the FPA that differ from what the Watermaster has recommended. That silence is an implicit acknowledgement that the Court is not limited by the nature of the Watermaster's recommendation, or by the extent of the recommended reduction, but only by whether the Watermaster has made a recommendation regarding that subarea's FPA for the Court to consider.

Here, the Watermaster recommended that no adjustment be made to the FPA for Alto. The issue of whether any adjustment of Alto's FPA was needed was thereby put on the table for decision. Notice was given of the Watermaster's annual adjustment motion. After the hearing on that motion n 6-2-22, the Court determined that it would hold an additional hearing on 8-25-22 concerning the specific issue of whether Alto's FPA should be reduced below PSY. (Order of 6-3-22.) That hearing was ultimately continued to 9-16-22, and notice of that continuance was given. That is more than sufficient to satisfy the notice requirement in paragraph 36, which does not prescribe any minimum period of notice at all.

The procedural prerequisites of a recommendation and notice having been satisfied, the Court may decide at this time whether Alto's FPA should be reduced to a level below the currently estimated PSY.

Substantive Restrictions on the Reduction of FPA Below PSY

The Court agrees with Mitsubishi that the judgment does not contemplate reductions in FPA below PSY. Although the judgment does not expressly state such a limitation, the underlying theme of the physical solution is that the parties have the right to produce water for beneficial use up to FPA so long as that level of production is sustainable. As the judgment puts it: "A fundamental premise of the Physical Solution is that all Parties will be allowed, subject to this Judgment, to Produce sufficient water to meet their reasonable beneficial use requirements. To the extent that Production by a Producer in any Subarea exceeds such Producer's share of the Free Production Allowance of that Subarea, Watermaster will provide Replacement water to replace such excess Production according to the methods set forth herein." (Judgment, ¶V(A)(22).) The "sustainable" level of production is the PSY. Thus, the parties have the right to produce without charge up to the PSY. The language of the statement of decision confirms that there is no power to rampdown FPA below PSY.

Re-Evaluating PSY

PSY is defined as "[t]he highest average Annual Amount of water that can be produced from a Subarea: (1) over a sequence of years that is representative of long-term average annual natural water supply to the Subarea net of long-term average annual natural outflow from the Subarea, (2) under given patterns of Production, applied water, return flows and Consumptive Use, and (3) without resulting in a long-term net reduction of groundwater in storage in the Subarea." (Judgment, ¶II(A)(4)(aa).)

Over the last three years, Alto's FPA has been reduced to just above PSY. Nevertheless, the storage levels have continued to drop, just as they have been for the last 10 years. If FPA is reduced to PSY, but groundwater storage is still declining notwithstanding the purchase and supply of replacement water, it's logical to question whether the PSY calculations are founded on correct assumptions.

For instance, the present calculation of PSY has been based on a 60-year study of flows from 1930 to 1990. The Court questions whether a 60-year period in the middle of the 20th century is still an appropriately representative period from which to measure the long-term averages specified in the definition of PSY, especially given the 32 years that have passed since 1990 and the climatic disruptions that we have been experiencing during that time.

If that is not the most representative period, should a different period be defined? Mr. Wagner has stated that, if the judgment were being negotiated today, it would be more prudent to select "a shorter, drier planning period (hydrologic base period) for local supply . . ., resulting in a lower estimated Production Safe Yield and consequently lower annual Free Production Allowance." (Wagner Decl., p. 6, ll. 18-21.) Is the Watermaster bound to rely upon what appears at this point in time to be a less-than-prudent period?

The Court acknowledges that the Watermaster re-evaluated PST three years ago. However, in his 2019 declaration, Mr. Wagner suggests that the changes were largely driven by changes in consumptive use, and did not consider changes in supply. At the time he stated:

> Periodic updates to PSY are necessary to capture changes in land use that may occur over time. Irrigation patterns, cropping, general land uses, consumptive use of water and patterns of return flow for example affect PSY. **The long-term average annual supply is generally based on the period 1930-31 to 1989-90**. The PSY update is focused on changes in consumptive uses from those reported by Webb [Albert. A. Webb and Associates]. The consumptive use is evaluated annually by the Watermaster Engineer and reported in Chapter 3 of the annual report....
>
> The current PSY estimate includes long-term water supply as specified in the Judgment, consumptive uses for 2017-2018, phreatophyte use as indicated in the Judgment, Subarea subsurface obligations and surface obligations....

(2019 Wagner declaration, p. 3, ll. 5-17, emphasis added.) Thus, the 2019 re-evaluation appears to re-evaluate all of the relevant factors except for supply. Why, with an additional and more recent 30 years of data, should the PSY calculation continue to rely upon the prior 60-year period for defining the long-term average? At the very least, should not the past 32 years of data be added to the original 60 years?

For all these reasons, the Court declines to order rampdown of FPA below PSY. Instead, the Court will order FPA to equal to PSY, by reducing FPA by an additional 0.1 percent to 54.4%, and shall order the Watermaster to re-evaluate PSY in all subareas as part of its annual motion in June of 2023.

SERVICE

Counsel for the Watermaster shall serve copies of this order on all parties by mail forthwith, and shall file a proof of service within seven days of the date of mailing.

Craig G. Riemer, Judge of the Superior Court

PROOF OF SERVICE

STATE OF CALIFORNIA }
COUNTY OF SAN BERNARDINO}

I am employed in the County of the San Bernardino, State of California. I am over the age of 18 and not a party to the within action; my business address is 13846 Conference Center Drive, Apple Valley, California 92307.

On September 19, 2022, the document(s) described below were served pursuant to the Mojave Basin Area Watermaster's Rules and Regulations paragraph 8.B.2 which provides for service by electronic mail upon election by the Party or paragraph 10.D, which provides that Watermaster shall mail a postcard describing each document being served, to each Party or its designee according to the official service list, a copy of which is attached hereto, and which shall be maintained by the Mojave Basin Area Watermaster pursuant to Paragraph 37 of the Judgment. Served documents will be posted to and maintained on the Mojave Water Agency's internet website for printing and/or download by Parties wishing to do so.

Document(s) filed with the court and served herein are described as follows:

NOTICE OF SERVING THE COURT'S SEPTEMBER 16, 2022 ORDER (1) DISCHARGING ORDER TO SHOW CAUSE WHY THE FPA OF ALTO SHOULD NOT BE REDUCED BY ANOTHER 4.5% OF BAP (2) REDUCING THE FPA IN ALTO BY ANOTHER 0.1 % OF BAP and (3) DIRECTING THE WATERMASTER TO REEVALUATE PSY FOR THE ENTIRE BASIN, AND PROOF OF SERVICE THEREON

_X_ (STATE) I declare under penalty of perjury under the laws of the State of California that the above is true and correct.

Executed on September 19, 2022 at Apple Valley, California.

Jeffrey D. Ruesch

EXHIBIT 3

William J. Brunick, Esq. [SB No. 46289]
Leland P. McElhaney, Esq. [SB No. 39257]
BRUNICK, McELHANEY & KENNEDY PLC
1839 Commercenter West
P.O. Box 13130
San Bernardino, California 92423-3130

Telephone: (909) 889-8301
Facsimile: (909) 388-1889
E-Mail: bbrunick@bmklawplc.com
E-Mail: lmcelhaney@bmklawplc.com

Attorneys for Defendant\Cross-Complainant,
MOJAVE WATER AGENCY

Exempt from filing fee pursuant to Gov't. Code Section 6103

SUPERIOR COURT OF THE STATE OF CALIFORNIA

IN AND FOR THE COUNTY OF RIVERSIDE

Coordination Proceeding Special Title (Cal. Rules of Court, rule 3.550) MOJAVE BASIN WATER CASES	JCCP NO.: 5265 Dept. 7, Riverside Superior Court Hon. Craig G. Riemer, Judge Presiding by assignment of the Chief Justice
CITY OF BARSTOW, Plaintiff, vs. CITY OF ADELANTO, et al., Defendant.	CASE NO.: CIV208568 **NOTICE OF SERVING COURT'S RULING OF JULY 3, 2024 AND PROOF OF SERVICE THEREON** Assigned for All Purposes to Dept. 7, Hon. Craig G. Riemer, Judge Presiding by assignment of the Chief Justice
AND RELATED CROSS ACTIONS	

PLEASE TAKE NOTICE THAT Defendant/Cross-Complainant Mojave Water Agency's Motion to Adjust Free Production Allowance for Water Year 2024-2025, heard on June 24, 2024 before the Honorable Craig G. Riemer, Judge Presiding by assignment of the Chief Justice in Department 7 of the above-entitled court, hereby serves the Ruling on Watermaster's Motion to Adjust Free Production Allowance for Water Year 2024-2025 dated July 3, 2024.

A copy of the Ruling and Proof of Service are attached hereto.

Dated: July 8, 2024

BRUNICK, McELHANEY & KENNEDY PLC

By: ______________________________
William J. Brunick
Leland P. McElhaney
Attorneys for Defendant/Cross-complainant,
MOJAVE WATER AGENCY

EXHIBIT 1

SUPERIOR COURT OF THE STATE OF CALIFORNIA, COUNTY OF RIVERSIDE

FILED
SUPERIOR COURT OF CALIFORNIA
COUNTY OF RIVERSIDE
JUL - 3 2024
J. Castillo

CASE TITLE: Mojave Basin Water Cases / City of Barstow v. City of Adelanto CASE NO.: CIV208568 / JCCP5265 DATE: June 27, 2024	Department 1	

PROCEEDING: Ruling on the Watermaster's Annual Motion to Adjust Free Production Allowance for Water Year 2024-2025

WATERMASTER'S MOTION TO REVISE PSY AND ADJUST FPA

The Mojave Water Agency, appointed as the Watermaster pursuant to the judgment in case #CIV208568, has moved for an annual adjustment of the free production allowance (FPA) regarding some of the five subareas in the Mojave Basin.

In 2022, the Court ordered the Watermaster to re-evaluate the production safe yield (PSY) of each of the subareas in the basin, and to seek the Court's approval of those revised estimates as soon as possible thereafter. (9-16-22 order, p. 1.) The Watermaster has done so. Although its current motion does not expressly seek approval of those revised estimates, the Watermaster subsequently clarified that it is asking the Court to approve the revised PSY for each subarea. (Responses to Questions by Court [hereinafter, Responses], p. 4, #9.)

In evaluating those requests, the Court has considered the following:

- The Watermaster's motion filed 5-1-24;
- The Watermaster's Annual Report lodged 5-3-24;
- Phelan Pinon Hills Community Services District's partial joinder filed 5-10-24;
- Golden State Water Company's opposition, and the declarations of Moore, Abrams, and Hastings in support of that opposition, all filed 5-21-24;
- The response filed by the California Department of Fish and Wildlife, and the declarations of Custis and Johnson in support of that response, all filed on 5-21-24;
- Comments by the City of Victorville and the Victorville Water District on the Watermaster's motion, filed 5-30-24;
- The Watermaster's Responses submitted at the 6-24-24 hearing; and
- The arguments offered at the hearing by the Watermaster and other interested parties.

The Watermaster's motion is granted in part and denied in part as explained below.

Revised PSY – In General

The Watermaster proposes to increase the PSY in all five subareas as follows:

Subarea	Existing PSY in acre feet	Proposed PSY for 2024-2025 in acre feet	Amount of Proposed Increase in acre feet	Percentage Increase
Alto	59,409	62,005	2,596	4.4%
Baja	12,189	12,749	560	4.6%
Centro	21,088	31,420	10,332	49.0%
Este	4,728	6,582	1,854	39.2%
Oeste	1,712	3,634	1,922	112.3%

In general, the Court approves the Watermaster's proposed PSY for each subarea. However, that approval is without prejudice to challenges to the manner in which the Watermaster has calculated PSY and the sufficiency of the factual investigation on which those calculations are based. For example, Golden State Water Company intends to bring a motion seeking the relief described in its opposition to the Watermaster's motion. Any such motion by Golden State shall be filed no later than 7-25-24, or by such later date to which the Watermaster may agree.

Revised PSY – Oeste

Although the Court generally accepts the proposed PSYs, it does not approve the proposed PSY for Oeste. The Watermaster recommended that the PSY be set at a number "equal to the average pumping of the past 5 years, 3,634 acre-feet." (Decl. of Wagner, p. 6.) As noted in the Court's tentative ruling, the Court has reservations about the PSY for Oeste for multiple reasons.

Initially, the Court is not clear as to which five years the Watermaster is referring. Is it water years 2020 through 2024? Is it water years 2019 through 2023, since 2024 is not yet finished? Or is it to the last five years of the 2001-2020 period that the Watermaster is relying upon for the calculations regarding Alto and Centro (Responses, p. 3, #6), given the clarification at the hearing that the Watermaster's reference to "the last 20 years" was intended to mean water years 2001 through 2020?

Second, the Court is troubled by the reliance upon a span of only five years. As noted in the tentative ruling, the judgment requires PSY to be based upon "a sequence of years that is representative of long-term average annual natural water supply to the

Subarea . . . ." (Judgment, p. 11.) At the hearing, Mr. Wagner opined that the "last five years" are representative of the last 20 years.

That assertion raises several concerns. First, in the context of the judgment, the Court is not sure that the average over a 20-year period constitutes a "long-term" average.

The Court is also concerned about apparent inconsistencies in the Watermaster's position. The Watermaster's Responses say that if the "Watermaster relied solely on data from the last 20 year period, the PSY would be approximately 4,300, not 3,634." (Responses, p. 5, #15.) But it appears to the Court that if the last five years are representative of the last 20 years, then the calculations based on those two periods should be approximately the same, not dramatically different.

Furthermore, the representation that the PSY would be 4,300 if one were to rely on the 20-year period also appears to contradict the declaration of the Watermaster's engineer, in which he represented: "Assuming the average pumping for the past 20 years, the PSY would be 2,983 acre-feet." (Wagner decl., p. 6.)

Another inconsistency in the Watermaster's representations concerning Oeste causes the Court concern. The engineer's declaration says: "The UMBM indicates a loss in storage of 1,588 acre-feet per year for the past 20 years." (Wagner decl., p. 6.) But the Responses represent that the loss for the last five years is 822 acre-feet per year. (Responses, p. 5, #17.) Both of those statements may be true, because the 20-year average could be 1,588 even though the 5-year average is only 822. But the Watermaster's failure to stick with a consistent time period does not assist the Court in evaluating the evidence presented and does not enhance the Watermaster's credibility.

Further, the motion appears to be inconsistent with the Annual Report. The motion says that the PSYs for Oeste, Este, and Baja are calculated on the basis of 5-year or 20-year periods. But the Annual Report, at p. 38, states: "PSY is based on long term average water supply (1931-1990) . . . ."

Most importantly, the assertion that the subarea continues to lose storage at the rate of 822 acre-feet per year is inconsistent with the Watermaster's justification for the proposed increase in PSY. The Watermaster's engineer opined that the PSY should be set at 3,634, reasoning: "Assuming water levels are indicating little or no loss of storage, the PSY would be about equal to pumping," and that average pumping is 3,634. (Wagner decl., p. 6.) But if it is true that the subarea is losing 822 acre-feet per year, then the assumption that the average level of pumping is resulting in "little or no loss of storage" is false.

For all these reasons, the Court declines to adopt the recommended PSY for Oeste. The PSY will remain at 1,712 for now. If the Watermaster recommends another increase in the future, the motion shall be supported by evidence and analysis that address each of the concerns described above.

Revised PSY – Baja

The Court approves, for water year 2024-2025 only, a PSY for Baja of 12,749. The evidentiary basis for that increase is unclear. Table 5-1, at pages 43 and 44 of the Annual Report, says that the PSY for Baja is 14,544 if based on water years 1931-1990, and 10,866 if based on water years 2001-2020.

FPA for Este:

Despite the increase of PSY to 6,582, the FPA for water year 2023-2024 (11,568) continues to greatly exceed it.

The only reason that the subarea is not being overdrafted is because verified production (4,114 in 2023-2024) is below PSY. In recent years, the Court has ramped-down the FPA in this and some other subareas in which production is below PSY to further the goal that, if production increases in the future, the FPA will be low enough to prevent free production in excess of PSY.

Consistent with that goal, the Watermaster recommends that FPA be reduced by 5% from 55% of BAP to 50% of BAP. The Court approves the Watermaster's proposed 5% reduction. The Court orders that the FPA for all producers in Este shall be reduced to 50% of BAP for Water Year 2024-2025.

FPA for Oeste:

For water year 2023-2024, the FPA governing parties' production is 50% of BAP, or 3,548 acre-feet. That greatly exceeds the PSY (1,712). As noted above, however, the Watermaster recommends that the PSY be set at 3,634, a number that the Watermaster characterizes as the "more conservative estimate[]." (Responses, p. 5, #17.) Because 3,634 is so close to the current FPA, the Watermaster recommends that the FPA remain at 50% of BAP.

The Court is not persuaded. Unless and until the Watermaster persuades the Court that the PSY should be raised, the Court is going to assume that the current PSY reflects the best estimate. Moreover, the Court does not consider a resolution that allows a greater level of production to be the most conservative approach. Given that the goal of this judgment is to bring free production down into balance with available supply, the Court resolves any doubts in favor of lower rather than greater production.

Accordingly, the Court declines to adopt the Watermaster's recommended FPA. The Court orders that the FPA for all producers in Oeste shall be reduced by 5% of BAP to 45% of BAP for Water Year 2024-2025.

FPA for Baja:

For water year 2023-2024, the FPA governing parties' production is 20.5% of BAP, or 13,562 acre-feet. The new PSY is 12,749. The Watermaster recommends that the FPA remain at 20.5%, arguing that the water levels in Baja have stabilized.

In its tentative ruling, the Court was skeptical: "Little if any analysis is offered in support of that proposal. It does not offer evidence that Baja is now stabilized. At most it says that the drop in some water levels has slowed (suggesting that the drops in most water levels have continued to drop at faster rate), and that water levels have recovered in some wells (suggesting that most wells have continued to drop). (Wagner decl., p. 5.) Besides, the issue is not whether there is balance between PSY and the current level of production within a subarea, but rather whether the FPA exceeds the PSY."

At the hearing, the Watermaster directed the Court to the Annual Report, figure 3-14, "Baja Subarea Hydrographs 2024." That page consists of a map surrounded by 34 impossibly small graphs. After reviewing that page on the Watermaster's website, where the graphs could be enlarged to make them somewhat more readable, they appear to show that the water level in some wells have increased; in some, leveled off; in some, declined; and in the rest the levels fluctuate to a degree that no trend can be clearly determined. Taken as a whole, it does not appear from that evidence that Baja has yet reached a point of equilibrium.

At 20.5% of BAP, the FPA in Baja is 13,562. At noted above, the revised PSY is 12,749. Assuming that the 12,749 PSY urged by the Watermaster is correct, FPA exceeds PSY by 813. Therefore, there is still room to reduce FPA without dropping below PSY.

The Court declines to adopt the Watermaster's recommendation that the FPA for Baja remain at 20.5% of BAP. Instead, the Court orders that the FPA for all producers in Baja is reduced by 1.0% to 19.5% of BAP for Water Year 2024-2025.

FPA for Alto:

The FPA is currently set at 50.4% of BAP. The Watermaster proposes to increase the FPA to 53.3%.

The Court is not inclined to increase FPA at this time. Given the unfortunate history of this basin, the Court is aggressive in reducing FPA, even when the FPA is relatively close to PSY, as shown in the case of Baja, above. By contrast, the Court will be slow to increase FPA.

As mentioned above, the Court has previously determined that it lacks the power under the judgment to set the FPA lower than the PSY. However, once the FPA has been reduced to a point that is relatively close to the PSY, the Court does not intend to micromanage the FPA each year, increasing it some years and decreasing it in others. The producers are entitled to more predictability, and the Court and the Watermaster would benefit from the opportunity to evaluate the accuracy of the model when applied for a longer period of time. If and when the water levels in Alto show increasing stability over several years, and when the storage levels are able to climb out of the "Area of Concern" where they have resided since about 2014 (Annual Report, figure 3-8), the Court is likely to gradually increase the FPA. However, it will not do so the first time that the FPA is less than the PSY, especially when that imbalance occurred because the PSY is increased as the result of a recalculation.

The Court orders that the FPA for all producers in Alto remains at 50.4% of BAP for Water Year 2024-2025

FPA for Centro:

The existing FPA for Centro is 55 percent of BAP, or 28,067 acre-feet. As noted in the chart above, however, the revised PSY is 31,420 acre-feet, 49 percent higher than the prior estimation. The difference between the existing FPA and the new PSY is 3,353 acre-feet, or 6.6% of BAP. Accordingly, the Watermaster proposes to reduce that differential by 5% by increasing the FPA from 55% of BAP to 60%.

The magnitude of the Watermaster's recommended increase is presumably a reflection of the provision in the judgment that the annual reduction of FPA in any subarea may not exceed 5% of BAP. (Judgment, p. 33.) The apparent reason for such a limitation is to moderate the impact of any such reduction on the affected producers. As the Watermaster notes, there is no comparable limit on the speed at which the Court may *increase* FPA. (Responses, p. 6.) Thus, the Court could increase the FPA by the 5% recommended or by the full 6.6%.

Nevertheless, the Court declines to do either at this time. In addition to the reservations described above concerning a possible increase of FPA in Alto, the Court is concerned about the affect of increased pumping on the public trust resources. The Court also notes that the model the Watermaster is developing does not yet extend to Centro, suggesting that the proposed PSY may not be accurate. On the other hand, the water storage in Centro is well above the Area of Concern. (Annual Report, figure 3-19.) Moreover, the degree to which FPA has fallen below PSY is greater in Centro (6.6%) than in Alto (4.4%).

In consideration of those conflicting factors, the Court finds that the FPA should be increased to move toward equalization of FPA and PSY, but that it should be done in a cautious and incremental manner. The Court orders that the FPA for all producers in Centro shall be increased by 1% from 55% of BAP to 56% of BAP for Water Year 2024-2025.

FUTURE MOTIONS TO ADJUST FPA

Regarding subsequent motions to adjust FPA:

1. The Court found it very cumbersome to search for documents referred in the points and authorities or Mr. Wagner's declaration. For instance, a reference to a document merely as "Appendix A of Exhibit 5" (Wagner decl., p. 3) does not materially assist the Court in locating the document when the moving papers are over 450 pages long. Accordingly, in any future motions to adjust FPA, every page of the declaration of the Watermaster's engineer and every page of any evidence authenticated by that declaration shall be sequentially numbered. All citations in either the memorandum of points and authorities or the engineer's declaration to any of that evidence shall include the page number on which that evidence appears.

2. If the parties are interesting in doing so, upon request the Court will reserve sufficient time on the hearing date to allow the parties to review the evidence in an oral presentation via PowerPoint or some similar means. Any such PowerPoint slides shall be shared with counsel for other represented parties at least five days in advance of the hearing.

3. Any expert opinions offered either in support of or in opposition to any motion shall be limited to opinions that (a) are stated to be more likely than not true and (b) are supported by such analysis and evidence to allow a finder of fact to understand the reasons for that opinion.

4. In the Court's tentative ruling, the Court had questioned Mr. Wagner's representations regarding FPA, all of which were higher than that calculated by the Court. At the hearing, Mr. Wagner explained that his calculations of FPA included, not only the production by parties who were subject to the judgment, but also minimal producers and other producers who are not parties to the judgment. In the next motion to adjust FPA:

4.a. The motion shall clearly distinguish between the FPA of parties to the judgment and the production by nonparties.

4.b. If the motion describes the production of nonparties, it shall explain the significance of that production to the Court's consideration of proposed changes to the FPA of parties. In particular, it shall answer the following questions:

i. Does "Producer" as defined in the judgment (at p. 11) include nonparty pumpers?

ii. Does "Free Production Allowance," as defined in the judgment (at p. 9), include water pumped by nonparty pumpers?

iii. Does the judgment require the Court to consider nonparty production when determining whether, and to what extent, the FPA of the parties to the judgment should be reduced? If not, does it allow the Court to do so?

5. The motion shall address the evidentiary basis for the proposed PSY for Baja.

SERVICE

Counsel for the Watermaster shall (a) serve copies of this order on all parties by mail forthwith and (b) file a proof of service within seven days of the date of mailing.

Craig G. Riemer, Retired Judge of the Riverside Superior Court, by Assignment of the Chief Justice

PROOF OF SERVICE

STATE OF CALIFORNIA }
COUNTY OF SAN BERNARDINO}

I am employed in the County of the San Bernardino, State of California. I am over the age of 18 and not a party to the within action; my business address is 13846 Conference Center Drive, Apple Valley, California 92307.

On July 8, 2024, the document(s) described below were served pursuant to the Mojave Basin Area Watermaster's Rules and Regulations paragraph 8.B.2 which provides for service by electronic mail upon election by the Party or paragraph 10.D, which provides that Watermaster shall mail a postcard describing each document being served, to each Party or its designee according to the official service list, a copy of which is attached hereto, and which shall be maintained by the Mojave Basin Area Watermaster pursuant to Paragraph 37 of the Judgment. Served documents will be posted to and maintained on the Mojave Water Agency's internet website for printing and/or download by Parties wishing to do so.

Document(s) filed with the court and served herein are described as follows:

Ruling on the Watermaster's Annual Motion to Adjust Free Production Allowance for Water Year 2024-2025

_X_ (STATE) I declare under penalty of perjury under the laws of the State of California that the above is true and correct.

Executed on July 8, 2024 at Apple Valley, California.

Joseph S. Salazar (signature)
Joseph S. Salazar

EXHIBIT 4

MOJAVE BASIN AREA WATERMASTER

Production Safe Yield & Consumptive Use Update

February 28, 2024

Prepared by:
Wagner & Bonsignore, Engineers
Robert C. Wagner, PE
Watermaster Engineer

FINAL DRAFT

Table of Contents

Appendix D: Este Water Supply Update

Appendix E: Baja Water Supply Update

Appendix F: Consumptive Use Update

Appendix G: Upper Mojave River Basin Groundwater Model

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

Nicholas F. Bonsignore, P.E.
Robert C. Wagner, P.E.
Paula J. Whealen

Martin Berber, P.E.
Patrick W. Ervin, P.E.
David P. Lounsbury, P.E.
Vincent Maples, P.E.
Leah Orloff, Ph.D, P.E.
David H. Peterson, C.E.G., C.H.G.
Ryan E. Stolfus

MEMORANDUM

To: Mojave Basin Area Watermaster

From: Robert C. Wagner, P.E.

Date: February 28, 2024

Re: **Updates for PSY, Consumptive Uses, and Free Production Allowance Recommendations (FPA) for Water Year 2024-25**

We have completed an update to the Production Safe Yield (PSY) for each of the five subareas consistent with direction from the Court during hearings from June 2022, and 2023. The PSY, indicated FPA and proposed FPA for 2024-25 are shown below.

Table 1
Updated Production Safe Yield and Proposed Free Production Allowance 2024-25

Subarea	Current PSY	Current FPA	Surplus/ (Deficit)	Indicated PSY	Indicated FPA	Proposed FPA
Alto	59,409	50.4%	(17,475)	62,005	53.3%	53.3%
Baja	12,189	20.4%	---	12,749	19.3%	20.4%
Centro	21,088	55.0%	11,540	31,420	61.6%	60.0%
Este	4,728	55.0%	---	5,108	25.3%	50.0%
Oeste	1,712	50.0%	(1,566)	2,970	41.9%	50.0%

Notes:
1. Current PSY as set by Watermaster, May 1, 2023.
2. Current FPA as set by Court September, 2023.
3. Alto and Oeste deficit determined by Upper Mojave River Basin Model (UMBM).
4. Baja PSY assumes $\Delta S=0$ based on Baja Hydrographs (Appendix E).
5. Centro surplus from proposed Table 5-1 based on UMBM. PSY includes adjustment for return flow from pumping the surplus (Appendix A).
6. Este, Fifteen Mile Valley surplus, 134 acre-feet per UMBM, for Lucerne Valley, $\Delta S=0$ based on water level response over time, see Este Hydrographs (Appendix D).
7. Surplus/Deficit for Oeste; see Appendix G. Proposed PSY see Appendix C.

2151 River Plaza Drive · Suite 100 · Sacramento, CA 95833-4133
Ph: 916-441-6850 or 916-448-2821 · Fax: 916-779-3120

With respect to the Oeste Subarea as shown in Table 1, the PSY and the FPA recommendations are based on an assessment of water level trends and is discussed in Appendix C. As indicated in Appendix C, we recommend PSY be set at 3,634 acre feet, and FPA at 50% of BAP.

The Appendices for each subarea discuss various elements of water supply use and disposal specific to that subarea. We have combined the Alto/Centro discussion into one document as those subareas are directly affected by the water supply conditions in Alto.

Different from previous evaluations for the Alto subarea, we have incorporated the UMBM to represent conditions in Alto, above the Lower Narrows, and in Oeste and the Fifteen Mile Valley portion of the Este subarea. A description of the model, its inputs, assumptions and output is included as Appendix G. The model results agree well with the water balance approach for Alto, that has traditionally been reported as Table 5-1 of the Watermaster Annual Report (Appendix A, Fig. 3)

Figure 1, generally shows the adjudicated boundary and the boundary of the five subareas. Figure 2, shows the area of investigation for the Model, as well as the Model boundary, and areas modified from the original model to isolate Oeste, Este and the upper portion of the Alto subarea. The original model's domain covered the Upper Mojave Basin from the Los Angeles County line in the west, to include Fifteen Mile Valley in the east; from the upper Mojave River watershed to include portions of the Transition Zone and including the VVWRA discharges.

The Court previously asked that we consider a drier and more recent hydrologic planning period. Water supply as measured at the Forks, during the 11-year period between 2011 and 2022 was only about 42% of the long-term average (1931-1990) supply.

This raised the concern that the basin could experience an average water supply over a long period of time, but over an extended dry period water supply shortages could result. For example, the 20 year period 1946-65 was the driest 20 years on record, about 50% of the 60 year Judgment's base period average; yet this was significantly wetter than the 11 years preceding 2023. Consequently, we updated the hydrologic base period for purposes of establishing PSY for Alto and Centro (2001-2020). This period is consistent with the guidance from California Department of Water Resources, Bulletin 84, 1967 that was used as guidance for the base period in the Judgment.

> "The base period conditions should be reasonably representative of long-time hydrologic conditions and should include both normal and extreme wet and dry years. Both the beginning and the end of the base period should be preceded by a series of wet years or a series of dry years, so that the difference between the amount of water in transit within the zone of aeration at the beginning and end of the base period would be a minimum. The base period should also be within the period of available records and should include recent cultural conditions as an aid for projections under future basin operational studies." (Bulletin 84, page, 12)

The period 2001-2020 (61,635 acre feet) was proceeded by dry years and ended with dry years as measured by USGS at the Forks. The period is about 6% drier than the base period average (65,538 acre feet). The period is entirely within the period of available record and includes recent cultural conditions. Water year 2022, the most recent year that data is available is assumed to represent pumping and consumptive uses on a forward-looking basis. For purposes of establishing PSY, and recommending FPA, 2001-2020 is an acceptable base period (Figure 3).

Each Subarea is discussed separately in the appendices as well as the consumptive use update for 2022 and the description of the UMBM:

Appendix A: Alto/Centro
Appendix B: Transition Zone
Appendix C: Oeste
Appendix D: Este
Appendix E: Baja
Appendix F: Consumptive Use Memo
Appendix G: Upper Mojave Basin Model

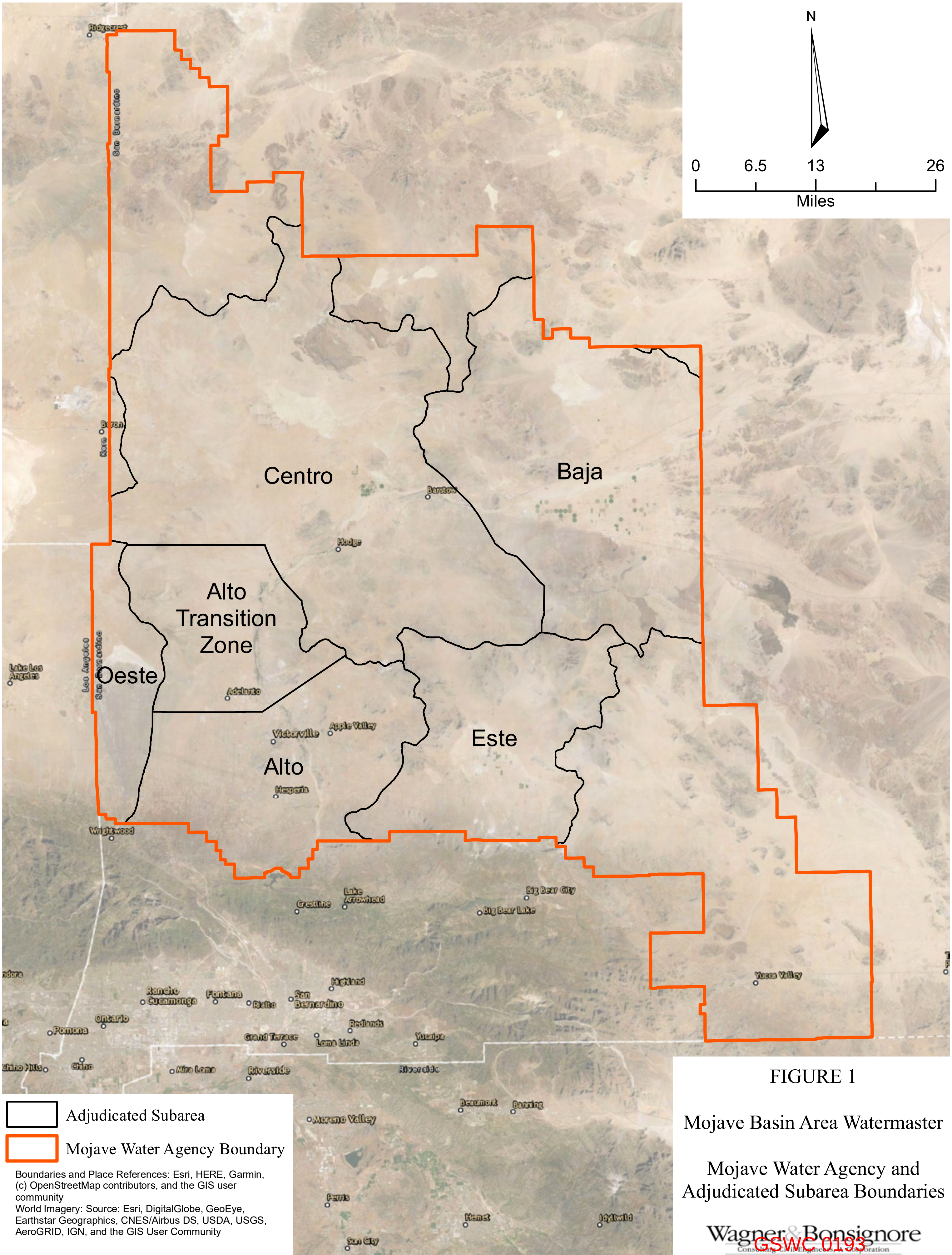

FIGURE 1

Mojave Basin Area Watermaster

Mojave Water Agency and Adjudicated Subarea Boundaries

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

GSWC 0193

June 2020

Q:\Drawings\Mojave Water Agency\Este Subarea\Este Water Supply - FIGURE 1 - Location Map.mxd

Figure 2

Free Body Diagram of Ground Water Model for Mojave Basin Area

San Bernardino County, California

Wagner Bonsignore
Consulting Civil Engineers, A Corporation

February 2024

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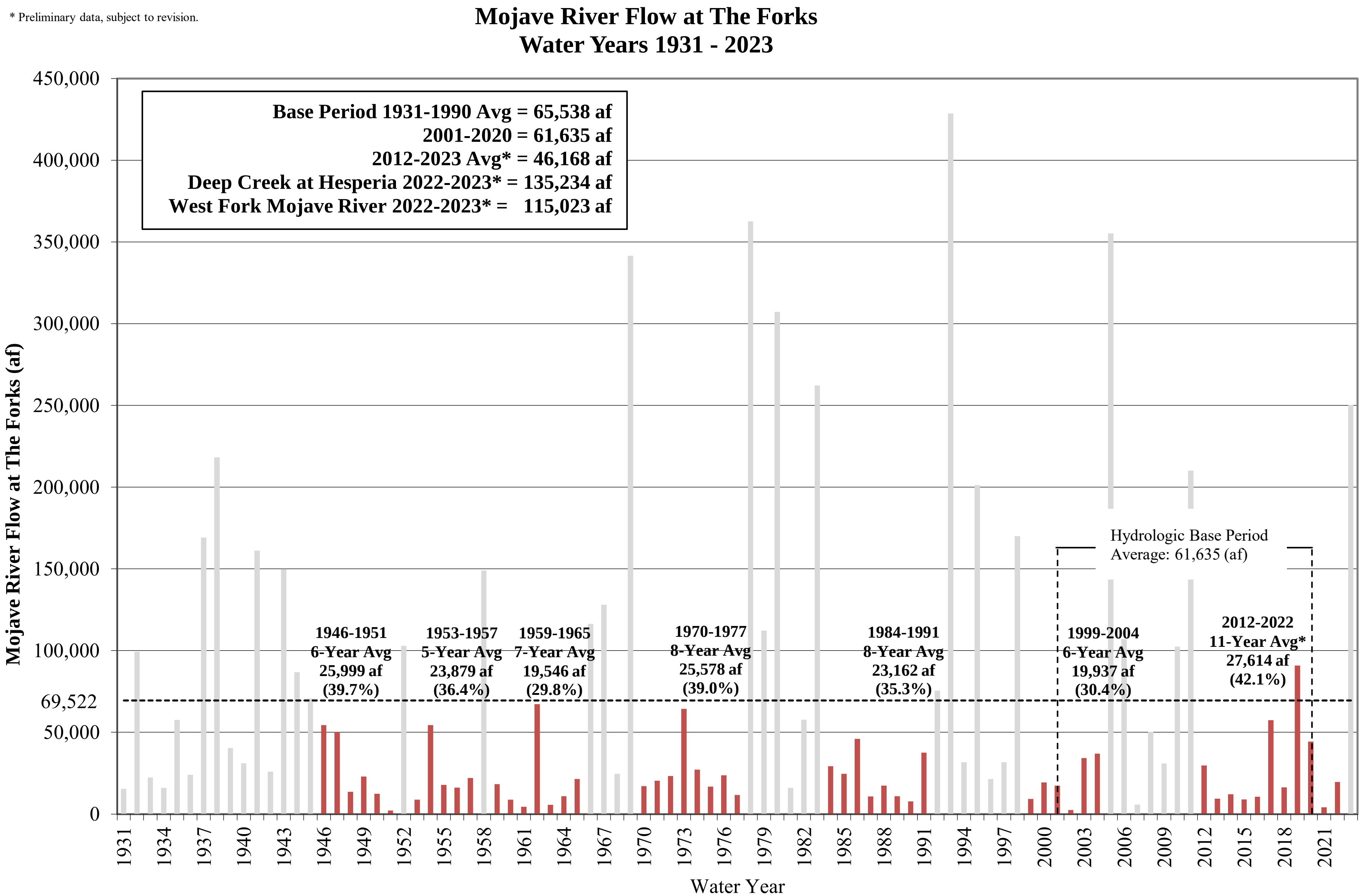
GSWC 0194

2/20/2024

Figure 3



Note: Discharge of Mojave River at The Forks from the addition of values as reported from USGS stations at West Fork Mojave River Near Hesperia, CA (10261000), and Deep Creek Near Hesperia, CA (10260500) from 1931-1971, the greater of 10260500 and Mojave River Below Forks Reservoir Near Hesperia, CA (10261100) from 1972-1974, and the addition of West Fork Mojave River Above Mojave River Forks Reservoir Near Hesperia, CA (10260950) and 10260500 from 1975-Present.

G:\MOJAVE WATERMASTER - 3040\Analysis\3040-225H-Mojave River Discharge (modified from 018x).xlsx, Forks Hydrograph (4)

Mojave Basin Area Watermaster

Appendix A

Alto & Centro Subarea

Water Supply Update

Prepared by:

Wagner & Bonsignore, Engineers

Robert C. Wagner, PE

Watermaster Engineer

February 28, 2024

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

Nicholas F. Bonsignore, P.E.
Robert C. Wagner, P.E.
Paula J. Whealen

Martin Berber, P.E.
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Ryan E. Stolfus

MEMORANDUM

To: Mojave Basin Area Watermaster

From: Robert C. Wagner, P.E.

Date: February 28, 2024

Re: **Production Safe Yield Update for Alto and Centro Subarea; Calculation of Outflow from Alto to the Transition Zone, and Calculation of Outflow to Centro.**

This memorandum presents the update for Production Safe Yield (PSY) for the Alto and Centro Subareas. These areas are shown on Figure 1, attached hereto. The Transition Zone described in Appendix B, is considered to be part of the Alto subarea by the Judgment, and serves to hydraulicly connect the portion of Alto above the Lower Narrows, to Centro, downstream from the Helendale Fault. For our analysis, the Transition Zone is treated separately in order to calculate the discharge across the Helendale Fault, as there is no long-term reliable measurement at that location. The calculation is described in Appendix B, Transition Zone Water Balance.

The Upper Mojave Basin Model (UMBM, Appendix G) was used to calculate the change in storage in Alto (above Lower Narrows), from 1951-2020, a 70 year period. For purposes of this analysis, we selected the 20 year period from 2001-2020 as the hydrologic base period for evaluating the change in storage (surplus/deficit) in Alto. Figure 2, shows the annual change and cumulative change storage in Alto, for 70 years. Approximately 1.1 million acre feet of groundwater has been depleted from the upper part of Alto since 1951.

The purpose of the Judgment is to arrest overdraft and to provide a funding mechanism to raise money to purchase imported water, to offset any annual deficit. The purpose of the PSY calculation is to help set the Free Production Allowance (FPA) to allocate the cost of imported water to producers that over pump their FPA. The UMBM is useful to determine the annual deficit (see Appendix G). The annual surplus/deficit in Alto, as indicated by the UMBM is -17,475 acre feet per year.

Table 5-1 Proposed for Alto and Centro is the water balance for Alto, Transition Zone and Centro Subareas (Table 1). Inflow to Alto, is the sum of the average gaged inflow (2001-2020) as measured at the USGS gaging stations at West Fork Mojave River, and Deep Creek near Hesperia; this sum is commonly referred to as the “flow at the Forks.” Also included is mountain front recharge, ungaged inflow and deep percolation of precipitation, and subsurface inflow from Oeste and Este subareas, as developed by the UMBM. Outflow consists of subsurface outflow, consumptive uses of production, phreatophyte use, and a calculation of outflow to Centro, shown as surface water outflow. This value is determined from the water balance for the Transition Zone.

For the Alto subarea, the water balance calculation produces a PSY value of 62,333 acre feet; Total production (including the Transition Zone) for the representative year (2022) less the deficit based the 2001-2020 average water supply (Table 1).

Figure 3, compares the PSY calculation based on Table 1 (Table 5-1) described above with the PSY calculation based on the UMBM. The model treats pumping from all sources the same. The Judgment however, only considers pumping for consumptives uses, as included in the Judgment as "B1" production. "B2" production is not considered for purposes of determining PSY. In the Alto subarea, a portion the water produced by the party Jess Ranch Water Company for its fish hatchery, was excluded from the Judgment and assigned "B2" status, recirculated water. The same status was assigned to the California Department of Fish and Wildlife fish hatchery pumping. Thus, to calculate the indicated PSY using the UMBM we subtract the "B2" pumping from total pumping. The calculation, production plus the surplus/deficit then equals the PSY.

As shown on Figure 3, the PSY value from the UMBM is 62,005 acre feet, and the Water Balance calculation is 62,233 acre feet or a difference of 0.37%. We note however that the model produces a larger deficit, 17,475 acre feet vs, 15,914 acre feet (9% greater). We note an important difference between the two, is the model's deficit is the average deficit for all uses calculated over a 20 year base period. The Water Balance calculation assumes an average water supply, but pumping, consumptive uses, and portions of outflow from a specific year (2022). The PSY is used to determine the FPA. In this case we recommend using the value from the UMBM (62,005).

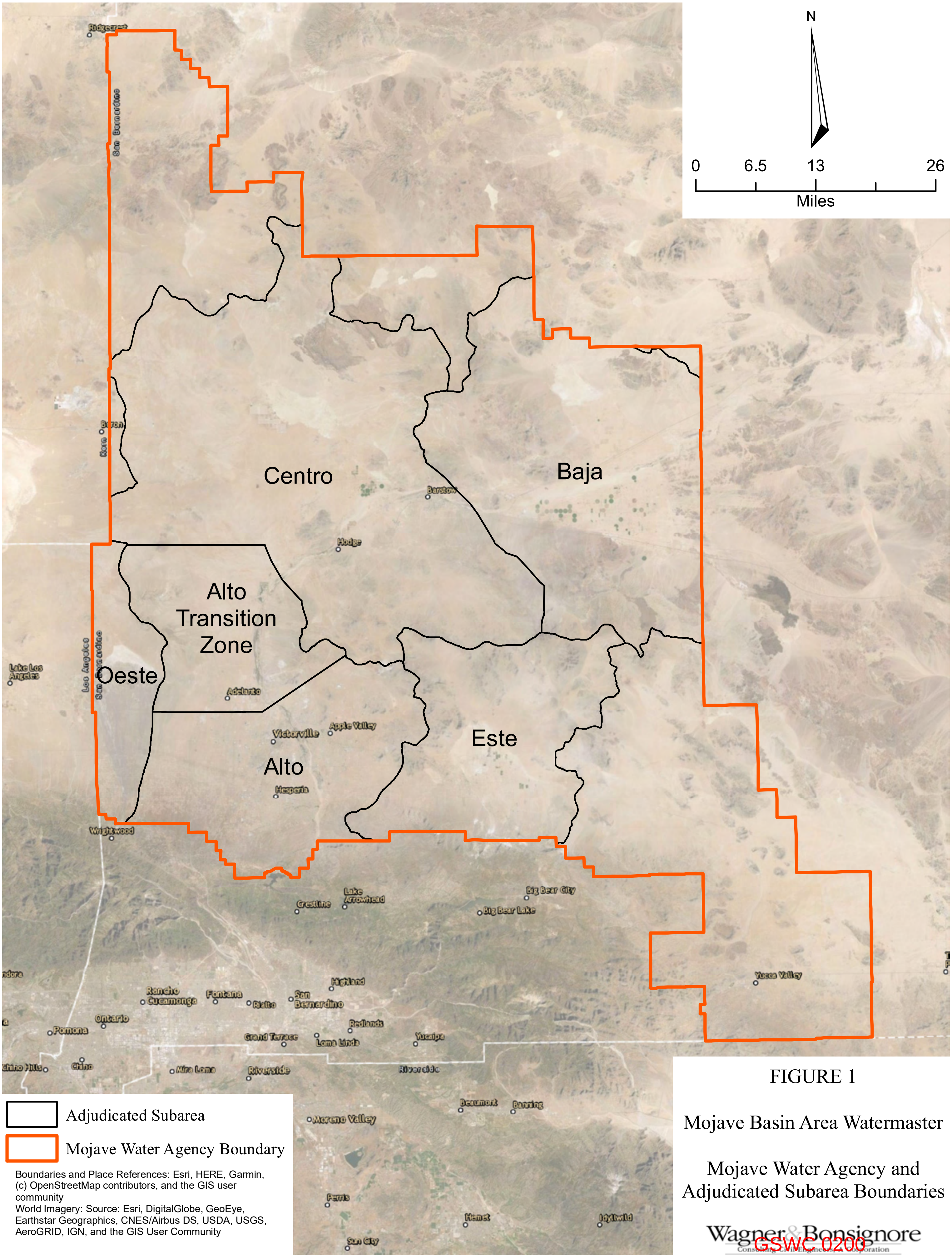
The inflow to Centro is considered to be the outflow from Alto. The outflow from Centro consists of average discharge (2001-2020) at the USGS Barstow gaging station, the net discharge from the Barstow wastewater treatment plant, subsurface discharge to the Baja subarea, water use by phreatophytes and consumptive use of production.

The subarea boundary between Baja and Centro is the Waterman Fault, located several miles downstream of the Barstow gage and downstream of the Barstow Wastewater discharge. However, for this purpose we have considered that the change in groundwater storage is small in the area upstream of the Watermaster Fault based on the limited change in water levels registered over time (see Centro hydrographs)

The resulting PSY calculation for Centro shows a surplus of 11,540 acre feet. The PSY is the sum of total pumping and the indicated deficit of 28,495 acre feet. However, we note that if the surplus were to be pumped and water use was similar to the current patterns of use, a return flow of 2,885 acre feet would result increasing the PSY to 31,420 acre feet (Table 1).

The UMBM was also used to simulate how the flow at Lower Narrows would change by purchasing and recharging the Alto deficit (-17,475 acre feet/year). Simulations assumed that the water supply for the period 2001-2020 repeated for the next 20 years, and production and consumptive uses were constant at the 2020 amount. The results are shown on Figure 4 and Table 2. Compared to no recharge, Baseline Scenario, the recharge scenario increased flow downstream of Lower Narrows by 9,022, acre feet per year.

Based on the foregoing, we recommend a PSY for Alto of 62,005 acre feet and for Centro of 31,420 acre feet.



Adjudicated Subarea

Mojave Water Agency Boundary

Boundaries and Place References: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
World Imagery: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 1

Mojave Basin Area Watermaster

Mojave Water Agency and Adjudicated Subarea Boundaries

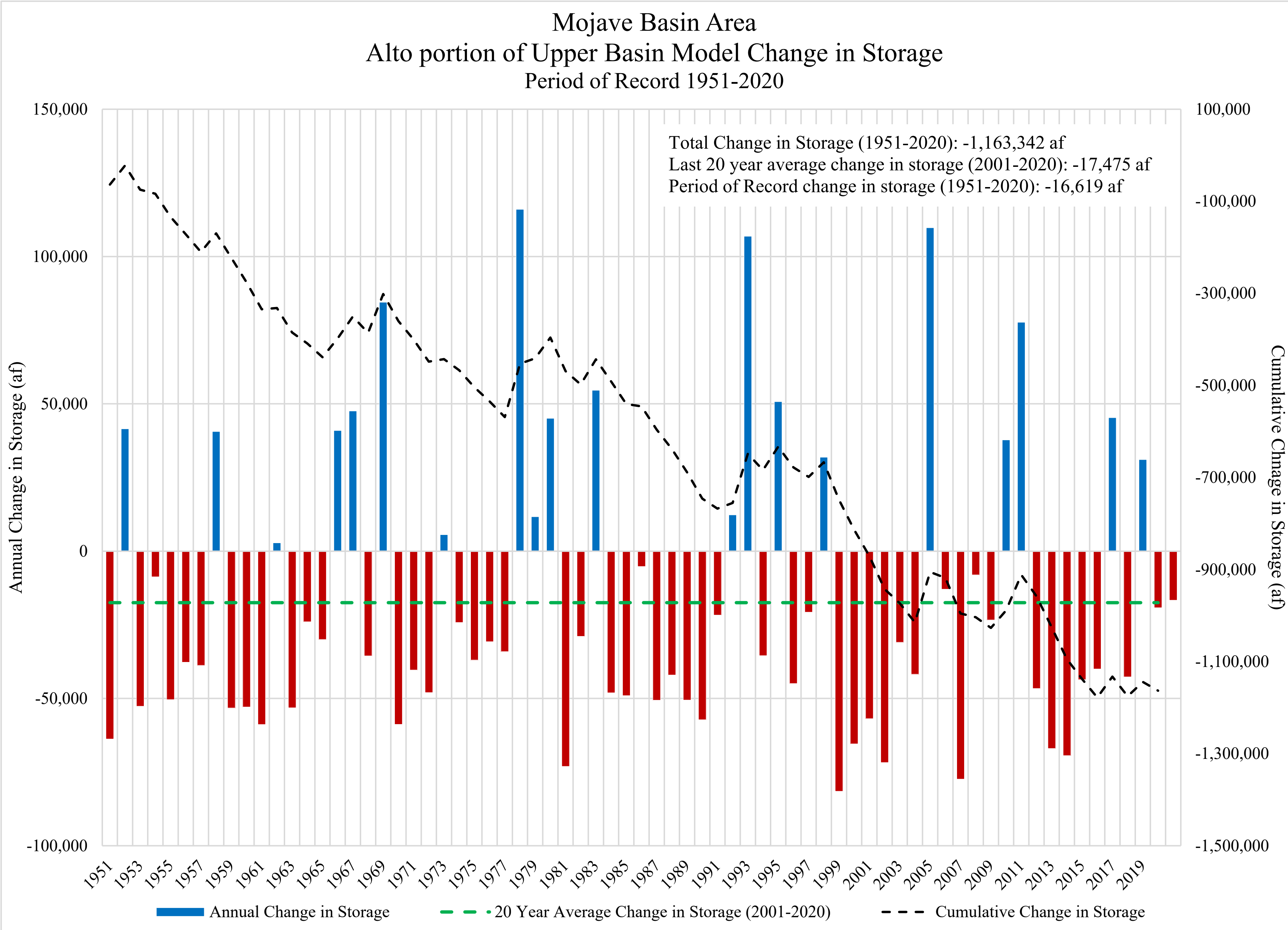
Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

June 2020

Q:\Drawings\Mojave Water Agency\Este Subarea\Este Water Supply - FIGURE 1 - Location Map.mxd

GSWC 0200

FIGURE 2



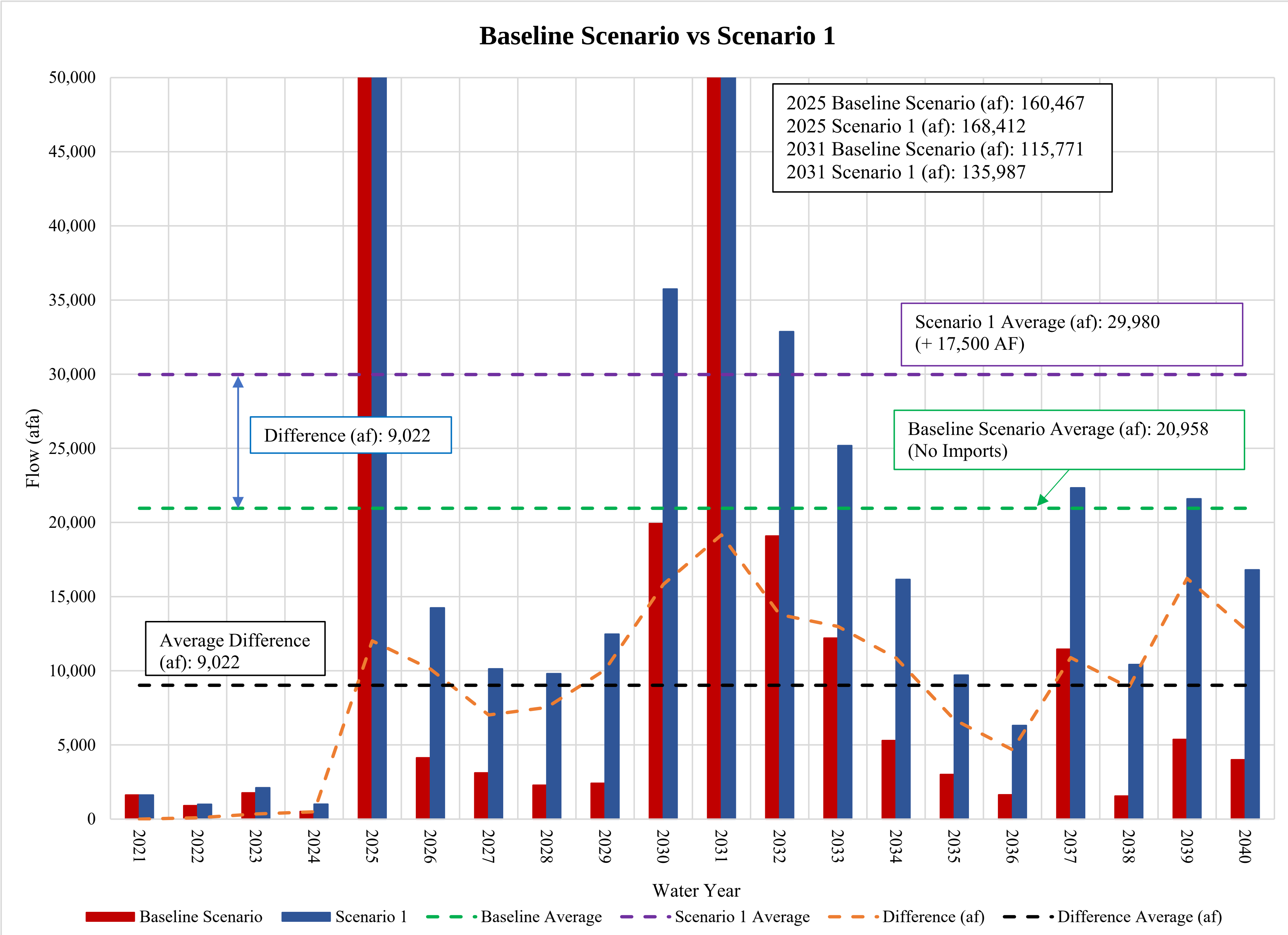
Mojave Basin Area
Alto portion of Upper Basin Model Change in Storage
Period of Record 1951-2020
Total Change in Storage (1951-2020): -1,163,342 af
Last 20 year average change in storage (2001-2020): -17,475 af
Period of Record change in storage (1951-2020): -16,619 af
Annual Change in Storage (af)
Cumulative Change in Storage (af)
150,000
100,000
50,000
0
-50,000
-100,000
100,000
-100,000
-300,000
-500,000
-700,000
-900,000
-1,100,000
-1,300,000
-1,500,000
1951 1953 1955 1957 1959 1961 1963 1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017 2019
Annual Change in Storage
20 Year Average Change in Storage (2001-2020)
Cumulative Change in Storage

FIGURE 3

Production Safe Yield Based on Model Output and 2021-2022 Current Year Pumping and Consumptive Use	
Alto above Narrows Production Average 2001 - 2020 (acre-feet)	81,968
2001 - 2020 Average Alto B2 Pumping (acre-feet)	14,118
Alto above Narrows B1 Pumping (acre-feet)	67,850
TZ (2001 - 2020) Average Pumping (acre-feet)	11,630
Modeled Pumping Alto + Transition Zone (acre-feet)	79,480
Alto above Narrows Modeled Deficit (2001 - 2020)	-17,475
Modeled Production Safe Yield (acre-feet)	62,005
Table 5-1 Production Safe Yield (acre-feet)	62,233
% Difference	0.37%

Current Production Safe Yield	59,409

FIGURE 4



Baseline Scenario vs Scenario 1
2025 Baseline Scenario (af): 160,467
2025 Scenario 1 (af): 168,412
2031 Baseline Scenario (af): 115,771
2031 Scenario 1 (af): 135,987
Scenario 1 Average (af): 29,980
(+ 17,500 AF)
Difference (af): 9,022
Baseline Scenario Average (af): 20,958
(No Imports)
Average Difference
(af): 9,022
Flow (afa)
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
Water Year
Baseline Scenario
Scenario 1
Baseline Average
Scenario 1 Average
Difference (af)
Difference Average (af)

DRAFT

TABLE 1

TABLE 5-1 Proposed

HYDROLOGICAL INVENTORY BASED ON VARIOUS SUPPLY ASSUMPTIONS AND 2021-22 CONSUMPTIVE USE, RETURN FLOW AND IMPORTS

(ALL AMOUNTS IN ACRE-FEET)

	ALTO	TRANSITION ZONE	CENTRO
WATER SUPPLY	2001-2020	2001-2020	2001-2020
Surface Water Inflow [1]	61,635	24,808	36,725
Mountain Front Recharge [2]	8,511	0	0
Groundwater Discharge to the Transition Zone [3]	0	5,112	0
Subsurface Inflow [4]	0	7,053	2,000
Este/Oeste Inflow [5]	4,785	62	
Imports[6]	0	15,095	
TOTAL	**74,931**	**52,130**	**38,725**
CONSUMPTIVE USE AND OUTFLOW			
Surface Water Outflow	36,725 [7]	36,725 [7]	7,500 [14]
Barstow Treatment Plant Discharge			2,475
Subsurface Outflow [8]	2,000	2,000	1,462
Consumptive use [9]			
Agriculture	949	949	5,863
Urban	40,171	6,456	6,885
Phreatophytes [10]	11,000	6,000	3,000
TOTAL	**90,845**	**52,130**	**27,185**
Surplus / (Deficit) [11]	(15,914)		11,540
Total Estimated Production[12]	78,147		16,995
Potential Return Flow from Surplus	0		2,885
PRODUCTION SAFE YIELD[13]	**62,233**		**31,420**

1 Average discharge of Mojave River by USGS, 2001-2020 (USGS stations at West Fork Mojave River Near Hesperia, CA (10261000), Deep Creek Near Hesperia, CA (10260500) and Lower Narrows Near Victorville, CA (10261500)).

2 Mountain front recharge as developed from Upper Basin Alto Model.

3 Groundwater discharge lost to Transition Zone below the Narrows.

4 Portion of water lost to Transition Zone from Alto (Upper Basin Model). Groundwater discharge to Harper Lake (USGS Stamos 2001).

5 Subsurface Inflow to Alto from Este and Oeste Subareas (Upper Basin Model).

6 Total discharge to Transition Zone from VVWRA, 2021-22 Water Year.

7 Estimated based on reported flows at USGS gaging station, Mojave River at Victorville Narrows and 2001-2020

8 Groundwater discharge to Baja 1462 AF; 3501 AF groundwater discharge from Barstow area to Harper Lake. (USGS Stamos 2001)

9 Includes consumptive use of "Minimals Pool" (estimated Minimal's production is 2,104 af).

10 From USGS Water-Resurces Investigation Report 96-4241 "Riparian Vegetation and Its Water Use During 1995 Along the Mojave River, Southern California" 1996. Lines and Bilhorn

11 Amount necessary to offset overdraft under the above assumptions.

12 Water production for 2021-22. Included in the production values are the estimated minimal producer's water use.

13 Imported State Water Project water purchased by MWA is not reflected in the above table.

14 Reported flows at USGS gaging station, Mojave River at Barstow (10262500).

TABLE 2

Annual Flow at the Lower Narrows Under Baseline Scenario and Scenario 1 Water Year Stream Flow 20 Year Scenario Runs			
Water Year	Baseline Scenario (af)[1]	Scenario 1 (af)[2]	Difference (af)[3]
2021	1,623	1,623	0
2022	907	994	87
2023	1,768	2,110	343
2024	515	1,006	491
2025	183,550	195,565	12,015
2026	4,128	14,243	10,115
2027	3,117	10,132	7,015
2028	2,285	9,809	7,524
2029	2,417	12,474	10,057
2030	19,925	35,744	15,819
2031	135,332	154,500	19,167
2032	19,083	32,874	13,791
2033	12,198	25,182	12,984
2034	5,296	16,157	10,861
2035	3,005	9,710	6,704
2036	1,639	6,310	4,671
2037	11,451	22,336	10,885
2038	1,550	10,425	8,876
2039	5,367	21,595	16,228
2040	4,002	16,806	12,804
Average	**20,958**	**29,980**	**9,022**

Note:

(1) Baseline Scenario: The last 20 years hydrology extended in the future with 2020 levels of production and return flows

(2) Scenario 1: Similar to the Baseline Scenario with 17,500 acre-feet imports per year spread out over three months (June-July-August) and delivered at Deep Creek.

(3) Difference: Baseline Scenario flow subtracted from Scenario 1 flow at the Lower Narrows.

Mojave Basin Area Watermaster

Appendix B

Transition Zone

Water Supply Update

Prepared by:

Wagner & Bonsignore, Engineers

Robert C. Wagner, PE

Watermaster Engineer

February 28, 2024

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

Nicholas F. Bonsignore, P.E.
Robert C. Wagner, P.E.
Paula J. Whealen

Martin Berber, P.E.
Patrick W. Ervin, P.E.
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David H. Peterson, C.E.G., C.H.G.
Ryan E. Stolfus

MEMORANDUM

To: Mojave Basin Area Watermaster

From: Robert C. Wagner, P.E.

Date: February 28, 2024

Re: **Transition Zone Water Balance**

This memorandum describes the purpose of the Transition Zone (TZ) as envisioned by the Judgment and presents the method for calculating outflow to the Centro Subarea from the Alto Subarea. We include water level hydrographs to demonstrate the basic assumption that water levels within the TZ are relatively stable over time (see Fig. 2 and 3). Also presented is the pumping history of the TZ demonstrating reduced pumping demand since the early 1950's with significant reductions during the past 30 years (see Fig. 4).

The TZ is the area generally lying between the Lower Narrows, Mojave River, and the Helendale Fault (see Fig 1). Department of Water Resources Bulletin 84, 1967 was a foundational technical document guiding development of the Judgment. The Alto Subarea was drawn to be consistent with the Upper Mojave Subunit identified in Bulletin 84 (Bull., 84, fig. 2, page 7). As a result, the boundary between Alto and Centro, was placed at the Helendale Fault, where limited stream gaging data existed at the time the Judgment was drafted. The TZ was considered to pass storms from Alto to Centro, without interference from pumping within the TZ. It was assumed that the consumptive use within the TZ could be reasonably determined on annual basis.

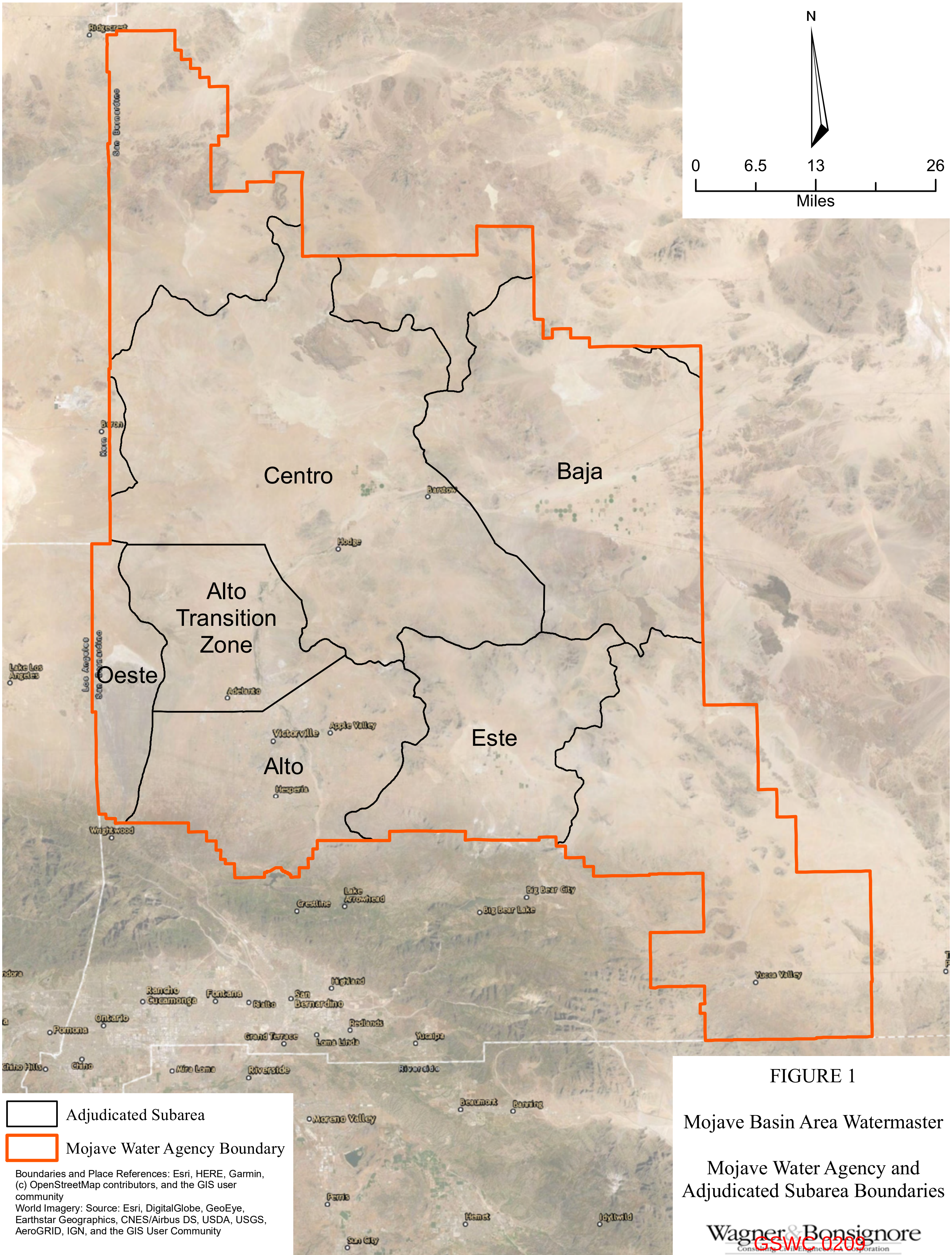
The pumping history in the TZ is shown on Fig. 4 and shows the decline in pumping since the early 1950's. The decline in pumping as well as the decline in consumptive use has contributed to the water level stability in the TZ, demonstrated by the water levels within the TZ. Also, contributing to the stability is the discharge of treated effluent from the Victor Valley Wastewater Reclamation Authority. Water pumped and used by producers contributing to sewers, upstream of Lower Narrows, is conveyed, treated and discharged in the TZ. The discharges are part of the basin water supply, contribute to downstream subareas and support riparian habitat.

To calculate outflow from the TZ to Centro, the following elements of water supply use and disposal with the TZ are included: Elements of Inflow generally include : a) measured flow at Lower Narrows, b) VVWRA discharge c) subsurface inflow, d) ungaged inflow

2151 River Plaza Drive · Suite 100 · Sacramento, CA 95833-4133
Ph: 916-441-6850 or 916-448-2821 · Fax: 916-779-3120

Elements of Outflow: generally, include e) subsurface outflow, f) consumptive use of production, g) phreatophyte water use, h) change in storage. For purposes of this analysis we assume, based on water levels, that change in storage over time is negligible or zero. Then by summing the elements of inflow and outflow, we calculate the outflow at Helendale Fault as supply to Centro. The calculation is shown Appendix A.

There is a makeup water obligation calculated on an annual basis that Alto owes to Centro. The obligation is to be satisfied every year, but is not part of the calculation of average annual outflow to Centro, as reported herein; however, it does contribute to the Centro water supply (see Watermaster Annual Reports, Figure 3-10, Tables 4-2, 4-3).



Adjudicated Subarea

Mojave Water Agency Boundary

Boundaries and Place References: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
World Imagery: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FIGURE 1

Mojave Basin Area Watermaster

Mojave Water Agency and Adjudicated Subarea Boundaries

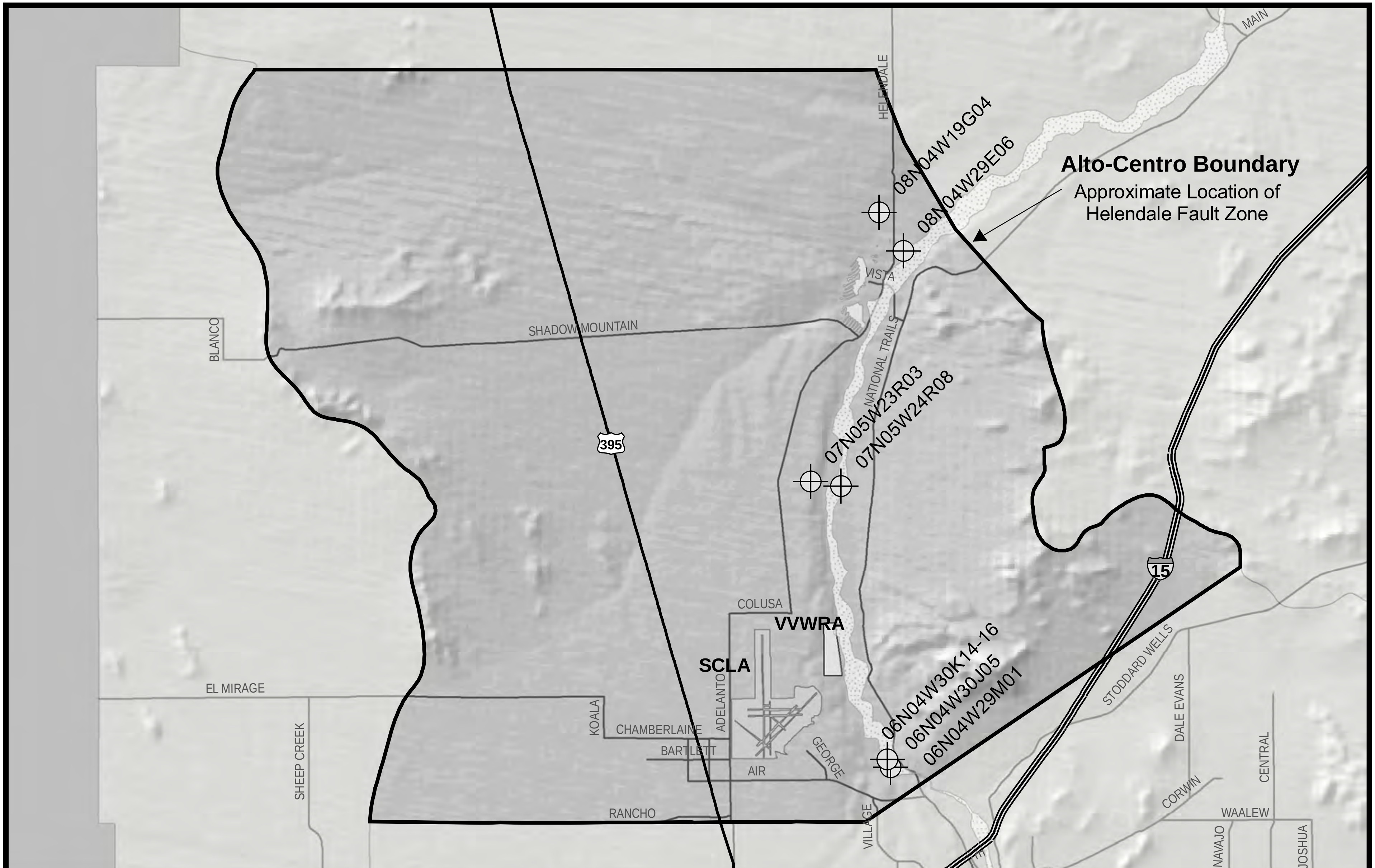
Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

GSWC 0209

June 2020

Q:\Drawings\Mojave Water Agency\Este Subarea\Este Water Supply - FIGURE 1 - Location Map.mxd

FIGURE 2



MOJAVE BASIN AREA WATERMASTER

Monitoring Wells

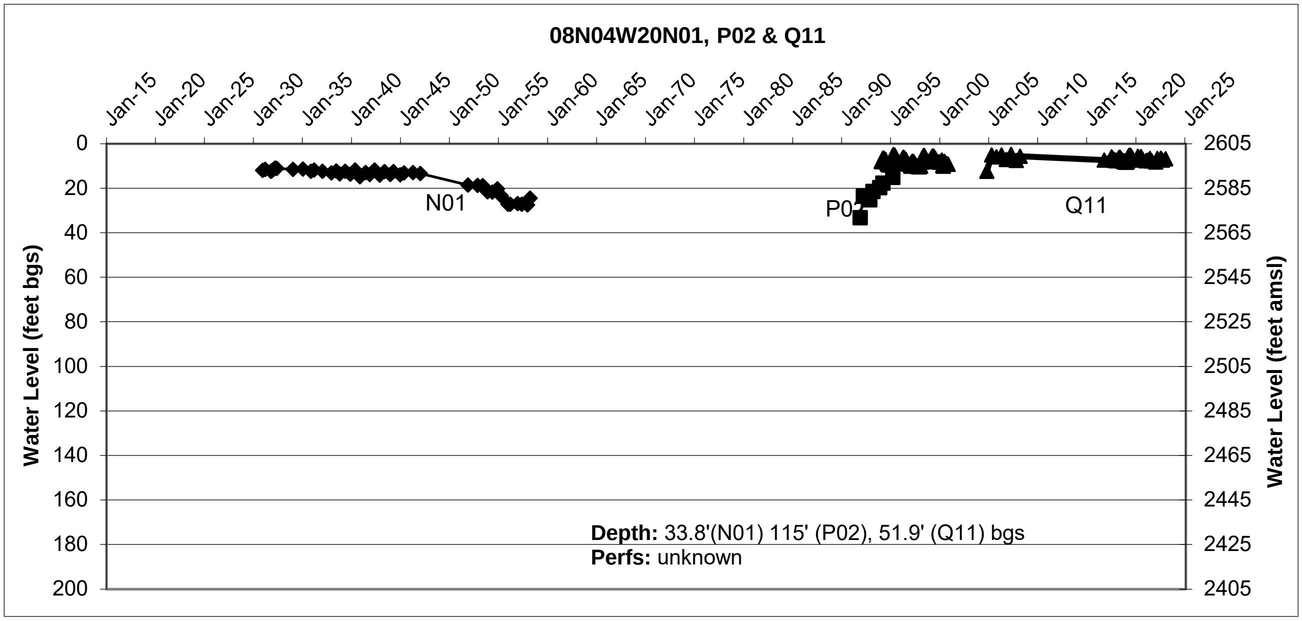
Alto Transition Zone Location of Water Level Monitoring Wells

0 1 2 4
Miles
N

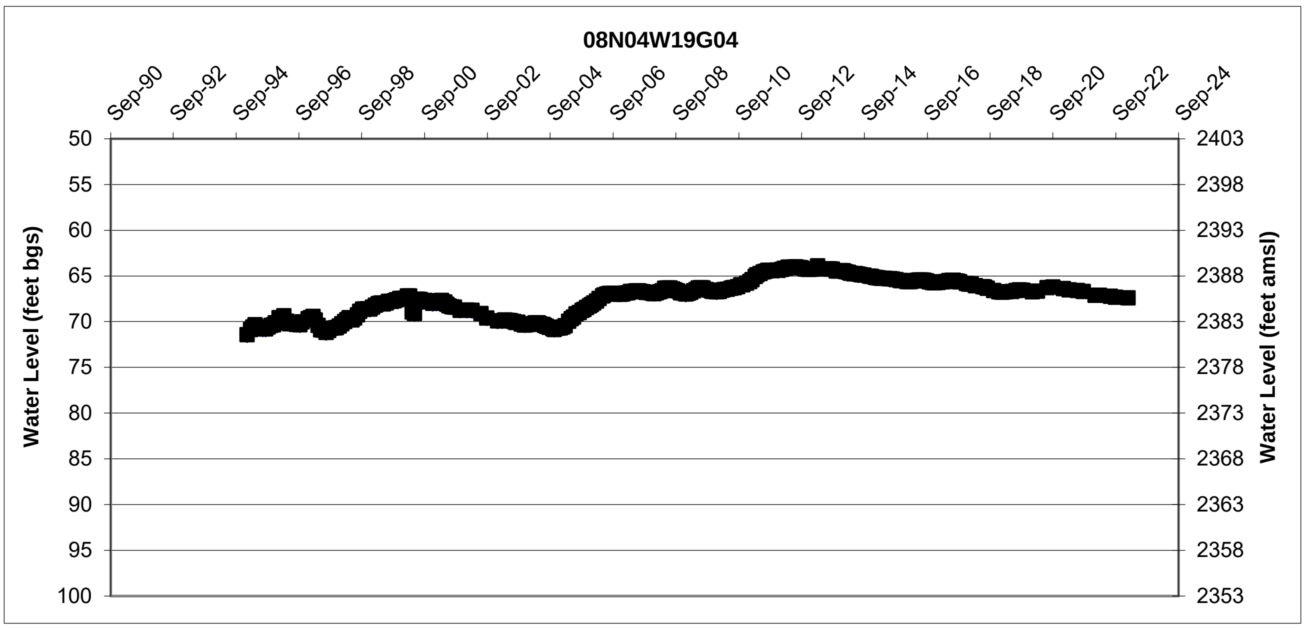
FIGURE 3-6

GSWC 0210

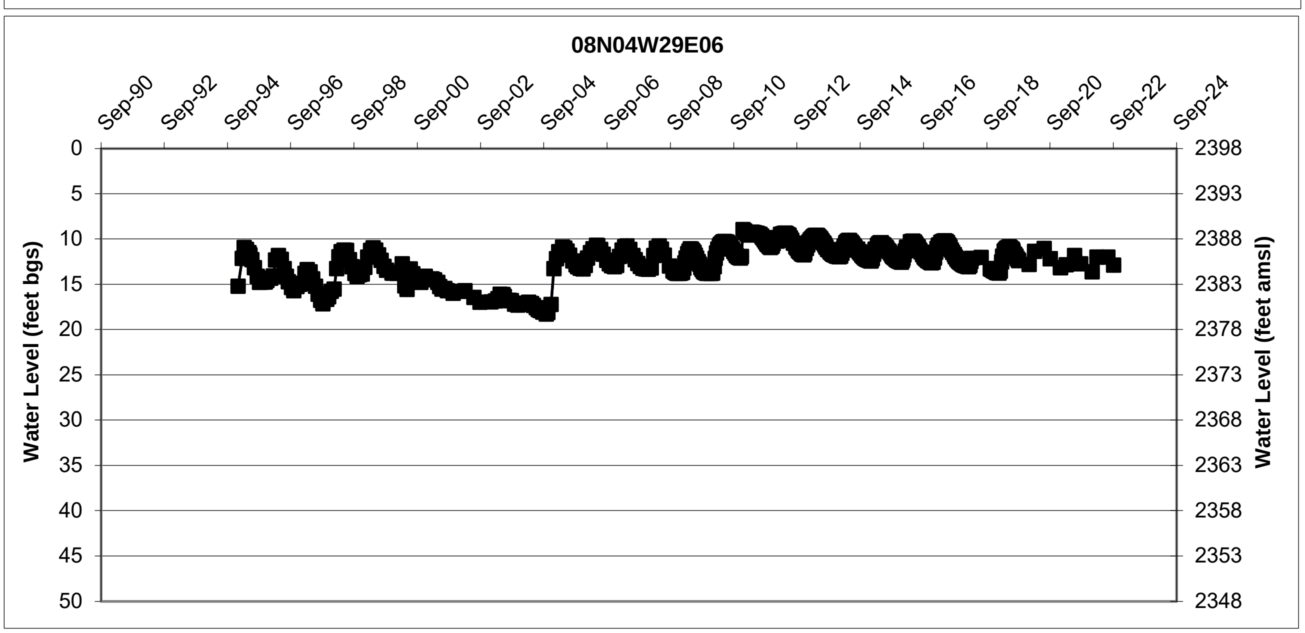
FIGURE 3



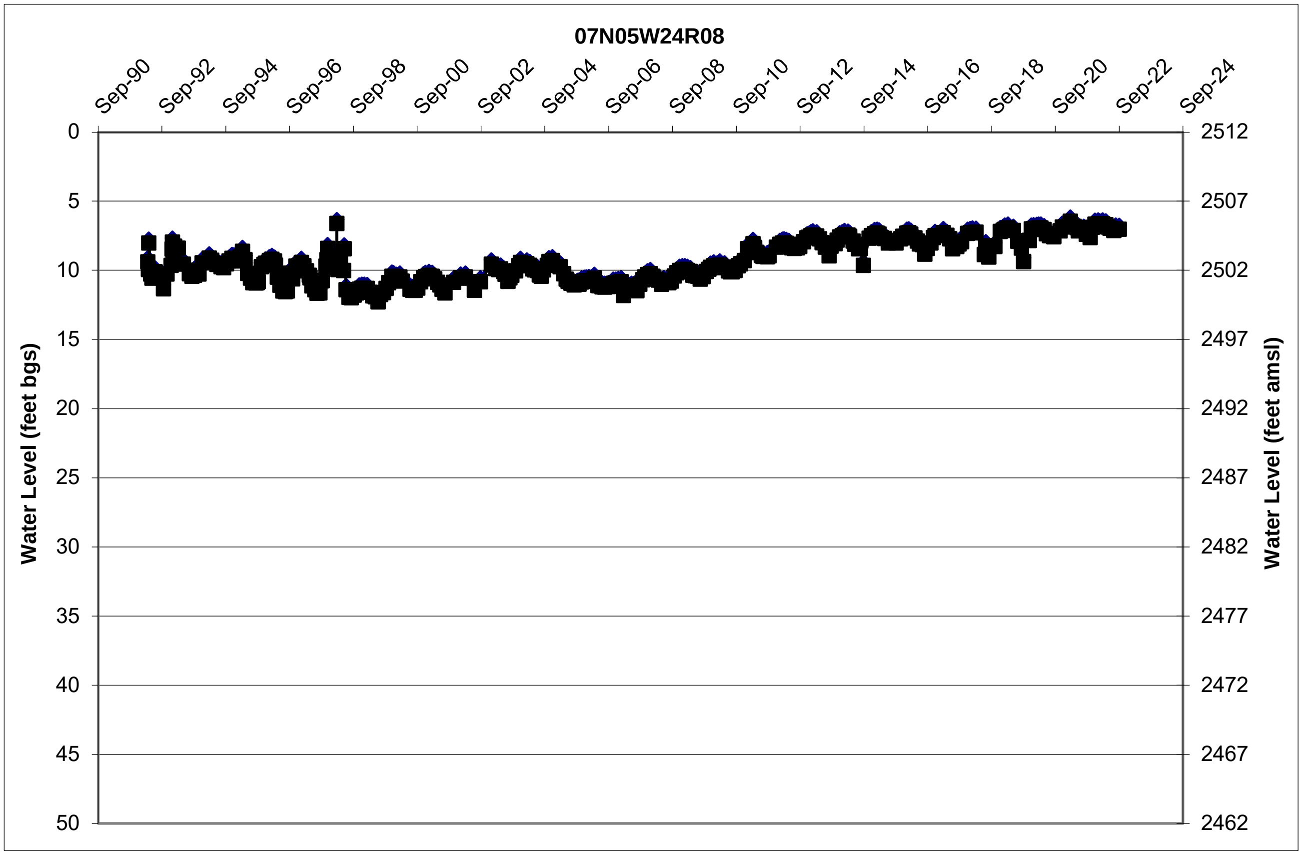
08N04W20N01, P02 & Q11
Jan-15 Jan-20 Jan-25 Jan-30 Jan-35 Jan-40 Jan-45 Jan-50 Jan-55 Jan-60 Jan-65 Jan-70 Jan-75 Jan-80 Jan-85 Jan-90 Jan-95 Jan-00 Jan-05 Jan-10 Jan-15 Jan-20 Jan-25
Water Level (feet bgs)
0 20 40 60 80 100 120 140 160 180 200
Water Level (feet amsl)
2605 2585 2565 2545 2525 2505 2485 2465 2445 2425 2405
N01
P0
Q11
Depth: 33.8'(N01) 115' (P02), 51.9' (Q11) bgs
Perfs: unknown

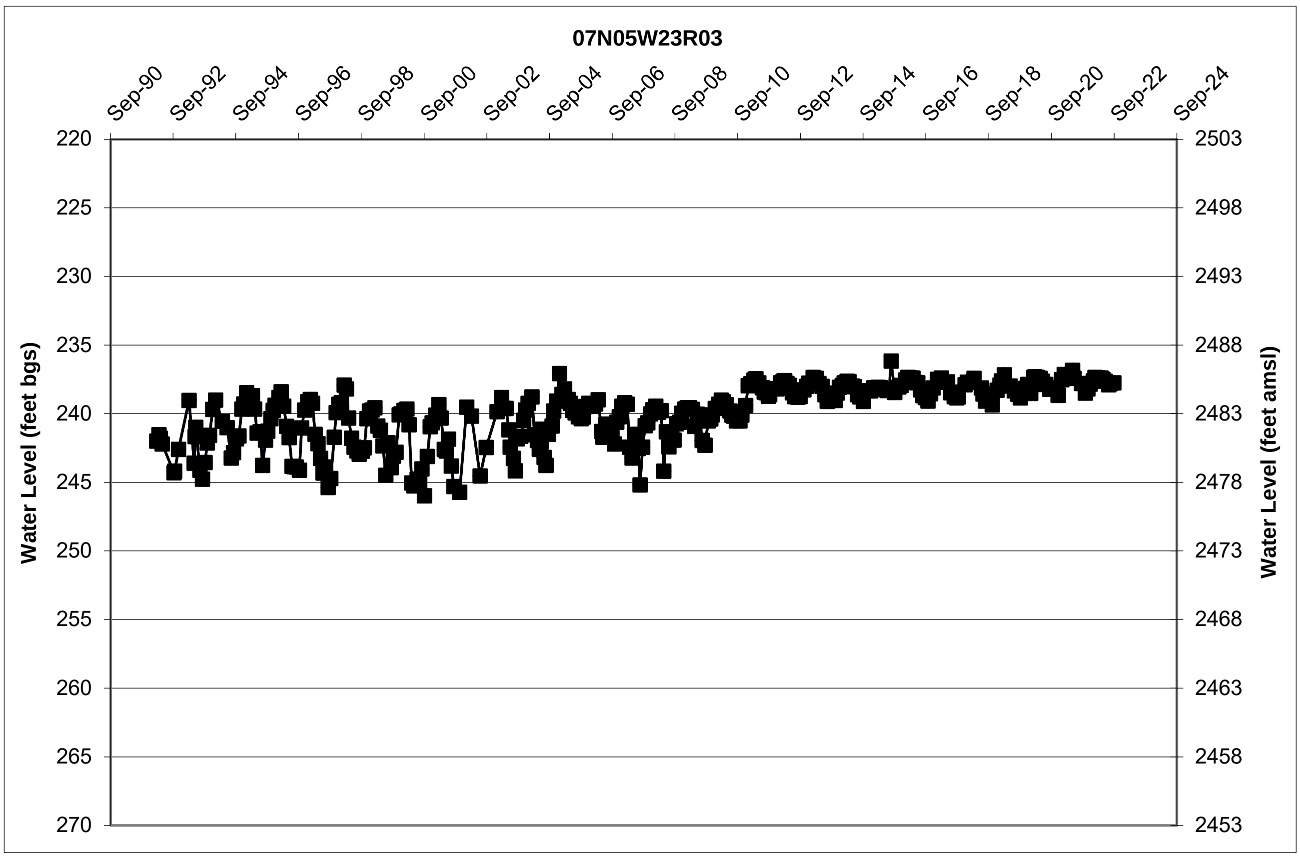


08N04W19G04
Sep-90 Sep-92 Sep-94 Sep-96 Sep-98 Sep-00 Sep-02 Sep-04 Sep-06 Sep-08 Sep-10 Sep-12 Sep-14 Sep-16 Sep-18 Sep-20 Sep-22 Sep-24
Water Level (feet bgs)
50 55 60 65 70 75 80 85 90 95 100
Water Level (feet amsl)
2403 2398 2393 2388 2383 2378 2373 2368 2363 2358 2353



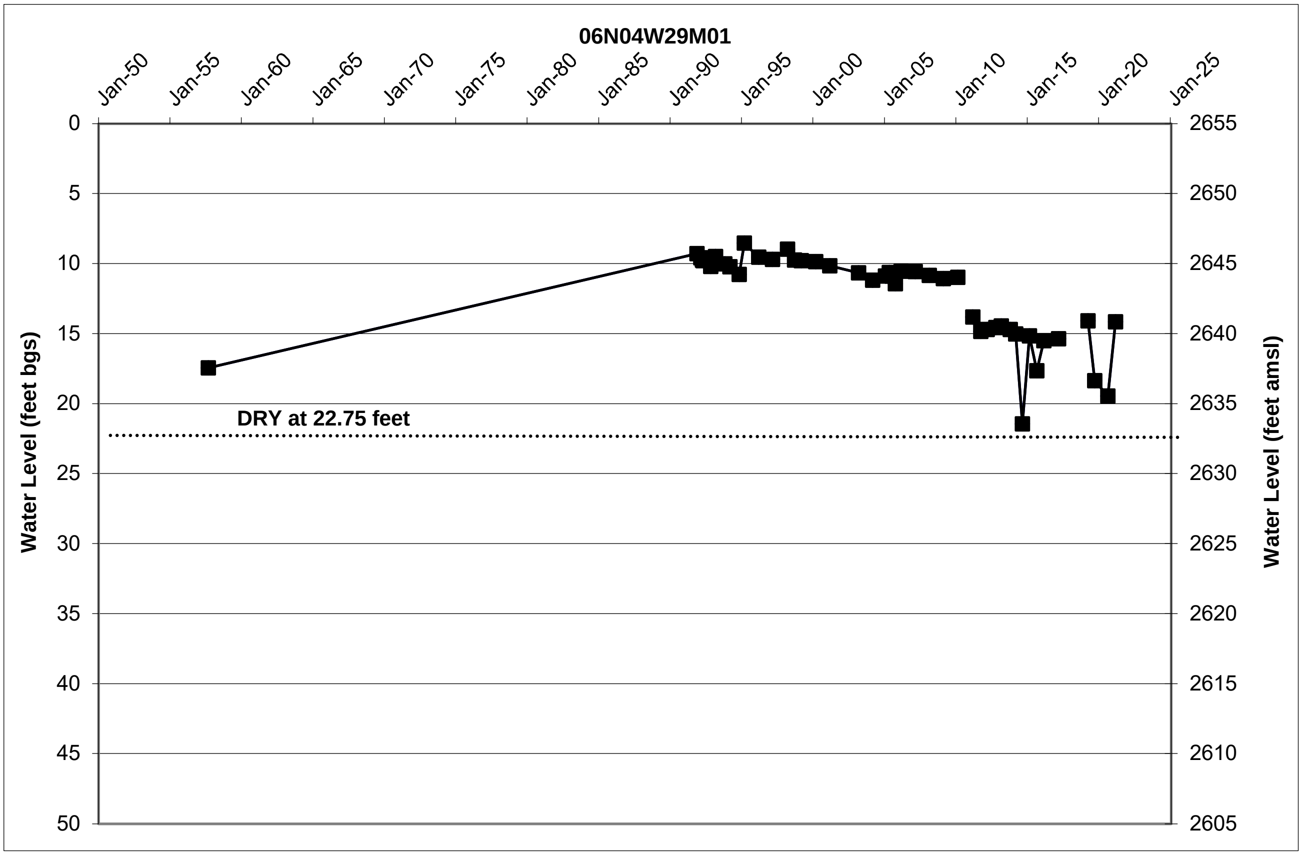
08N04W29E06
Sep-90 Sep-92 Sep-94 Sep-96 Sep-98 Sep-00 Sep-02 Sep-04 Sep-06 Sep-08 Sep-10 Sep-12 Sep-14 Sep-16 Sep-18 Sep-20 Sep-22 Sep-24
Water Level (feet bgs)
0 5 10 15 20 25 30 35 40 45 50
Water Level (feet amsl)
2398 2393 2388 2383 2378 2373 2368 2363 2358 2353 2348

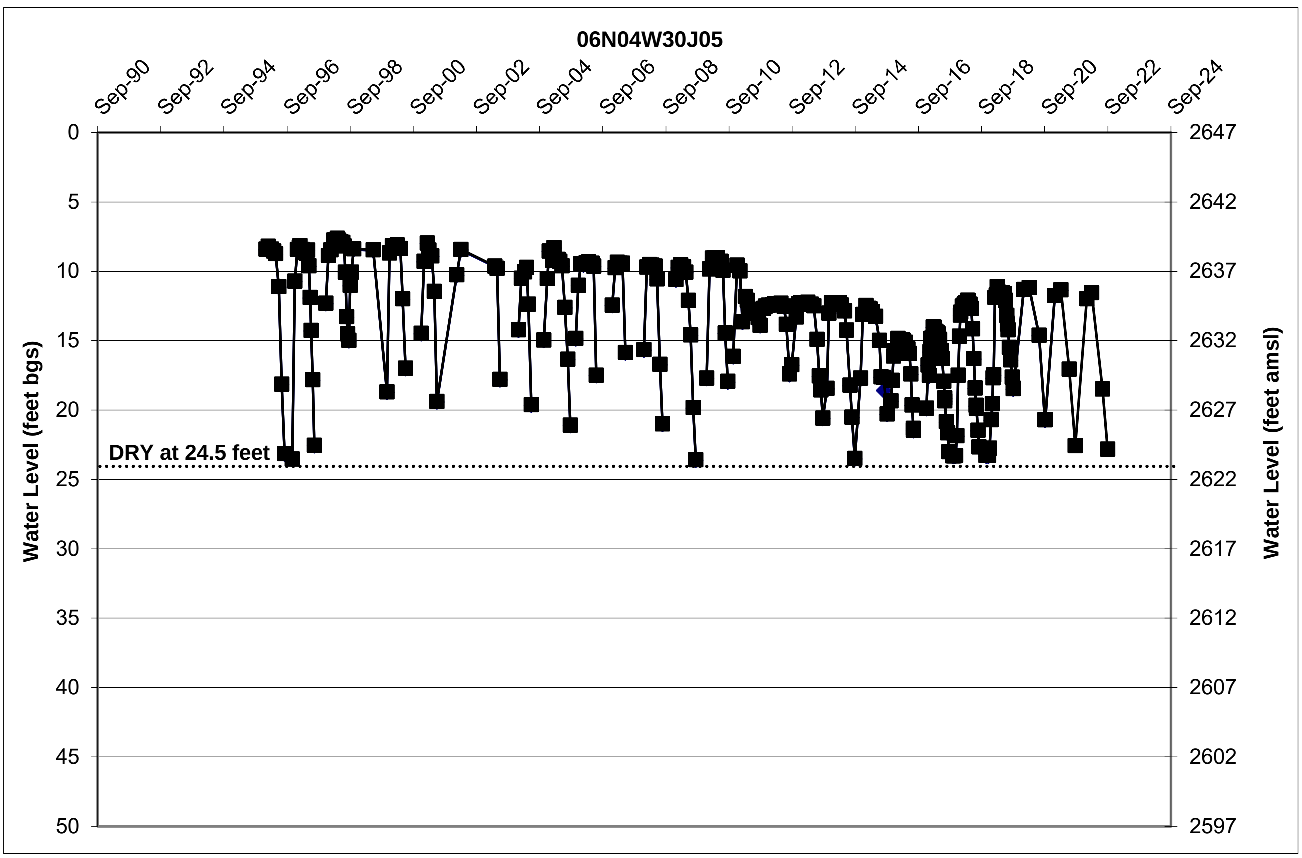


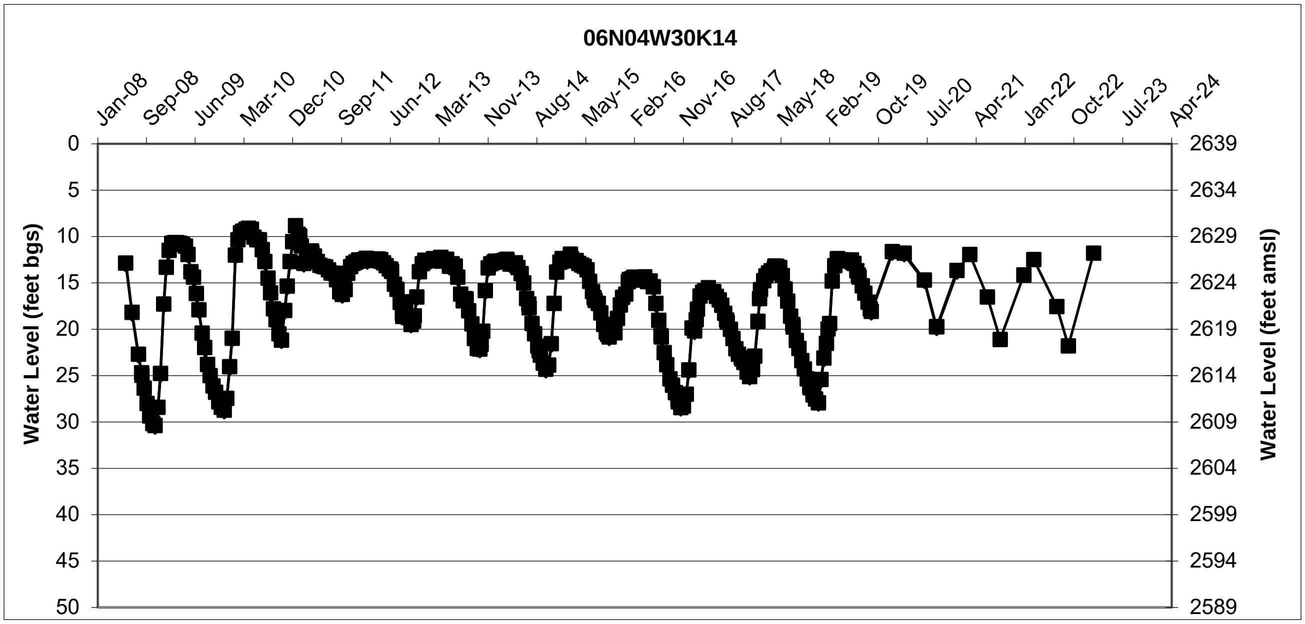


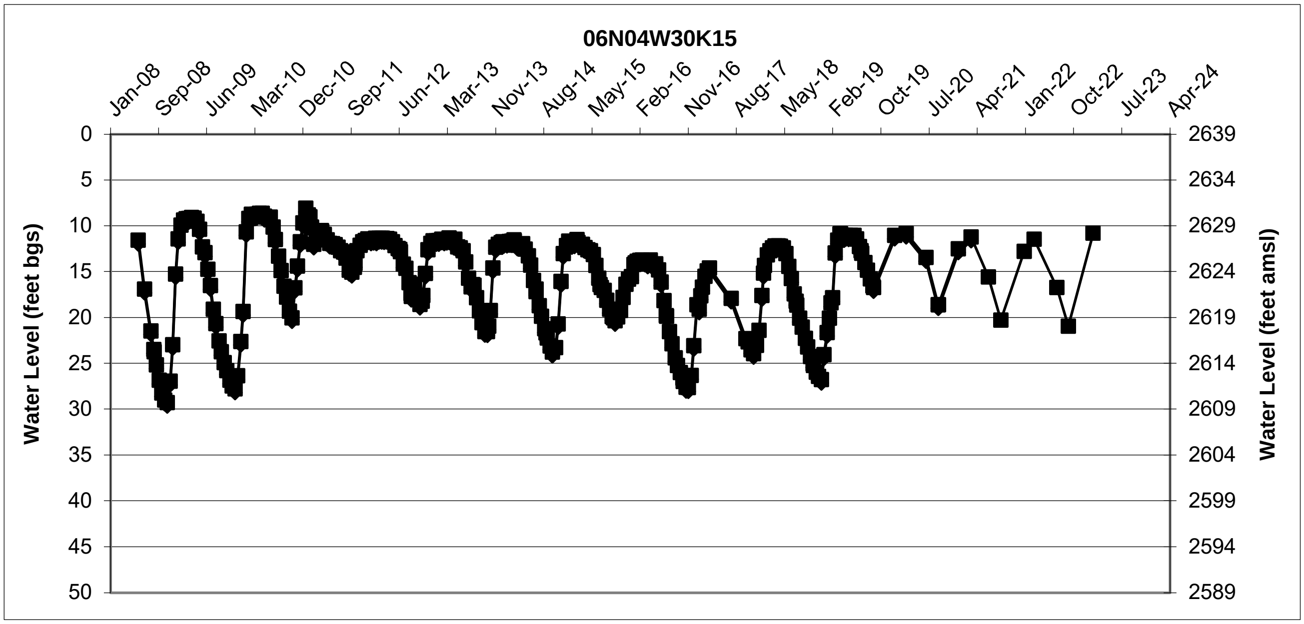
GSWC 0212

FIGURE 3-8


06N04W29M01
Jan-50
Jan-55
Jan-60
Jan-65
Jan-70
Jan-75
Jan-80
Jan-85
Jan-90
Jan-95
Jan-00
Jan-05
Jan-10
Jan-15
Jan-20
Jan-25
Water Level (feet bgs)
Water Level (feet amsl)
DRY at 22.75 feet
0
5
10
15
20
25
30
35
40
45
50
2655
2650
2645
2640
2635
2630
2625
2620
2615
2610
2605


06N04W30J05
Sep-90
Sep-92
Sep-94
Sep-96
Sep-98
Sep-00
Sep-02
Sep-04
Sep-06
Sep-08
Sep-10
Sep-12
Sep-14
Sep-16
Sep-18
Sep-20
Sep-22
Sep-24
Water Level (feet bgs)
Water Level (feet amsl)
DRY at 24.5 feet
0
5
10
15
20
25
30
35
40
45
50
2647
2642
2637
2632
2627
2622
2617
2612
2607
2602
2597


06N04W30K14
Jan-08
Sep-08
Jun-09
Mar-10
Dec-10
Sep-11
Jun-12
Mar-13
Nov-13
Aug-14
May-15
Feb-16
Nov-16
Aug-17
May-18
Feb-19
Oct-19
Jul-20
Apr-21
Jan-22
Oct-22
Jul-23
Apr-24
Water Level (feet bgs)
Water Level (feet amsl)
0 5 10 15 20 25 30 35 40 45 50
2639 2634 2629 2624 2619 2614 2609 2604 2599 2594 2589


06N04W30K15
Jan-08
Sep-08
Jun-09
Mar-10
Dec-10
Sep-11
Jun-12
Mar-13
Nov-13
Aug-14
May-15
Feb-16
Nov-16
Aug-17
May-18
Feb-19
Oct-19
Jul-20
Apr-21
Jan-22
Oct-22
Jul-23
Apr-24
Water Level (feet bgs)
Water Level (feet amsl)
0 5 10 15 20 25 30 35 40 45 50
2639 2634 2629 2624 2619 2614 2609 2604 2599 2594 2589

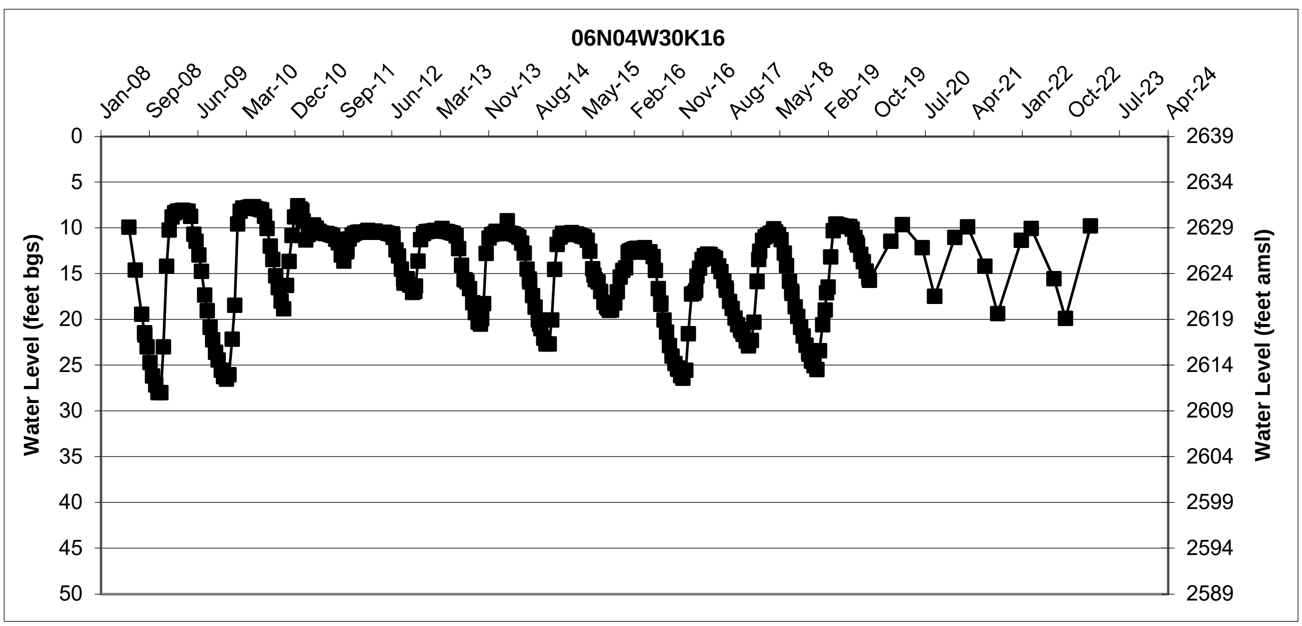
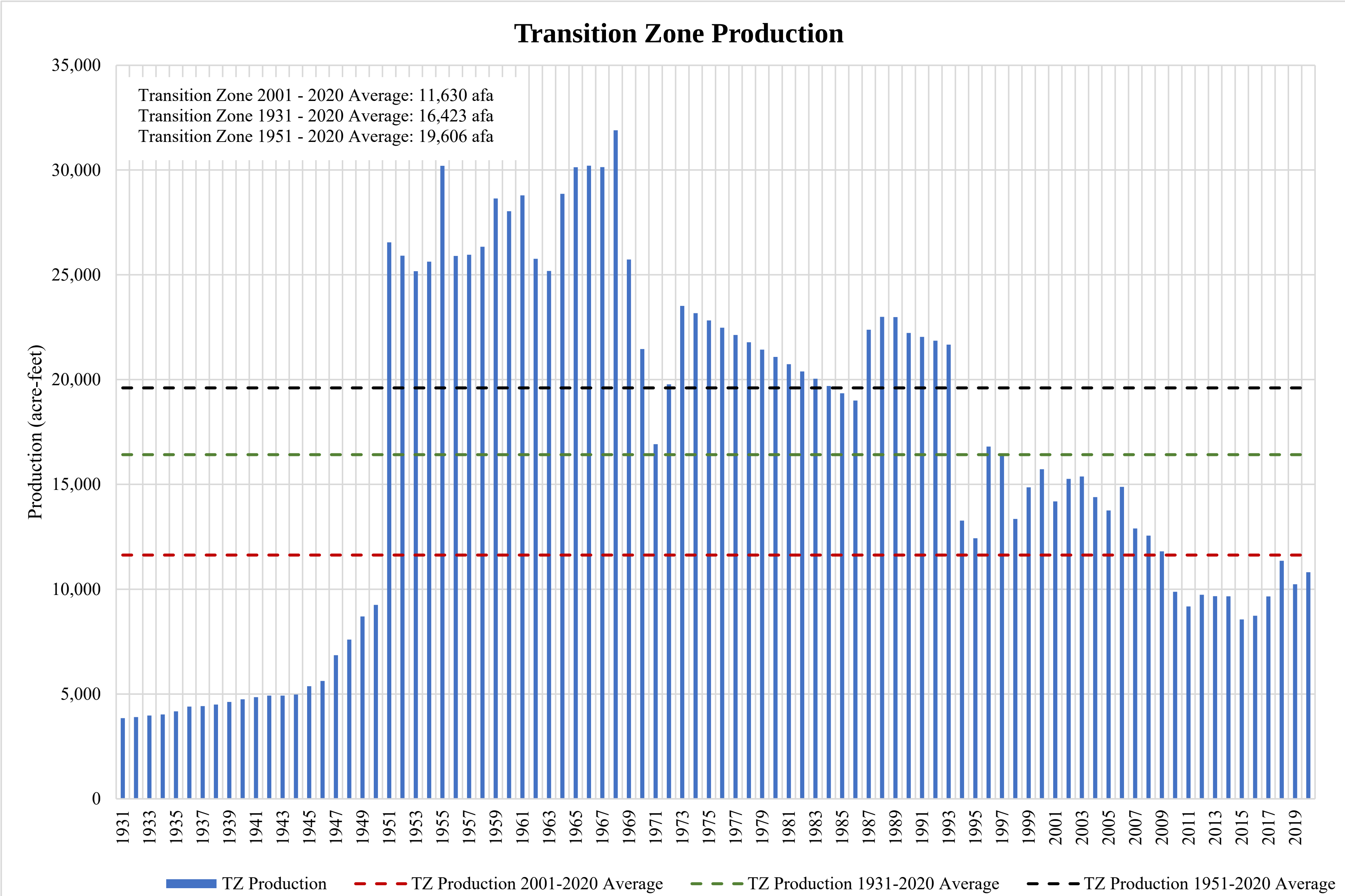

06N04W30K16
Jan-08
Sep-08
Jun-09
Mar-10
Dec-10
Sep-11
Jun-12
Mar-13
Nov-13
Aug-14
May-15
Feb-16
Nov-16
Aug-17
May-18
Feb-19
Oct-19
Jul-20
Apr-21
Jan-22
Oct-22
Jul-23
Apr-24
Water Level (feet bgs)
Water Level (feet amsl)
0 5 10 15 20 25 30 35 40 45 50
2639 2634 2629 2624 2619 2614 2609 2604 2599 2594 2589

FIGURE 3-9

FIGURE 4



Note:
1931 - 1993 data from USGS "Simulation of Ground-Water Flow in the Mojave River Basin, California", Stamos. 2001
1994 - 2020 data from Mojave Watermaster.

Mojave Basin Area Watermaster

Appendix C

Oeste Subarea

Water Supply Update

Prepared by:

Wagner & Bonsignore, Engineers

Robert C. Wagner, PE

Watermaster Engineer

David H. Peterson, C.E.G, C.Hg

February 28, 2024

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

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Ryan E. Stolfus

MEMORANDUM

To: Mojave Basin Area Watermaster

From: Robert C. Wagner, P.E. and David H. Peterson, C.E.G., C.Hg

Date: February 28, 2024

Re: **Water Supply Update for Oeste Subarea**

This memorandum updates the estimates of groundwater production and supply for the Oeste Subarea of the Mojave River Groundwater Basin. Sources of water supply to the subarea were previously evaluated by Wagner & Bonsignore (WBE) and summarized in a draft August 7, 2020 memorandum.

The purpose of the current evaluation is to provide Watermaster with an update on the state of knowledge about available groundwater supply for the Oeste Subarea to develop an updated Production Safe Yield. The scope of the current evaluation was limited to review of available reports and data; no field studies or modeling were performed. Because little new information has been developed for the Oeste subarea since the prior WBE water supply study in 2020, the references for that study were used in the current update.

The location of the Oeste Subarea with respect to other subareas of the Mojave River Area is shown on Figure 1. The Oeste Subarea is bounded along the western side by the San Bernardino-Los Angeles County line. The eastern boundary generally follows the basin boundary established by California Department of Water Resources for the El Mirage groundwater basin.

Water supply to the Oeste Subarea is obtained entirely from groundwater, pumped from the regional aquifer underlying the subarea and from a shallow perched aquifer in the vicinity of El Mirage Dry Lake. No subsurface inflow from other subareas has been documented. Potential sources of groundwater recharge and water supply to the subarea have been identified in various previous studies as consisting of:

- Natural recharge from infiltration of surface water runoff at the base of the mountain front bounding the southern margin of the subarea, also referred to as mountain-front recharge. The source of mountain front recharge is predominantly from surface water flows in the Sheep Creek Wash (see Figure 1), although other smaller watersheds may also contribute to basin recharge;

- Infiltration of excess water in agricultural fields, individual septic systems, and municipal and industrial sources, referred to as return flows.

As noted in the *State of the Basin* portion of the Watermaster's 29th Annual Report (2021-22), water levels have declined over time and will likely continue to decline as water production (see Fig 5) increases with projected population growth. Review of water levels over the past 15 to 20 years indicates water levels are variable but stable. However, the past 15 to 20 years may not be representative of water supply conditions in the longer term. The report also notes that population is expected to increase in the future, which will increase water demand and likely result in water level declines.

Hydrogeologic Setting

Geologic Units and Aquifers

The geology of the Oeste subarea and vicinity is shown on Figure 2. The southern margin of the subarea as bounded by the San Gabriel Mountains, made up of older, consolidated and metamorphosed bedrock units of Paleozoic age. At the northwest and northeast margins of the subarea, the alluvial deposits are bounded primarily of older granitic bedrock. These older bedrock units are generally considered to be relatively impermeable and non-water-bearing, although wells have locally been developed in more fractured areas of the bedrock units.

Within the valley floor north of the San Gabriel Mountains, the groundwater basin contains large, alluvial-filled structural depressions that are downfaulted between the Garlock and San Andreas fault zones (Stamos and others, 2017). The deposits filling the basin consists of sediments of Quaternary to Tertiary age, which are derived locally from the upland bedrock areas at the margins of the basin. As described in a hydrogeologic study by California State University Fullerton (2009), the oldest of the basin-filling formations are the Pliocene-age sandstone of the Phelan Peak formation, conglomerate and sandstone of the Harold formation, and sandstone and conglomerate of the Shoemaker Gravel. Overlying these older basin-fill formations are alluvial fan deposits ranging from early Pleistocene (deposited in past 2 million years) to Holocene (deposited in past 11,000 years) in age. In the vicinity of El Mirage dry lake, the alluvial fan sediments are interbedded and overlain by an extensive zone of clayey lake (playa) deposits.

Faulting

The main faults described in the Oeste subarea are the Mirage Valley fault, a northwest-trending fault located at the north end of the Mirage Valley, and the San Andreas fault, located south of the subarea in the area of Wrightwood. Neither of these faults was identified by the USGS (Stamos and others, 2001) as a barrier to groundwater flow in the subarea.

Groundwater Conditions

Review of well hydrographs prepared annually by MWA (see Figure 3) and groundwater elevation maps prepared by USGS from 1996 to 2016 indicate that groundwater levels in the Oeste subarea generally range widely, from about 500 to 600 feet below ground surface in the Phelan-Pinion Hills area in the more southerly part of the subarea, to about 100 to 300 feet in the vicinity of El Mirage and El Mirage Dry Lake. Water levels in the vicinity of a perched aquifer zone near Mirage Dry Lake identified by USGS are generally shallower than surrounding areas. The USGS Regional Water Table Maps spanning the period from 1996 to 2016 show a groundwater depression, presumably due to pumping, at the southern margin of El Mirage Dry Lake. However, monitoring by MWA indicate that groundwater levels are generally rising within the pumping depression.

Based on DWR (1967) and USGS (various years) water level data, a groundwater divide was identified downgradient and north of the Sheep Creek Wash. The groundwater divide (or broad high ridge) generally trends roughly north-northeast from the head of the wash. The groundwater elevation and contouring data suggest that a portion of the recharge from Sheep Creek flows north-northwest and eventually, across the western subarea boundary, toward the Antelope Valley groundwater basin. These conditions are depicted on the ground water elevation map prepared by USGS as part of a study of the Antelope Valley-El Mirage groundwater basin boundary (Stamos and others, 2017; see Figure 4).

Interpreting water-level trends in many of the wells is problematic, as levels are likely affected by pumping and can vary widely from year to year. In general though, water levels in the Phelan-Pinion Hills area appear to continue to decline since the 1980s to 1990s. However, water levels in some wells in this area (05N07W24D03, 05N07W31J03, 05N07W33J02), while varying year to year, are generally trending level. Further north in the area of El Mirage, shallower wells (water levels in the range of about 60 to 120 feet) presumably completed in the shallow perched aquifer, are generally little changed.

Water Supply

Estimates of Surface Flows

The U.S. Geological Survey (Hardt, 1971, Stamos and others, 2001; Izbicki, 2007) and California Department of Water Resources (1967) have concluded that the low annual precipitation on the desert floor is used to meet growth and transpiration requirements of native vegetation, but is not considered to represent a source of groundwater recharge.

Previous studies identify that native recharge to the Oeste subarea is primarily from surface water flows originating from Sheep Creek. In the 1996 *Judgement After Trial* for the adjudication of the groundwater rights in the Mojave River Basin, the ungaged surface inflow to Oeste subarea was estimated at 1,500 acre-feet per year (AFY; Appendix C, Table C-1). However, Table C-1 does not indicate the portion of the surface flows that infiltrate to become groundwater recharge.

Historically, streamflow in Sheep Creek wash did not always follow the same course every year and would occasionally shift course over the surface of the alluvial fan. In recent years, a series of levees has restricted the flow to fewer active channels (Izbicki, 2002). At the mountain front, the Sheep Creek Wash is about 250 feet wide. Based on channel geometry, Izbicki (2002) estimated that the average annual flow from Sheep Creek Wash into Oeste Subarea was about 2,027 AFY (reported as 2.5 cubic hectameters). However, flow was estimated to decrease substantially downstream, with the channel width decreasing to less than 10 feet, indicating that most surface water infiltrated near the mountain front.

An analysis of estimated discharge from the Sheep Creek watershed was also performed in 2012 (unpublished data) by Watermaster. Based on the watershed area and a weighted mean annual precipitation of 24.9 inches, average annual surface flow was estimated at about 1,132 AFY at Sheep Creek Wash.

From review of the sources above, the volume of surface flows entering Oeste subarea at Sheep Creek has been estimated to range from about 1,132 AFY (Watermaster) to 2,027 AFY (USGS; Izbicki, 2002).

Native Mountain-Front Recharge

In a USGS study by Hardt (1971), it was noted that about 92 percent of long-term groundwater recharge originates in the San Bernardino Mountains. The San Gabriel Mountains, which are the source of surface runoff to Sheep Creek and Oeste Subarea, only contributes about five percent of basin recharge. The remaining three percent were attributed to underflow from adjacent areas. Based on an analog model of the basin, Hardt (1971) estimated annual recharge from the mountain front area, extending from the Mojave River to Sheep Creek was about 9,300 AFY. At five percent of this amount, recharge from the Sheep Creek area would be less than about 500 AFY.

In a 2001 study and groundwater model by USGS (Stamos and others, 2001), estimates of mountain front recharge were presented, ranging from 10,000 to 13,000 AFY, with most of the recharge occurring in the Upper Mojave Basin (Este, Alto, and Oeste subareas). The study also concluded that the recharge occurred in the upper reaches of ephemeral streams and washes. The study was focused on developing a groundwater model for the basin and recharge was not directly measured. However, as part of model calibration, the groundwater model estimated annual recharge for the period 1931-1990 at 1,941 AFY for the Oeste subarea.

A hydrogeologic study of the Oeste subarea was performed for the Mojave Water Agency in 2009 by California State University, Fullerton (Laton and others, 2009). The water budget performed for that study cited three sources for estimates of groundwater recharge; 1,100 AFY from DWR (1967), 7,147 AFY from Horne (1989; reference not located or verified), and the estimate derived from Stamos and others (USGS, 2001). Based on analysis of long-term groundwater level trends, Laton and others (2009) concluded that the estimate by Horne (1989) was likely high, and that average annual water supply to Oeste subarea was most likely in the range of 1,000 to 3,000 AFY. Return flows associated with municipal and agricultural consumptive use were not identified in the recharge estimates.

Studies by the USGS (Izbicki, 2002, 2004) and Izbicki and Michel (2004) identified the processes leading to recharge, but did not quantify the annual recharge in Sheep Creek Wash. Age-dating of groundwater samples from wells throughout the Mojave Basin indicates that along the course of the Mojave River, shallow groundwater within the Floodplain Aquifer is very young, indicating that recharge from surface flows occurs rapidly after large storm events (Izbicki and Michel, 2004; see Figures 2 and 3). However, groundwater collected in the vicinity of the Sheep Creek fan indicates that only samples in the upper reaches of the wash (near the mountain front) contained recently recharged water (i.e., less than about 50 to 70 years old). About six miles down-valley to the northeast, a groundwater sample analyzed for carbon activity indicated the water may have been recharged as much as 18,000 to 20,000 years ago. This isotopic sample data indicates that infiltrated water moves very slowly from the base of the mountain front, northward into the Mojave Basin.

Return Flows

Consumptive use studies performed by Watermaster for the period 2012 and 2019 calculated total return flows associated with consumptive use (domestic/septic, agricultural, municipal and industrial activities) in the range of about 800 to 1,200 AFY, with most years falling in the range of about 1,000 AFY.

Water Supply Summary

Estimates of surface flow from the Sheep Creek drainage have ranged from about 1,100 to 2,000 AFY. However, arriving at a precise estimate of native recharge to the Oeste subarea is problematic because the amount of discharge from the ephemeral streams and washes has never been measured directly. Therefore, it is uncertain how much of the estimated surface runoff infiltrates the upper reaches of Sheep Creek Wash to recharge the regional aquifer (Stamos and others, 2001). Based on the previously cited studies, total groundwater recharge and water supply to Oeste subarea is estimated below:

Process	Recharge, AFY
Mountain Front Recharge	
Hardt, 1971	<500
Stamos and others, USGS, 2001	1,971
Laton and others, CSUF, 2009 (various sources)	1,000 – 3,000
Return Flows	
Watermaster	1,000

The estimate derived from Hardt (1971) is very approximate and seems low compared with available estimates of surface flows to the subarea. While the model-derived recharge estimate from Stamos and others (2001) was not directly measured, it represents an estimate based on calibration to measured groundwater level records (i.e., hydrographs) and so would appear to be a more reasonable approximation. Given the limitation that surface water flows from Sheep Creek may only be in the range of about 1,100 to 2,000 AFY, the estimate of 1,941 AFY by Stamos and others (2001) would be at the high end. When compared with the range of recharge estimates cited by Laton and others (2009), it appears that recharge to upper Sheep Creep Wash area may be in the range of about 1,000 to 2,000 AFY. Combined with annual estimates of return flows associated with consumptive use, available information suggests the annual water supply to Oeste subarea is in the range of about 2,000 to 3,000 acre-feet.

Consumptive Use and Outflows

As provided byWatermaster , the total consumptive use and outflows for the Oste Subarea for the past five years are listed below, in acre-feet:

2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	5-Year Average
3,732	3,372	3,328	3,374	3,083	3,378

The reported outflows shown above include 800 AFY of subsurface flow, as estimated in Table C-1 of the Judgment.

Change in Storage

As described above, published estimates of the annual water supply to the subarea are approximate and not well quantified. Additionally, USGS studies indicate that the rate of movement of recharged groundwater from the mountain front to the groundwater basin is very slow. This suggests that the effects of drought or wet years would be attenuated to the point that they might not be identifiable in the hydrographs. Therefore, the ability to estimate short-term changes in storage based on water levels may be limited.

From the comparison of water supply and consumptive use/outflows, it appears that at the higher end of the water supply estimate (3,000 AFY), consumptive use/outflows are relatively closely balanced. However, the lower end of the water supply estimate (2,000 AFY) suggests that the aquifer may be depleting by up to about 1,000 AFY. If the loss is distributed over the area of the 105,100-acre subarea (Laton and others, 2009), an estimated 1,000 acre-feet of annual storage loss in the regional aquifer would be expected to only cause small annual changes in water levels, on the order of a few tenths of a foot or less. However, in the vicinity of El Mirage, water levels are dropping in some wells at rates of about 0.4 to 1.7 feet per year since 1999, while others in the same area are unchanged or rising during the same period. Presumably, the larger water level changes, such as those observed near El Mirage are in response to higher amounts of local pumping in that area.

Discussion and Conclusions

Of the water supply sources discussed, the largest unknown with the widest range of published estimates is mountain-front recharge. Based on information provided in the annual Watermaster reports, the total estimated pumping for Oeste subarea for the past five water years is shown below:

	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	Average
Verified Production	3,706	3,380	3,439	3,560	2,893	3,396
Non-Stipulating Parties*	238	238	238	238	238	238
Totals	3,944	3,618	3,677	3,798	3,131	3,634

* Estimated groundwater pumping based on land use, crop type, and climate data

As indicated above, production has been fairly consistent in the most recent five years and about half of the verified production reported at the time of the Judgment (6,261 AF in 1995-96). Therefore, the decline in pumping over time should presumably correlate to changes in the trends of water levels. However, the well hydrographs do not appear to indicate changes in slope or trend of the data after 1996. Given the general low gradients of the water table and very slow rate of groundwater movement in the Regional Aquifer, it is possible that changes in the water table from historical pumping will take some time to become evident in monitoring data.

Available data reviewed indicate that water supply to the subarea may be in the range of 2,000 to 3,000 AFY. In this range, water supply is roughly equal or somewhat below verified production. The historic declines in some wells suggests that some storage loss is occurring. Given the slow water level declines and historical rate of change in the subarea, it is likely that pumping exceeds supply by a small, but unverified amount. Continued monitoring of conditions in the subarea will likely be needed to confirm a long-term rate of storage change. Based on the foregoing, and an assessment that water levels remain relatively unchanged over a long time period, the PSY is for Oeste is likely about equal to the pumping over that period of time. Given that the UMBM indicates a deficit, in conflict with water levels appearing somewhat stable, and given that pumping and land use have changed significantly, the Engineer recommends basing PSY on the most recent years of pumping, the five year average of 3,634 acre feet.

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Attachments

Figure 1 - Location Map
Figure 2 – Subarea Geologic Map
Figure 3 – MWA 2023 Hydrograph Map, Oeste Subarea
Figure 4 – Water Table Map (USGS, 2017)
Figure 5 – Oeste Production Graph

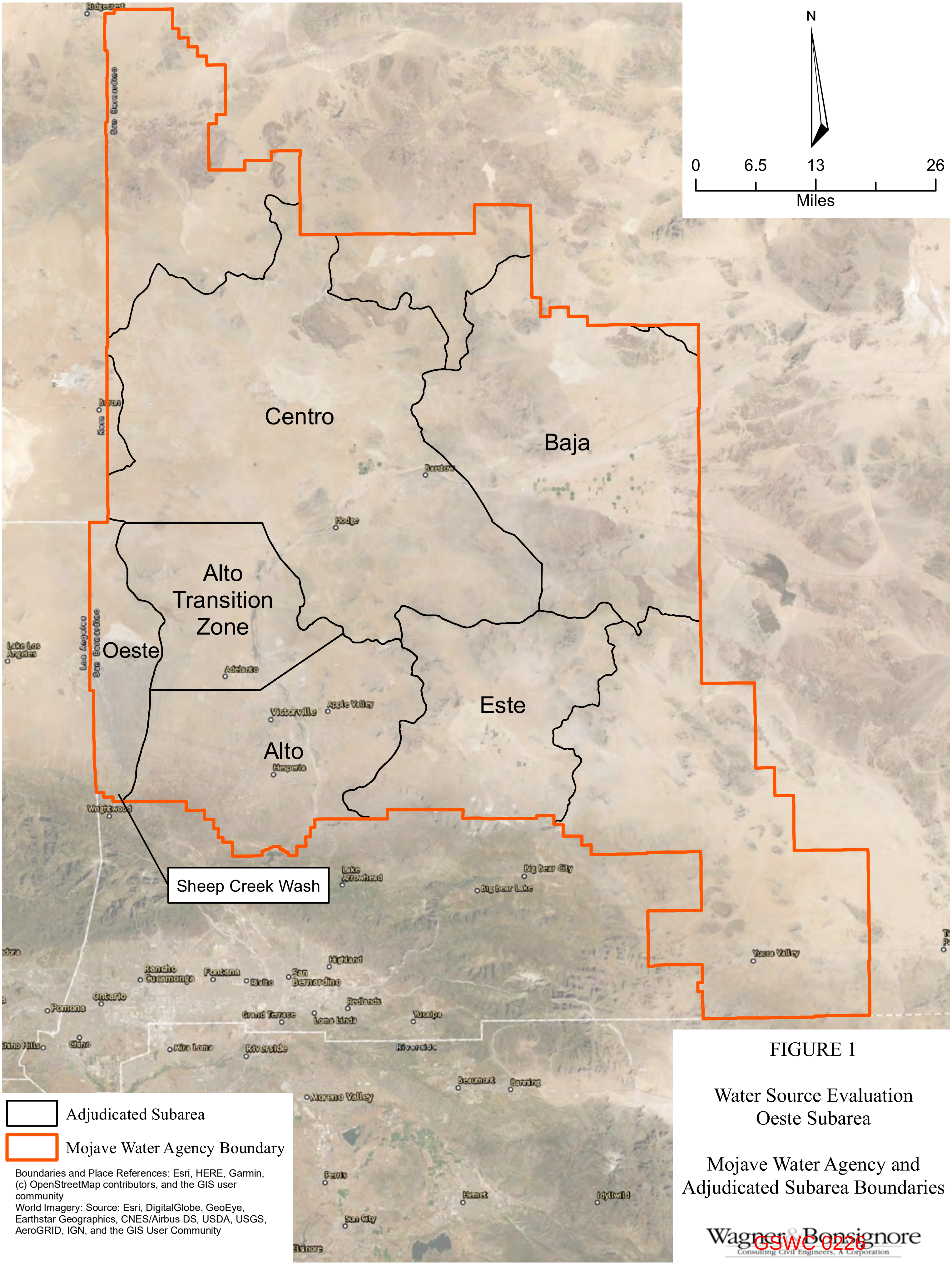


FIGURE 1

Water Source Evaluation
Oeste Subarea

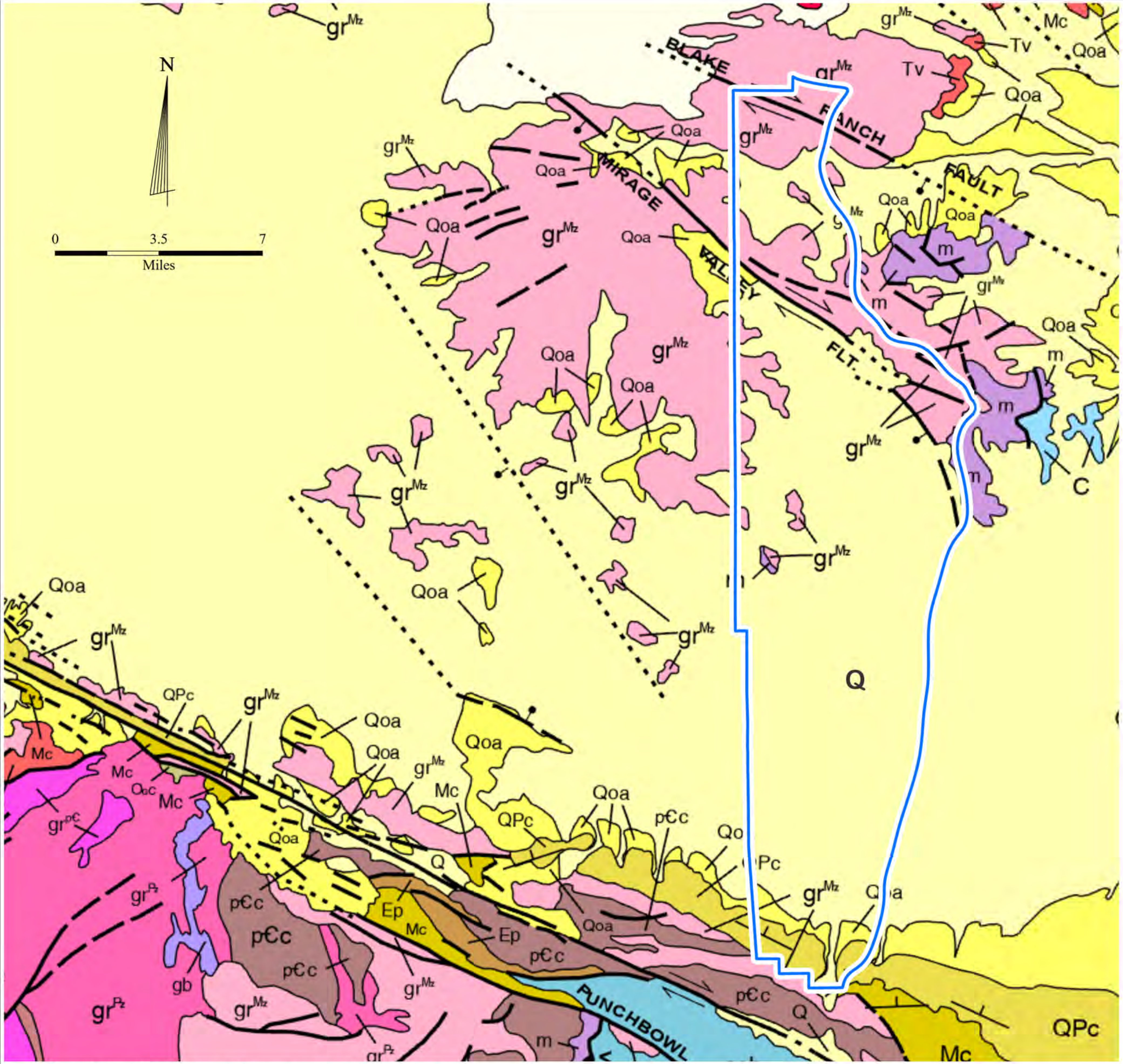
Mojave Water Agency and
Adjudicated Subarea Boundaries

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

GSWC 0226

Q:\Drawings\Mojave Water Agency\Oeste Subarea\Water Source Evaluation\FIGURE 1 - Subareas.mxd

August 2020



Oeste- Adjudicated Subarea

Q; Alluvium, lake, playa, and terrace deposits; unconsolidated and semi-consolidated. Mostly nonmarine, but includes marine deposits near the coast

Qoa; Older alluvium, lake, playa, and terrace deposits

QPc; Pliocene and/or Pleistocene sandstone, shale, and gravel deposits; mostly loosely consolidated

Tv; Tertiary volcanic flow rocks; minor pyroclastic deposits

Ep Sandstone, shale, and conglomerate, well consolidated

Mc; Sandstone, shale, conglomerate, and fanglomerate; moderately to well consolidated

gb; Gabbro and dark dioritic rocks; chiefly Mesozoic

grMz, grMz?; Mesozoic granite, quartz monzonite, granodiorite, and quartz diorite

grPz Paleozoic and Permo-Triassic granitic rocks

m; Undivided pre-Cenozoic metasedimentary and metavolcanic rocks of great variety. Mostly slate, quartzite, hornfels, chert, phyllite, mylonite, schist, gneiss, and minor marble

C; Shale, sandstone, conglomerate, limestone, dolomite, chert, hornfels, marble, quartzite; in part pyroclastic rocks

Sch; Schists of various types, mostly Paleozoic or Mesozoic age

pCc; Complex of Precambrian igneous and metamorphic rocks. Mostly gneiss and schist intruded by igneous rocks; may be Mesozoic in part

FIGURE 2

Mojave Basin Area Watermaster

Regional Geology

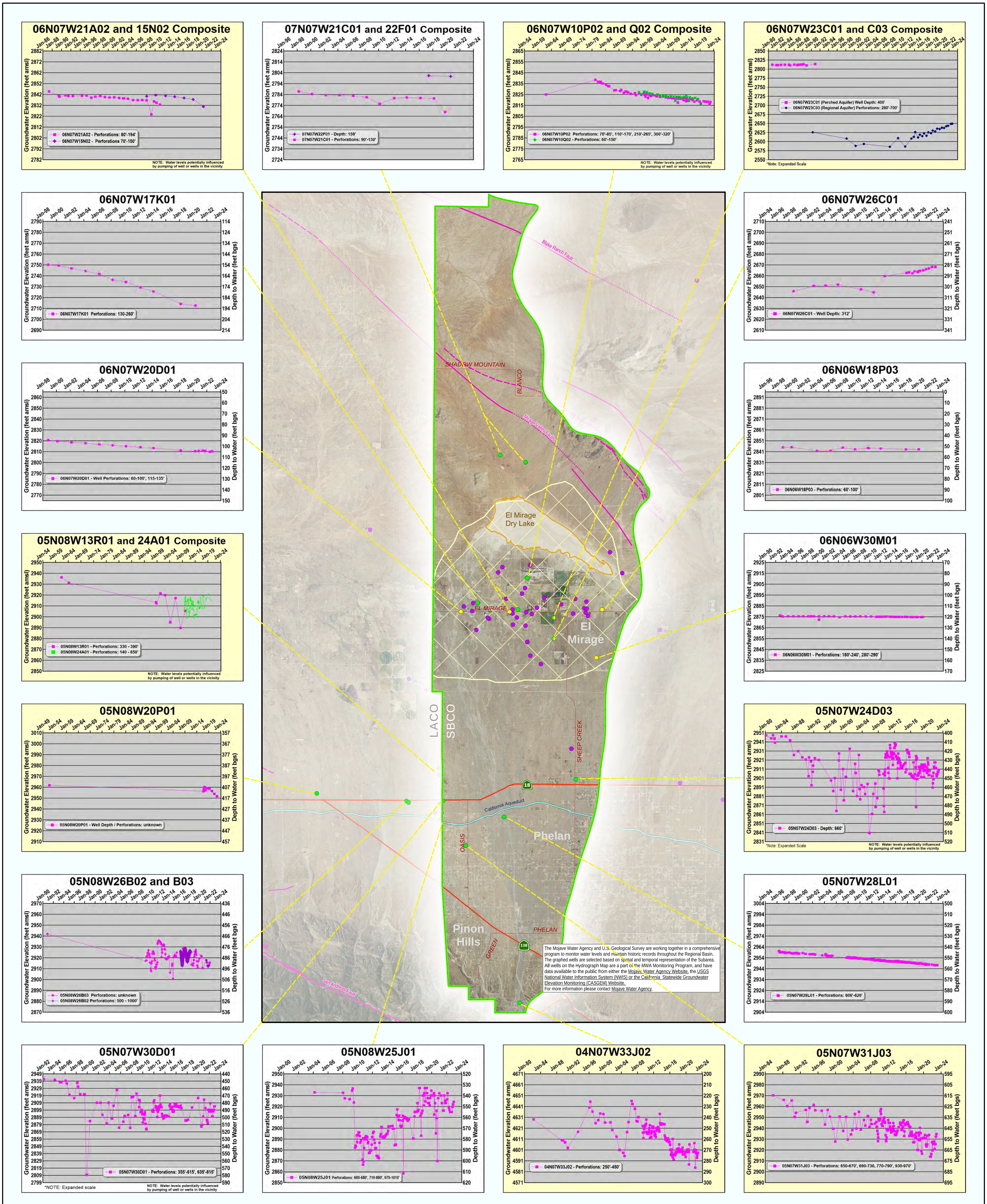
Oeste Subarea

Wagner & Bonsignore

Consulting Civil Engineers, A Corporation

Geologic Data per California Geologic Survey REST server, based on 2010 Geologic Survey, https://gis.conservation.ca.gov/server/rest/services/CGS/Geologic_Map_of_California/MapServer accessed Oct., 23, 2023.

 October 2023



Mojave Water Agency

Data Sources:
MWA, US Census,
USGS/NWIS,
Date: February 2023
Mojave Water Agency
Water Resources Department

Graphed Wells
- Perched
- Water Table
- Water Table and Perched
- MWA Monitoring Program Wells
- USGS Perched Water Table
- CA Geologic Faults (CGS, USGS)

Figure 3

Oeste Subarea Hydrographs 2023

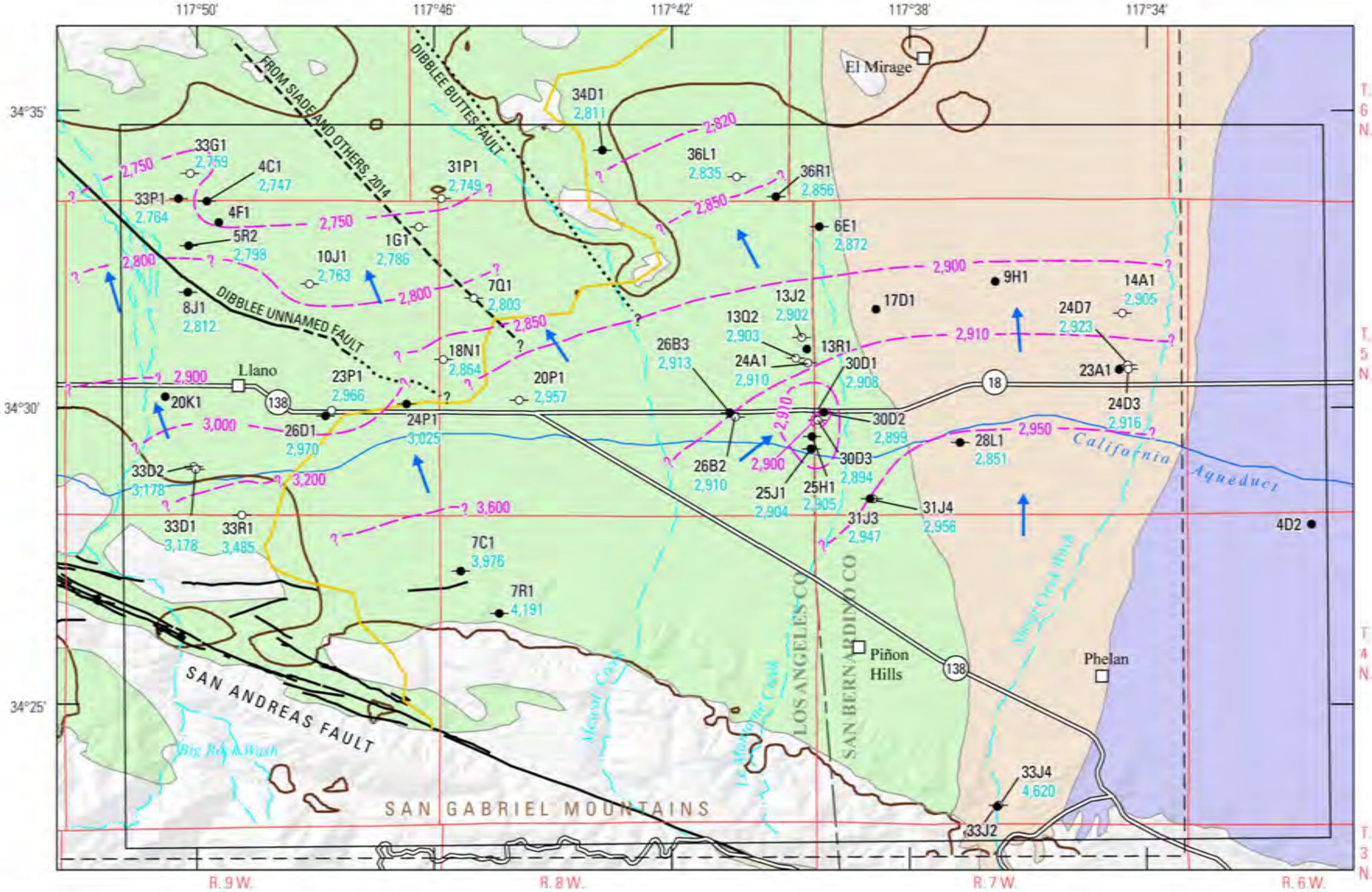
- Recent record
- Long-term record (begins ~1950 to ~ 1980)
- Very long-term record (begins ~1920)

0 0.5 1 2
Miles

N

GSWC 0228

FIGURE 4 - Groundwater Levels
Water Source Evaluation, Oeste Subarea



Base modified from U.S. Geological Survey and other Federal and State digital data, various scales; Geographic Coordinate System; North American Datum of 1983

0 — 4 MILES
0 — 4 KILOMETERS

EXPLANATION

- **Antelope Valley groundwater basin**
- **El Mirage Valley groundwater basin**
- **Upper Mojave River Valley groundwater basin**
- **Groundwater-level study area**
- **Gravity study area**
- –2,900–? **Approximate line of equal groundwater-level altitude, 2014**—Interval varies; dashed where approximate; queried where uncertain; hachures indicate depression.
- **Fault**—Dashed where approximately located or inferred, dotted where concealed (modified from Dibblee, 1959, 1960c; Bryant, 2005; Siade and others, 2014).
- **Buried contact of alluvium and basement based on 2014 gravity data (see fig. 5)**
- **Ridge of highest basement altitude**
- **General direction of groundwater flow**
- 24P1 ● **Well with hydrograph shown in figure 11 and abbreviated state well number**
- 20P1 2,957 ● **Well with groundwater-level data and hydrograph shown in figure 11 and identifier**—Top number is abbreviated state well number. Bottom number is altitude of groundwater level, in feet above NAVD 88.
- 33J4 2,956 ○ **Well with groundwater-level data**—Top number is abbreviated state well number. Bottom number is altitude of groundwater level, in feet above NAVD 88.

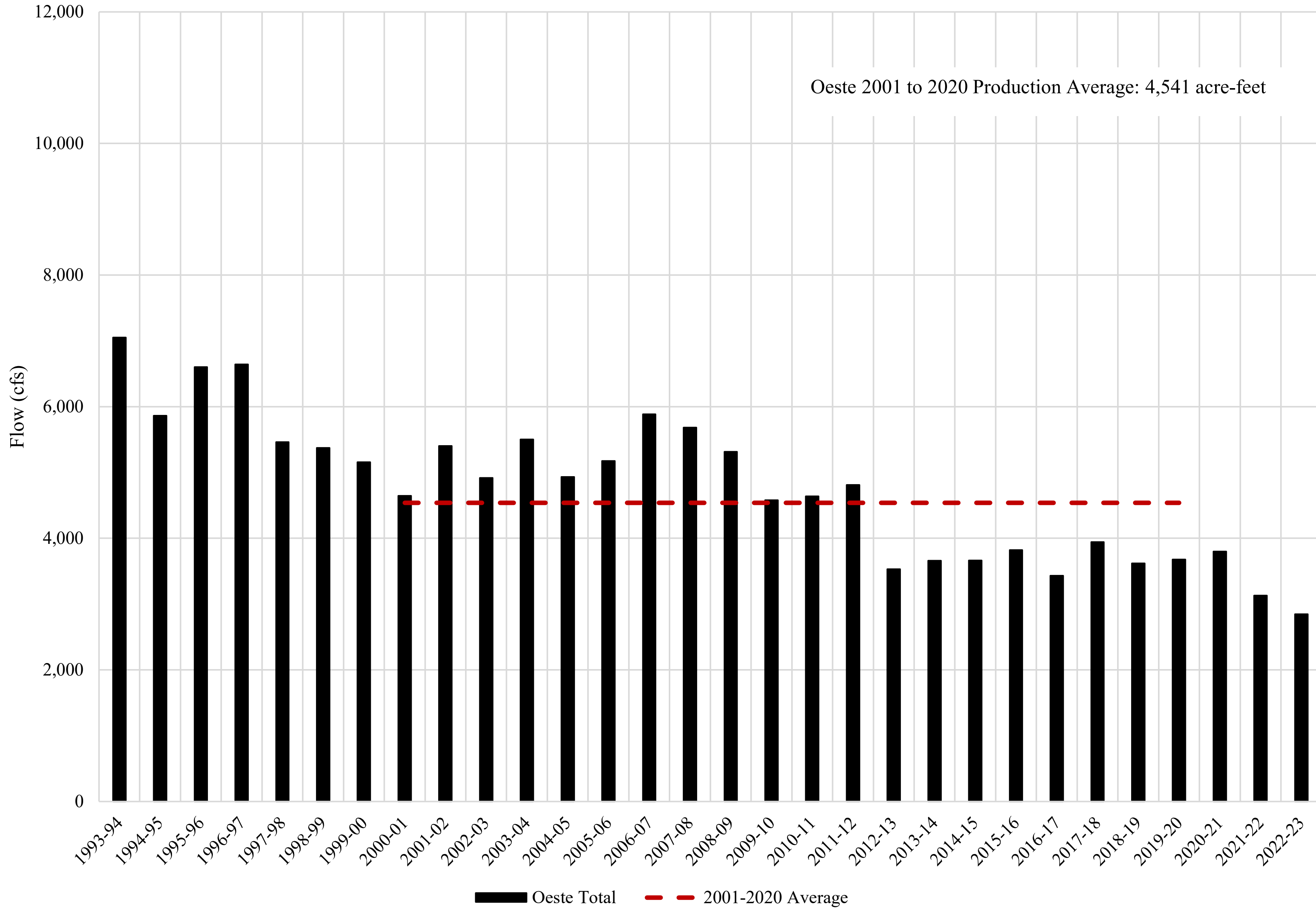
Figure 10. Groundwater-level altitude, general direction of groundwater flow, and location of wells with groundwater-level hydrographs shown in figure 11, near Piñon Hills, California.

Source: Stamos and others, 2017

FIGURE 5

Oeste Production

1993 to 2023



Mojave Basin Area Watermaster

Appendix D

Este Subarea

Water Supply Update

Prepared by:

Wagner & Bonsignore, Engineers

Robert C. Wagner, PE

Watermaster Engineer

David H. Peterson, C.E.G, C.Hg

February 28, 2024

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

Nicholas F. Bonsignore, P.E.
Robert C. Wagner, P.E.
Paula J. Whealen

Martin Berber, P.E.
Patrick W. Ervin, P.E.
David P. Lounsbury, P.E.
Vincent Maples, P.E.
Leah Orloff, Ph.D, P.E.
David H. Peterson, C.E.G., C.H.G.
Ryan E. Stolfus

MEMORANDUM

To: Mojave Basin Area Watermaster

From: Robert C. Wagner, P.E. and David H. Peterson, C.E.G, C.Hg

Date: February 28, 2024

Re: **Water Supply Update for Este Subarea**

This memorandum updates the estimates of groundwater production and supply for the Este Subarea of the Mojave River Groundwater Basin. Sources of water supply to the subarea were previously evaluated by Wagner & Bonsignore (WBE) as part of a water budget for the years 1995 to 2014, summarized in a draft January 20, 2016 memorandum. An updated water supply evaluation through 2020 was also prepared and submitted to Watermaster in a June 19, 2020 draft memorandum.

The purpose of the current evaluation and memorandum is to provide Watermaster with an update on the state of knowledge about available groundwater supply for the Este Subarea to develop an updated Production Safe Yield (PSY). The current evaluation was limited to review of available reports and data; no field studies or modeling were performed. The current update relies largely on the prior WBE studies (2016 and 2020 draft memorandums) and on the data and findings presented in a U.S. Geological Survey hydrogeologic study and groundwater model for the Lucerne Valley (Stamos and others, 2022).

The location of the Este Subarea with respect to other subareas of the Mojave River Area is shown on Figure 1. The Este Subarea consists of Fifteenmile Valley to the west and the Lucerne Valley to the east, separated by the northwest-trending Helendale fault. Water supply for the Este Subarea is obtained entirely from groundwater, pumped from aquifers within the subarea. No subsurface inflow from other subareas has been documented and there are no additional surface deliveries of water from outside the Este Subarea, with the exception of treated wastewater deliveries from the Big Bear Area Regional Wastewater Agency (BBARWA). Direct infiltration of the small amount of annual precipitation to the ground is considered to be negligible (USGS; various studies). Potential sources of groundwater recharge and supply to the subarea, shown on Figure 1, have been identified by various previous studies to include:

- Natural recharge from surface water runoff at the base of the mountain front bounding the southern margin of the subarea, also referred to as mountain-front recharge;

- Infiltration of treated wastewater from irrigation and unlined storage basins at the Big Bear Area Regional Wastewater Agency (BBARWA) facility in Lucerne Valley and minor return flows from individual septic systems; and

- Infiltration of excess irrigation water in agricultural fields, also referred to as irrigation return flows. Agricultural irrigation has historically occurred mainly in Lucerne Valley, although small farms in Fifteenmile Valley are also irrigated with groundwater (mainly to grow jujubes).

From a hydrogeologic perspective, a fundamental challenge in estimating the various water supply and use inputs to the subarea is that Fifteenmile Valley and Lucerne Valley, which make up the subarea, are essentially separate groundwater basins, separated by a fault that reportedly allows minimal groundwater flow between them (Stamos and others, 2001). Therefore, estimates of recharge or change in storage are not uniform throughout the Este subarea and the two valleys are essentially non-connected basins.

Hydrogeologic Setting

Geologic Units and Aquifers

The geology of the subarea and vicinity is shown on Figure 2. Prior studies by the USGS generally show Fifteenmile Mile Valley as lying within the Mojave River Basin and the Lucerne Valley as lying within the adjacent Morongo Basin, with the Helendale fault representing the basin boundary. However, as defined by the 1996 Mojave Basin Area Adjudication, Fifteenmile and Lucerne Valleys are managed collectively as one of five subareas within the Mojave Basin Area. Prior geologic studies for the vicinity identify the Este Subarea as underlain and bounded to the south, north, and east by bedrock units, generally of pre-Tertiary age (older than about 65 million years). Locally, the bedrock upland areas also consist of volcanic units of Tertiary age. These older bedrock units are generally considered to be relatively impermeable and non-water-bearing, although wells have locally been developed in more fractured areas of the bedrock units.

Sediments deposited within Fifteenmile and Lucerne Valleys were derived from the bedrock upland areas bounding the valley. Within the Este Subarea, the oldest of the basin deposits are sedimentary strata of the Old Woman Sandstone of late Tertiary age. The formation underlies most of the Fifteenmile and Lucerne Valleys and ranges in thickness from about 600 to 1,000 feet. The formation is described in a study by CSU Fullerton (2005) as the primary water producing aquifer in the Este Subarea.

The Old Woman Sandstone is overlain in most areas of the subarea by unconsolidated alluvial fan deposits, basin alluvium, and playa deposits ranging from Pleistocene to Holocene in age. In the 2022 study of the geohydrology of the Lucerne Valley (Stamos and others, 2022), the alluvial units within the Lucerne Valley are divided by their depositional environment (lake, fan, playa units), underlain and surrounded by generally non-water bearing bedrock formations. The groundwater model developed for the valley breaks out the basin fill within Lucerne Valley as four units or layers; a surficial and generally unconfined aquifer extending to depths of about 150 to 180 feet, underlain by a laterally extensive, less permeable confining layer consisting primarily of lake deposits. This underlying impermeable layer generally correlates to the "perched zone" depicted on yearly hydrograph maps prepared by MWA (see Figure 4). The near-surface aquifer and confining (perched) layer are underlain by older alluvial deposits, divided by age and texture into two, generally confined to semi-confined aquifer units. Based on age, depth, and lateral extent, it appears that the deepest of the four hydrologic units in the USGS model is likely correlative to the Old Woman Sandstone.

Faulting

The Este Subarea is traversed by several west- to northwest-trending faults, including the North Frontal Fault Zone along the base of the San Bernardino Mountains, the Helendale fault dividing Fifteenmile and Lucerne Valleys, and the Lenwood fault, along the northeastern margin of the subarea. In general, these faults are considered to be potential barriers to groundwater flow. Groundwater level data collected by USGS studies from the subarea indicate that the Helendale fault zone represents a barrier to groundwater flow, with water levels on the southwest side of the fault higher than the northeast (Lucerne Valley) side, essentially separating Fifteenmile and Lucerne Valleys hydrogeologically. Groundwater monitoring data from wells near the Helendale fault indicate that water levels are generally higher on the southwest side of the fault, ranging from about 20 to 250 feet across the fault (CSU Fullerton, 2005). The potential for groundwater flow across the fault from Fifteenmile Valley into Lucerne Valley is not verified, although prior analysis by the USGS (Stamos and others, 2020) indicates that flow across the fault is minimal.

Groundwater Conditions

As discussed, the Helendale fault acts as a groundwater divide, in effect separating Fifteenmile and Lucerne Valleys hydrogeologically. Previous studies by USGS indicate that groundwater flow across the Helendale fault, from Fifteenmile Valley to Lucerne Valley is minimal (Stamos, 2001; Stamos and others, 2020). Water level data indicate that groundwater flow within the Fifteenmile Valley area is generally to the west-northwest, toward the Alto Subarea and Mojave River. Groundwater flow in the Lucerne Valley generally flows towards and converges in the vicinity of Lucerne Dry Lake, with no documented flow out of the valley.

Review of well hydrographs by MWA (see Figure 4) indicate that groundwater levels in the Lucerne Valley generally range from about 120 to 200 feet below ground surface. Typically, water levels in the vicinity of the perched zone identified by USGS are shallower than surrounding areas. In general, water levels trends over time in most of the hydrographs for Lucerne Valley area are relatively flat; that is, appear to be relatively stable or only slightly declining over time. Also, water levels in wells 05N01W25G01, 05N01E17D01, and 05N01W36R01 appear to have rebounded in the mid-1990s, after the Judgement.

Water levels in the Fifteenmile Valley are on the order of about 20 to 80 feet below ground surface, which is generally shallower than in Lucerne Valley. Locally however, water levels in Fifteenmile Valley are deeper, in the range of 200 to 350 feet deep (State Well No. 04N01W21J01 and 04N02W16E01, respectively). In general, the shallowest groundwater measurements appear to be from wells located near and on the southwest side of the Helendale fault. The hydrographs for wells in Fifteenmile Valley indicate that several continue to record declining water levels (04N01W07R01, 04N01W18Q01, 04N01W09P06, 04N01W10R01). However, the rate of decline appears to be small, on the order of about 0.15 to 0.2 feet per year.

Water Supply

Mountain-Front (Natural) Recharge

Areas of potential mountain-front recharge identified by USGS (Izbicki, 2004) are shown on Figure 3. Estimates of the volume of native recharge occurring along the mountain-front within the Este Subarea are approximate with the more recent estimates based largely on groundwater models. The Stipulated Judgment (Table C-1), provided a surface water inflow estimate of 1,700 acre-feet of ungaged surface water inflow into the Este Subarea, although the resulting amount of infiltration and groundwater recharge to deeper aquifers is not known. In the 2005 *Este Hydrologic Atlas*, CSU Fullerton cited estimates of groundwater recharge from several sources, although only the estimate from the Department of Water Resources (DWR; Bulletin 84, 1967) was for the entire Este Subarea. DWR estimated 1,050 AFY of recharge associated with surface inflow.

For the current update, the range of values of possible mountain front recharge to Este Subarea and Lucerne Valley are listed below:

Source of Data – Mountain-front Recharge	Average, AFY
DWR, Bull. 84 (1967), Este Subarea	1,050
USGS, Shaefer (1979) – Lucerne Valley only	1,000
Wagner & Bonsignore (2016) – Este Subarea (average of published data)	1,375
USGS, Stamos et al (2022) – Lucerne Valley only	635-940

The two estimates of recharge for the entire subarea (Shaefer, 1979 and Wagner & Bonsignore, 2016) indicate that mountain-front recharge is in the range of about 1,050 to 1,375 AFY.

As noted by the USGS (Stamos and others, 2001), the discharge from streams and washes draining the mountain front have never been directly measured. Given the infrequency of large storm events contributing significant recharge to the subarea, specific field-level measurements are not available. In general, the USGS estimates are model-derived, based on precipitation data and adjusted during model calibration. Of the estimates, the most recent mountain-front recharge to Lucerne Valley in the USGS 2020 model (635 to 940 AFY) appears to be most area-specific and was adjusted during model calibration to be consistent with groundwater level data. As such, it may represent a reasonable approximation of recharge to Lucerne Valley, but not the entire Este subarea.

The primary areas contributing the bulk of the mountain-front recharge to the Mojave River Basin appear to be in the Sheep Creek Wash (Oeste Subarea) and headwaters of the Mojave River (Alto Subarea; Izbicki and Michel, USGS, 2004), to the northwest. However, the USGS has also identified evidence of mountain-front recharge at the southeast end of Fifteenmile Valley. When the extent of the mountain-front recharge areas in Lucerne and Fifteenmile Valleys identified by USGS (Izbicki and Michel, 2004), are compared, the potential recharge to Fifteenmile valley appears to be several times larger than the area identified in Lucerne Valley. Presumably, the mountain-front recharge to Fifteenmile Valley is also greater than that to Lucerne Valley, although the actual amount remains unconfirmed. The USGS also performed isotopic analysis of groundwater samples from Fifteenmile and Lucerne Valley and found that groundwater at the base of the mountains was relatively young (less than about 70 years old), indicating recent recharge. However, away from the mountain front, estimated groundwater age was over 10,000 years old. This suggests that the rate of recharge of groundwater to the valleys from native recharge is very slow.

BBARWA Return Flows

Return flows from treated wastewater deliveries to the Big Bear Area RWA (BBARWA) to Lucerne Valley were calculated by Watermaster, based on reported deliveries, less the consumptive use for alfalfa. From the period of 1996 to 2018, Watermaster has calculated return flows ranging from a low of 63 AFY in 2018, to a high of 1,936 AFY in 1998, with an average over that period of 792 AFY. Consultants for the project known as "Replenish Big Bear" presented information to MWA (January 25, 2024) representatives indicating basin recharge from BBARWA to be 1610 acre feet per year for a 10 year period 2012-2024. While the "Replenish Big Bear" project is a potential loss of recharge to Este, it is not currently known when the project will be fully implemented.

Estimates of return flows were also developed for the years 1980 to 2016 from model simulations of the USGS Lucerne Valley Hydrologic Model (2020). Return flows simulated by USGS have ranged from 300 to over 2,000 AFY, with an average of 944 AFY.

Overall, the calculated average return flows between Watermaster and USGS are similar. As discussed, it has been observed that water levels are rising in the area of BBARWA, indicative of local recharge. However, as shown on Figure 3, the BBARWA facility is located within and overlying the area identified by USGS and depicted on MWA hydrographs as a shallow perched zone. Review of cross sections presented in the *Irrigation Management Plan* for the facility (Water Systems Consulting, Inc., 2016), as well as drillers reports for the monitoring wells at the BBARWA facility indicate that clays were encountered at depths of about 150 to 180 feet, likely corresponding to the perched or confined layer described by USGS (Layer 2 of Stamos et al, 2020). Therefore, it appears likely that infiltrated water at the BBARWA facility is limited by the confining layer. It is not currently known if the infiltrated water from BBARWA remains perched and isolated on the confining layer, or if it enters deeper aquifers down-gradient (northwest) of the facility.

In their 2022 report, the USGS (Stamos et al) indicated that recharge from water from septic systems from the town of Lucerne Valley and surrounding basin is difficult to quantify, but assumed to be negligible. Citing studies by others (Umari and others, 1995), the USGS indicated that using 1928 and 2010 population estimates, the amount of potential recharge from septic effluent ranged from about 20 to 455 AFY during those years. However, the USGS also indicated that actual amounts of recharge could be less, due to lower population before 1928, losses from evaporation of near-surface systems, and time required for effluent to migrate to the water table.

Irrigation Returns

Irrigation returns or return flows are defined by the USGS (2020) as water applied to agricultural fields that is not used by plants or lost through evaporation. It is presumed the water undergoes deep percolation to aquifers. For the Lucerne Valley Hydrologic Model (2020), the USGS evaluated historical crop use, groundwater production, both verified (since 1996) and estimated from crop consumptive use. Based on the model simulation, irrigation returns in Lucerne Valley for the period from 1942 to 2016 were calculated to average 1,900 AFY. No estimate for Fifteenmile Valley was made in that study.

In an updated water budget for Este Subarea, Watermaster estimated agricultural return flows during the period 1996 to 2018 ranged from 876 to 3,036 AFY, with an average of 1,896 AFY. Of the average, about 384 AFY was calculated for Fifteenmile Valley, with the remaining 1,512 AFY estimated for Lucerne Valley. The Watermaster analysis assumes that groundwater production (pumping) minus consumptive water use (i.e., crop irrigation) equals the return flows to the subsurface. As previously discussed though, soil-moisture data from Lucerne Valley suggests that at least locally, return flows may be lower than estimated by the consumptive use analysis.

As shown on Figure 4, many areas of agricultural irrigation in the Lucerne Valley lie within the area of the perched or confining layer identified by USGS. As with the infiltrated water from the BBARWA facility, it appears that infiltration of most of the agricultural return flows in Lucerne Valley would be limited by the confining layer at depth. As a result, most of the estimated 1,512 AFY return flows in Lucerne Valley may be limited to increasing storage of the uppermost aquifer. Agricultural acreage in Fifteenmile Valley has historically been less than Lucerne Valley, reflected by the lower calculated return flow average of 384 AFY. However, a widespread perched zone has not been documented.

Water Supply Summary

The estimated total annual water supply to the Este Subarea presented below represents studies spanning varying time frames. Based on consumptive use models, estimates of returns from the BBARWA facility and from agricultural irrigation are based on data from as recently as 2016 to 2018. However, the contribution of native mountain-front recharge to the water supply for the subarea is poorly understood, varies most widely, and represents varying base periods and geographic areas. Based on the information reviewed, estimates of the current ranges of input from the various water supply sources is listed below:

Water Supply Source	Time Period Evaluated	Annual Supply (AFY)
Agricultural Return Flows	1942 - 2018	1,896 - 1,900
BBARWA Disposal	1980 - 2024	792 – 1,600
Mountain-front Recharge	1936 - 2016	1,050 – 1,375
Total Estimated Range		3,738 - 4,875

Consumptive Use and Outflows

As provided in the Watermaster Annual Reports for the past five water years, the total consumptive use and outflows for the Este Subarea are listed below, in acre-feet:

2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	5-Year Average
4,027	3,834	4,318	4,579	4,706	4,393

The reported outflows shown above include 200 AFY of subsurface flow to Alto subarea.

Change in Storage

Based on the above estimates, the water supply and consumptive use/outflows appear to be relatively closely balanced.. This would indicate that storage loss in recent years is relatively small. This seems to be supported by the observation that annual changes in water levels shown on the MWA Hydrograph Map on Figure 4 are also small, especially since the mid-1990s. As discussed by USGS (2022), water level changes continue to be influenced by regional movement of groundwater to partially refill a historical pumping depression in the area of the Lucerne dry lake. They also note that water levels near the valley margins are declining as water moves to the middle of the valley. Therefore, it may be difficult to separate the relatively small effects of current pumping from the larger regional effect of long-term water-level recovery.

The USGS groundwater model for Lucerne Valley (Stamos and others, 2022) estimated that reduced pumping starting in the mid-1990s decreased the rate of storage depletion. From 1942 to 1995, the average depletion of groundwater storage in Lucerne Valley was calculated at about

7,700 AFY, decreasing to about 2,900 AFY for the period from 1996 to 2016. It should be noted however that verified pumping in Este also generally decreased over time and is reported by Watermaster to range from 4,029 to 4,304 AFY during the last five water years. Presumably, the overall decrease in pumping correlates to a smaller amount of storage loss over the past five years.

Discussion and Conclusions

The elements of water supply to the Este subarea are approximate values taken from several published sources, although none of the water supply inputs have been directly measured. Infiltration of treated wastewater or agricultural irrigation returns are based on consumptive use analysis, which assumes that any water not consumed by plants or directly evaporated is returned to the aquifer. While the analysis provides a reasonably estimate of water use, factors such as climatic conditions, salinity, and pests and diseases can affect the estimated water demand by crops.

Of the water supply sources discussed, the largest unknown with the widest range of published estimates is mountain-front recharge. MWA is currently in the early stages of a project to install a stream gauge in the watershed to the south of the subarea, to monitor periodic runoff events to Fifteenmile Valley. While this gauging data will eventually provide additional information to estimate mountain-front recharge, it may be several years before sufficient data are collected to understand this input to the water balance.

While most water supply inputs are estimated, one directly observable element of the water balance that can be measured is water levels in wells. In general, the historical water levels shown on the hydrograph (Figure 4) are relatively stable, or are only changing at a small rate. Interpretation of small water level changes, particularly in the Lucerne Valley, are difficult because water levels have been recovering near Lucerne Dry Lake, with associated declines in water levels at the valley margins (Stamos and others, 2022). Overall though, they appear to support the conclusion the water supply is very near to or slightly less than groundwater production.

Based on information provided from Watermaster, the total estimated pumping for Este subarea for the past five water years is shown below:

	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	Average
Verified Production	4,101	4,029	4,227	4,304	4,114	4,155
Non-Stipulating Parties*	954	954	954	954	954	954
Totals	5055	4983	5181	5258	5068	5108

* Estimated groundwater pumping based on land use, crop type, and climate data
See Fig 5

As indicated, verified and estimated pumping together appear to exceed the estimated water supply of 3,730 to 4,875 AFY. However, water levels throughout Lucerne Valley generally remain little changed in recent years and within Fifteenmile Valley, water levels are either relatively stable, or are declining slowly. Based on these observations, it appears that recharge and pumping are fairly closely balanced. Based on average production, this would indicate a production safe yield of 4484 AFY (Total Production minus deficit).

We note that results from the Upper Mojave Basin Model indicate that the losses/gains in Fifteen Mile Valley are negligible (70 year average, -191 acre feet, 20 year average +134 acre feet). The water levels, as shown on Figure 4, suggest little to no change in storage over at least the last 10-20 years; some wells show slight declining water levels, and some water levels are rising. In light the foregoing and Figure 4, the PSY could be considered to be equal to the pumping in Este or about 5100 acre feet.

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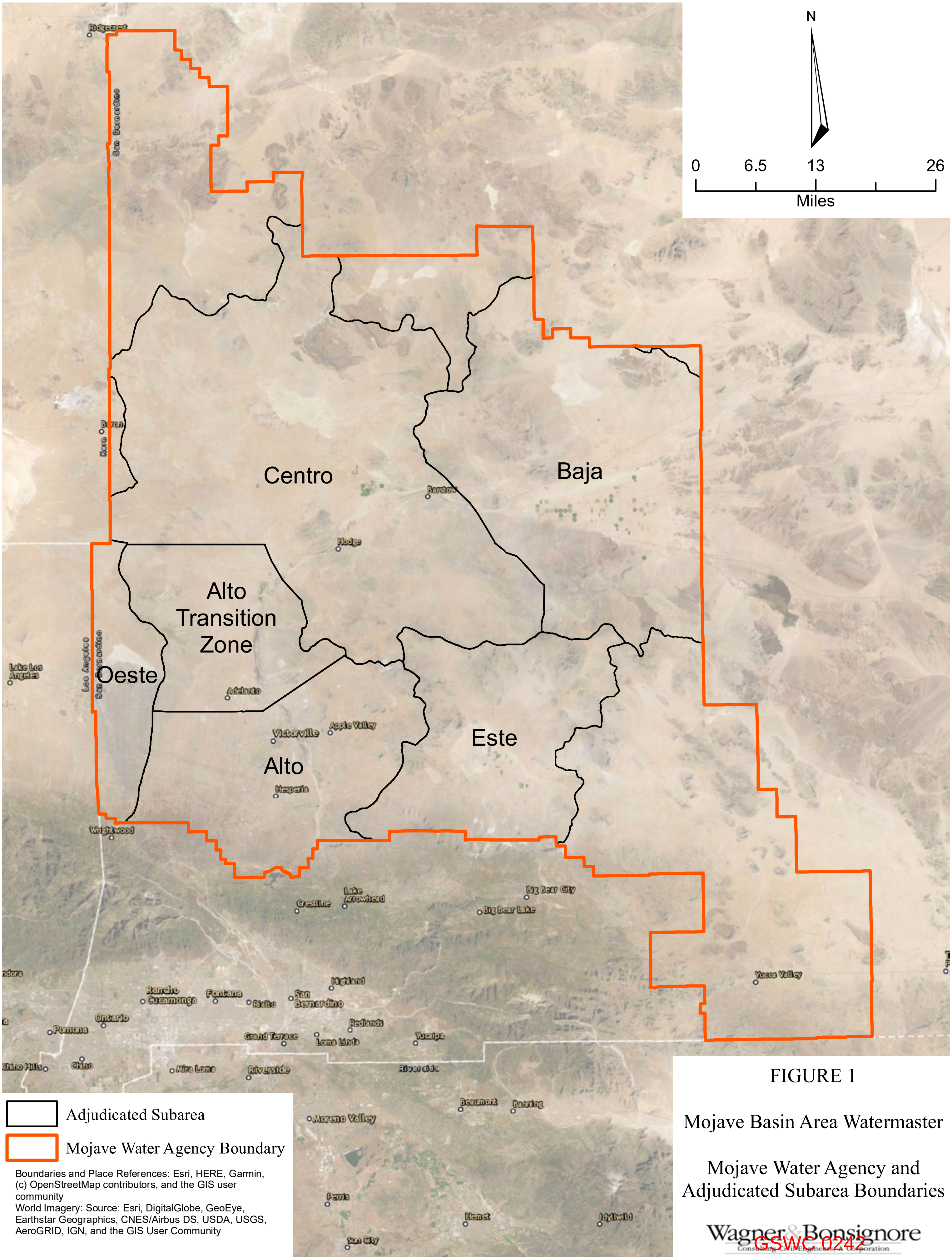


FIGURE 1

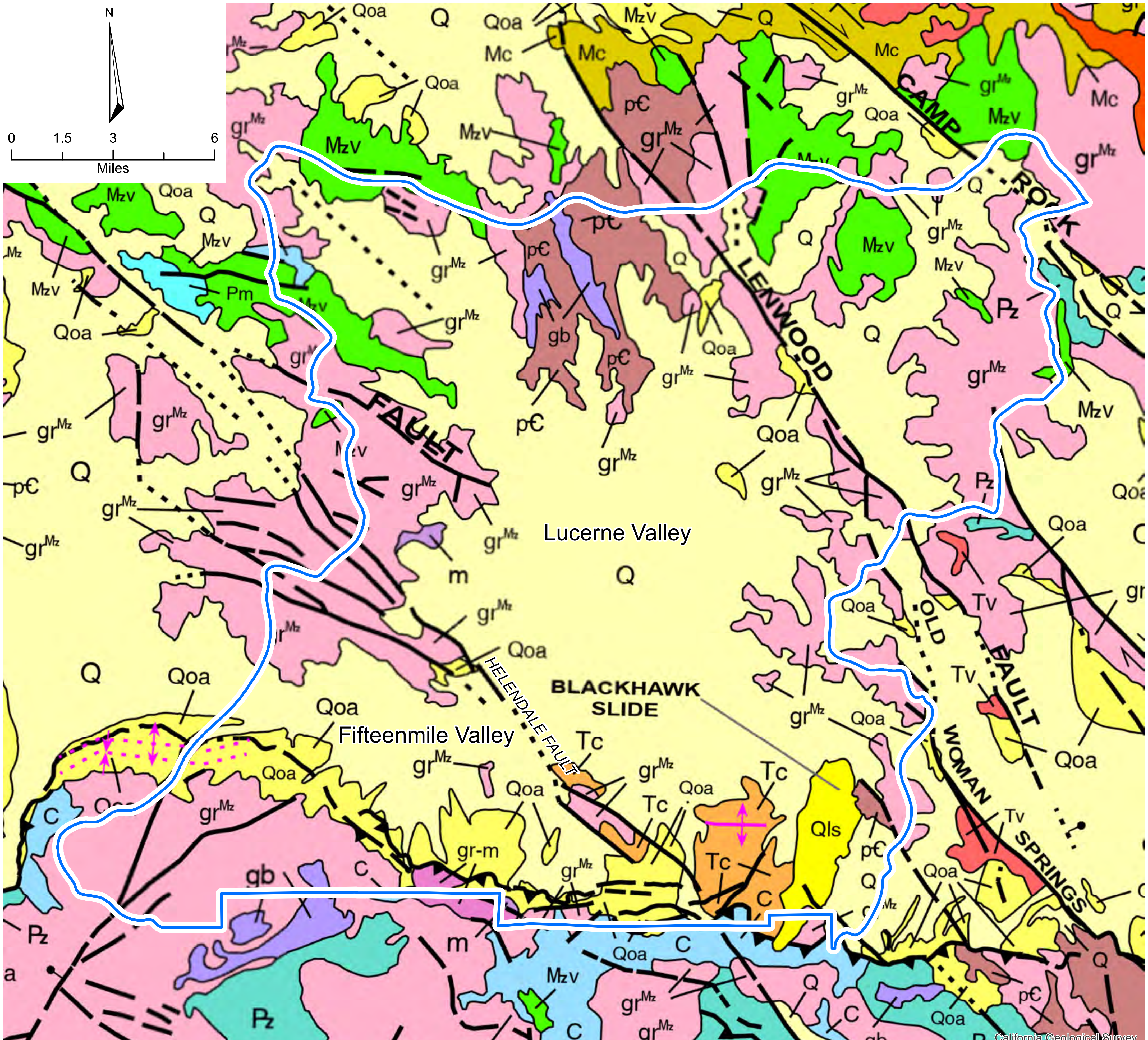
Mojave Basin Area Watermaster

Mojave Water Agency and Adjudicated Subarea Boundaries

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

June 2020

Q:\Drawings\Mojave Water Agency\Este Subarea\Este Water Supply - FIGURE 1 - Location Map.mxd



- Adjudicated Subarea
- Q; Alluvium, lake, playa, and terrace deposits; unconsolidated and semi-consolidated. Mostly nonmarine, but includes marine deposits near the coast
- Qls; Selected large landslides, such as the Blackhawk Slide on the north side of San Gabriel Mountains; early to late Quaternary
- Qoa; Older alluvium, lake, playa, and terrace deposits
- Qv, Qv?; Quaternary volcanic flow rocks; minor pyroclastic deposits
- Tc; Undivided Tertiary sandstone, shale, conglomerate, breccia, and ancient lake deposits
- Mc; Sandstone, shale, conglomerate, and fanglomerate; moderately to well consolidated
- Tv; Tertiary volcanic flow rocks; minor pyroclastic deposits
- gr-m; Granitic and metamorphic rocks, mostly gneiss and other metamorphic rocks injected by granitic rocks. Mesozoic to Precambrian
- Mzv; Undivided Mesozoic volcanic and metavolcanic rocks. Andesite and rhyolite flow rocks, greenstone, volcanic breccia and other pyroclastic rocks; in part strongly metamorphosed. Includes volcanic rocks of Franciscan Complex: basaltic pillow lava, diabase
- grMz, grMz?; Mesozoic granite, quartz monzonite, granodiorite, and quartz diorite
- gb; Gabbro and dark dioritic rocks; chiefly Mesozoic
- Pz; Undivided Paleozoic metasedimentary rocks. Includes slate, sandstone, shale, chert, conglomerate, limestone, dolomite, marble, phyllite, schist, hornfels, and quartzite
- Pm; Shale, conglomerate, limestone and dolomite, sandstone, slate, hornfels, quartzite; minor pyroclastic rocks
- C; Shale, sandstone, conglomerate, limestone, dolomite, chert, hornfels, marble, quartzite; in part pyroclastic rocks
- m; Undivided pre-Cenozoic metasedimentary and metavolcanic rocks of great variety. Mostly slate, quartzite, hornfels, chert, phyllite, mylonite, schist, gneiss, and minor marble
- pC; Conglomerate, shale, sandstone, limestone, dolomite, marble, gneiss, hornfels, and quartzite; may be Paleozoic in part

FIGURE 2

Mojave Basin Area Watermaster

Regional Geology
Este Subarea

Wagner&Bonsignore
Consulting Civil Engineers, A Corporation

GSWC 0243

June 2020

Q:\Drawings\Mojave Water Agency\Este Subarea\Este Water Supply - FIGURE 2 - Regional Geology.mxd

Q:\Drawings\Mojave Water Agency\Este Subarea\Este Water Supply - FIGURE 3 - Locations of Recharge.mxd

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0 1.5 3 6
Miles

Perched Water Table (USGS)

Este Subarea

Locations of Potential Recharge

Big Bear Area RWA

Mountain Front Recharge

Source: Perched Water Table (USGS) digitized from *Este Subarea Hydrographs, 2020*, Mojave Water Agency, 2020.
Mountain Front Recharge is derived from WRI Report 03-4314, Figure 3, Izbicki, J.A., and Michel, R.L., U.S. Geological Survey, 2004. Areas shown are percent modern carbon greater than 90.
Heledale Fault per Bryant, W.A. (compiler), 2005, Digital Database of Quaternary and Younger Faults from the Fault Activity Map of California, version 2.0: California Geological Survey Web Page, (http://www.consrv.ca.gov/CGS/information /publications/QuaternaryFaults_ver2.htm), August 2015.

FIGURE 3

Mojave Basin Area Watermaster

Potential Recharge Locations
Este Subarea

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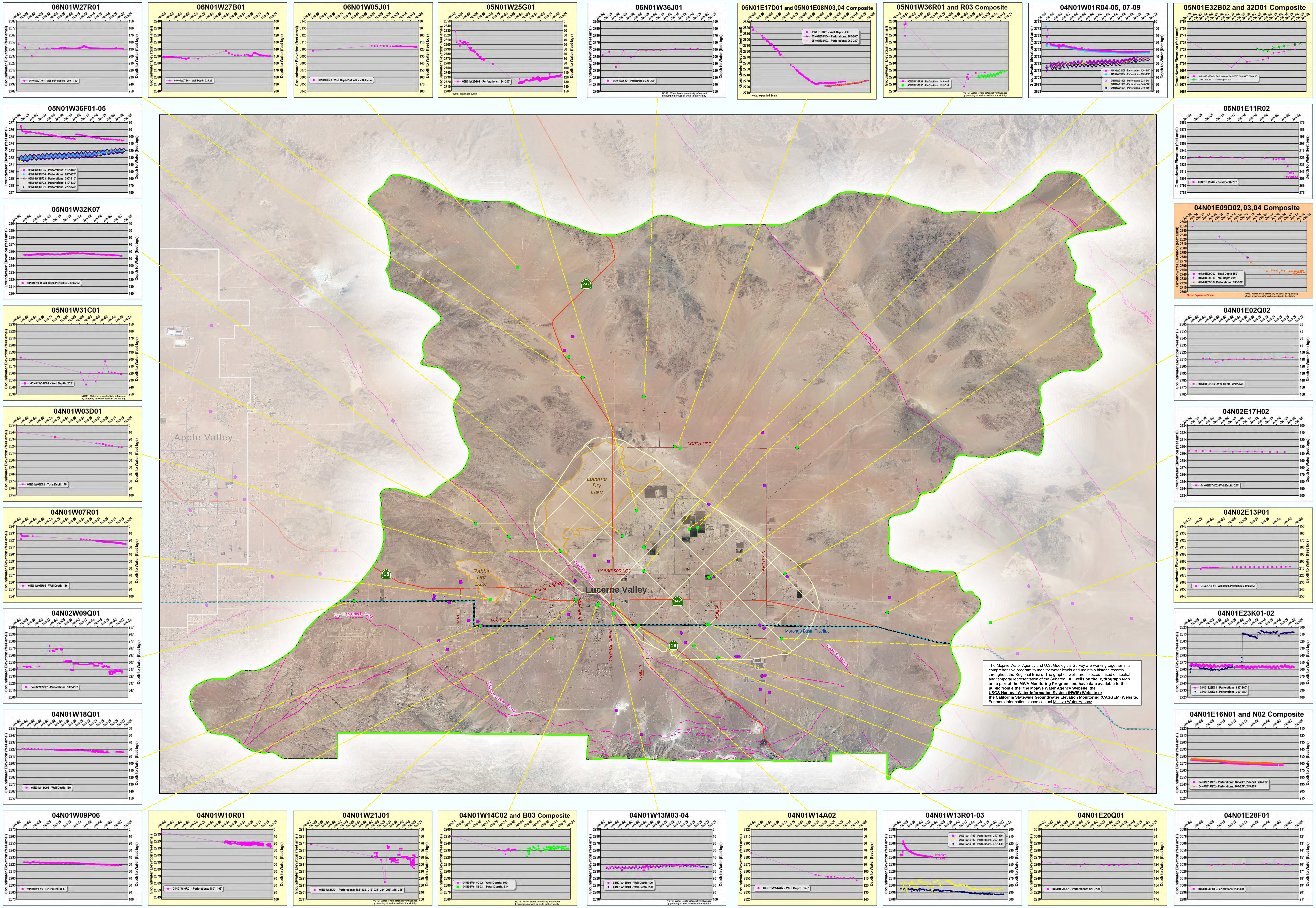
GSWC 0244

June 2020



Mojave Water Agency

Data Sources:
MWA, US Census,
USGS/NWIS,
DWR Bulletin 84 1967
Date: February 2023
Mojave Water Agency
Water Resources Department

- Graphed Wells
- MWA Monitoring Program Wells
- MWA Recharge Pipeline
- CA Geologic Faults (CGS, USGS)
- USGS Perched Water Table

FIGURE 4

Este Subarea Hydrographs 2023

- Recent record
- Long-term record (begins ~1950 to ~ 1980)
- Very long-term record (begins ~1920)

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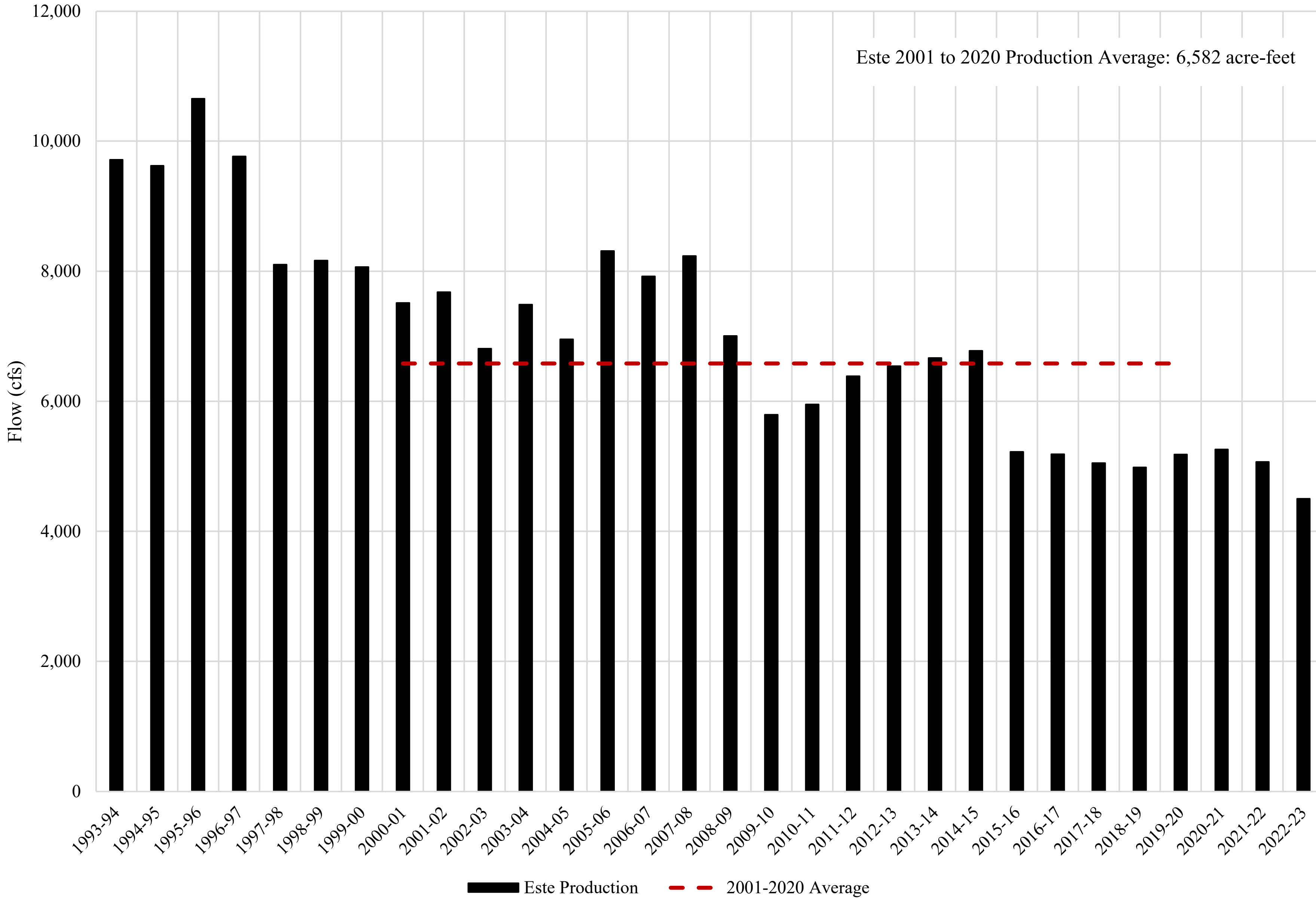
FIGURE 4

GSWC 0245

Figure 5

Este Production

1993 to 2023



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Mojave Basin Area Watermaster

Appendix E

Baja Subarea

Water Supply Update

Prepared by:

Wagner & Bonsignore, Engineers

Robert C. Wagner, PE

Watermaster Engineer

Leonardo Urrego-Vallowe, EIT

February 28, 2024

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

Nicholas F. Bonsignore, P.E.
Robert C. Wagner, P.E.
Paula J. Whealen

Martin Berber, P.E.
Patrick W. Ervin, P.E.
David P. Lounsbury, P.E.
Vincent Maples, P.E.
Leah Orloff, Ph.D, P.E.
David H. Peterson, C.E.G., C.H.G.
Ryan E. Stolfus

MEMORANDUM

To: Mojave Basin Area Watermaster

From: Robert C. Wagner, P.E.

Date: February 28, 2024

Re: **Production Safe Yield and Water Supply Update for Baja Subarea**
Recommendation for Free Production Allowance for Water Year 2024-25
Evaluation of Water Levels as indicator of Change in Storage

This memorandum sets forth findings from our review of water supply conditions in the Baja subarea and makes a recommendation for Production Safe Yield (PSY) based on significant reduction in pumping since 2015-2016 (-60%), and evaluation of changing water levels. In addition, we discuss two different approaches to the Baja Subarea water balance, changes to the estimate of phreatophyte usage, assumptions of ungaged tributary inflow, and the need to change the estimated production by minimal producers. While the water balances included herein serves as a coarse crosscheck for the PSY recommendation, we are using the water level hydrographs to form the basis for our recommendation.

The Baja Subarea is one of the five subareas within the Mojave Basin Area Adjudication (**Figure 1**). The boundaries along the Mojave River are generally downstream of the Waterman Fault area, near Nebo and continuing to Afton. There are no gages for measuring inflow to Baja, as the USGS gaging station at Barstow is about 5 miles upstream from the Waterman Fault. The gage at Barstow, adjusted for Waterman Fault, is considered the inflow to Baja. There is also no measurement for ungaged inflow (tributaries and desert washes) or mountain front recharge. Estimates of subsurface inflow were determined by USGS, Stamos, 2001, and are assumed representative of the subsurface inflow currently, as water levels near the subarea boundary between Centro and Baja are reasonably stable over time.

The USGS gaging station, Mojave River, Afton has been considered to represent outflow from the Baja subarea, and in general when the river carries sufficient flow to reach Afton this assumption is reasonable. However, storms occur that produce flow at Afton and are not measured at Barstow, understating the recharge potential to Baja.

2151 River Plaza Drive · Suite 100 · Sacramento, CA 95833-4133
Ph: 916-441-6850 or 916-448-2821 · Fax: 916-779-3120

Water Balances
Baja Table 5-1 (1931-1990), attached as Table 1, shows an estimate of long-term average water supply for the period 1931-1990 (17,358 acre feet), and an estimate of average outflow at Afton of 6,066 acre feet for the 1953-1990 (based on published records). For this analysis we have included an estimate of tributary inflow, (3,571 acre feet) based on the method described by Stamos, 2001. In this analysis, we have included the ungaged tributary inflow on the supply side (Table 1), assuming it is measured as outflow and recorded at Afton.

Baja Table 5-1 (2001-2020), attached as Table 2, shows an estimate of supply for the period 2001-2020, based on USGS measurements at Barstow, wastewater discharge at Barstow, and the elements shown on Table 2. Outflow is based on USGS measurements at Afton, adjusted to account for seasonal measurements where no flow is measured at Barstow. Phreatophytes use is shown as the average of the last 4 years, based on satellite imagery and earth surface energy balance to compute evapotranspiration.

Table 1 indicates a surplus based on long term average supply and outflow and current year consumptive uses of 1,795 acre feet. Table 1 also assumes that phreatophyte use is consistent with past estimates (2,000 acre feet). Table 2 indicates a deficit of 1,883 acre feet. Table 2 is based on estimate of supply for the 20 years (2001-2020), and current consumptive by phreatophytes and beneficial uses.

The PSY estimate based on long term supply is 14,544 acre feet (Table 1) and based on the 2001-2020 is 10,866 acre feet (Table 2). The average of PSY for two periods based on current consumptive uses is 12,705.

Phreatophytes
We estimated the current water use (evapotranspiration, ET) by phreatophytes in the Baja riparian habitat zone near Camp Cady. Exhibit H of the Judgment defines the "Harvard/Eastern Baja Riparian Zone" as the reach of the Mojave River that flows west to east from Harvard Road to Iron Ranch/Iron Mountain area. The Baja riparian area is about 1,389 acres (**Figure 2**). In 1996, Lines and Bilhorn estimated long term average water use by riparian plant communities to be about 2,000 acre feet per year (AFY) in this area.[1] In 2011, a study by the U.S. Bureau of Reclamation (USBR) and Utah State University (USU) estimated riparian ET for Baja to be about 2,000 AFY for 2007 and 2,500 AFY for 2010.[2]

The Watermaster has annually reported the amount of riparian use in the Baja subarea water balance. For this analysis the Watermaster Engineer relied on ET values computed from satellite-

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[1] The estimate by Lines and Bilhorn (1996) relied on mapping using false-color infrared and low-level oblique photographs, vegetation and areal-density classification, and application of water-use rates from other studies.
[2] USBR and USU (2011) relied on mapping using airborne lidar, multispectral and thermal infrared data, vegetation and surface classification using multispectral imagery, and application of an ET model involving energy fluxes for soil and canopy components.

based imagery tools, which are publicly available from the online platform OpenET which provides ET data from multiple satellite-driven models. We estimated an average ET for the Baja riparian area of 984 AFY (see **Table 3**). The satellite-based model METRIC (Mapping EvapoTranspiration at high Resolution with Internalized Calibration) was selected for this calculation; the METRIC method computes ET as the residual of an energy balance applied at the earth's surface. We note that the method described to compute ET of riparian plant communities by remote sensing is less reliable than the same method applied to agricultural ET estimates.[3] Further, we understand and expect the California Department of Fish and Wildlife may have a better understanding of the riparian water use in Baja; we welcome their input and collaboration to establish a reliable value to include for the habitat elements of Exhibit H.

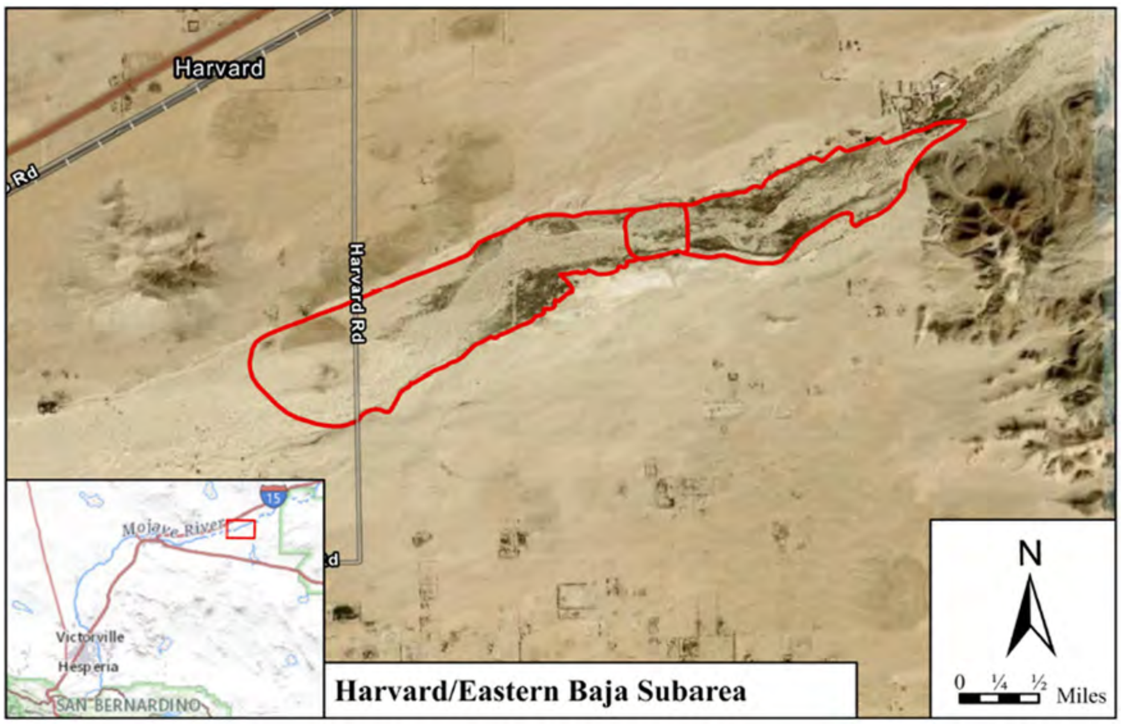

Figure 2. Harvard/Eastern Baja Riparian Zone.

[3] OpenET data is not a reliable method for ET estimates over open water bodies.

Table 3. Total ET for Baja riparian zone.

Water Year	Total ET (AFY)
2019	822.6
2020	694.8
2021	1,144.7
2022	1,275.6
4-year average	984.4

Minimal Producers

Minimal Producers, those pumpers not subject to the Judgment, have been estimated to pump 2,228 acre feet in the Baja subarea. This value has not been updated in several years, and likely overstates the actual water use by minimal producers. For example, the total population of Baja is about 4,000 residents, and assuming 57.5 gpdc, the total indoor water use would be only 258 acre feet, suggesting almost 2,000 acre feet of outdoor water use by minimal producers. We question this value. Total pumping in Baja has declined from more than 30,000 acre feet in 2015 to less than 13,000 acre feet in 2022, including the estimate for minimal producers. MWA will be undertaking the task to update minimal producer use in Baja in the next two years. We have included the current estimate, although we believe this overstates actual minimal producer use by about 50%.

Total Pumping and Water Level Response

Water production in Baja has been declining since before entry of Judgment (1996), from about 50,000 acre feet in 1996 to about 12,500 acre feet in 2023 (-75%). Historical water pumping in Baja is shown in **Figure 3**. Since 2016, pumping has further declined about 60%. The significance of this decline is apparent in the water level hydrographs that show changes in water levels throughout Baja over time (**Figure 4**). For many decades, most of the wells show a long term decline, meaning a depletion of groundwater in storage. However, consistent with the rapid reduction in pumping in the past 9-10 years, and the magnitude of the reduction in pumping over the past 30 years, water levels in some wells seem to be "flattening", meaning either having reached a low point, or will soon. Some wells show a rebound in water level, and some still are declining. Wells indicating flattening or recovery are in areas where pumping has declined significantly in recent years. Water level hydrographs are attached for inspection.

Production Safe Yield for Baja Subarea

The definition of production safe yield as used in the Judgment compares long term average supply to near term consumptive use. The base period for long term supply from the Judgment is 1931-1990, and the near term consumptive use has been considered to be 2017-2018 water year conditions. For this analysis we considered two base periods 1931-1990 and 2001-2020 with certain adjustments based on published values. The PSY calculation as shown on Tables 1 and 2 add the elements of supply and subtracts the elements of outflow to determine a surplus or a deficit. The surplus/deficit is added to the Total Production to determine the PSY. In effect, the PSY can be described as Pumping (P) plus Change in Storage equals PSY; P=PSY if change in storage is zero for some finite period.

As noted above, we calculate a small surplus under long term (1,795 acre feet) conditions and a similar deficit (1,883 acre feet) under shorter term conditions. The water level hydrographs for Baja suggest that the actual value is somewhere between the two. Assuming the water levels will continue to behave as shown for the past several years, and assuming that pumping does not increase, the PSY for Baja is likely about equal to or slightly greater than the current pumping for 2022, or about 12,749-acre feet. Based on the foregoing, we recommend PSY be set at 12,749 acre feet.

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Lines, G.C., 1996, Ground-water Surface water relations along the Mojave River, southern California

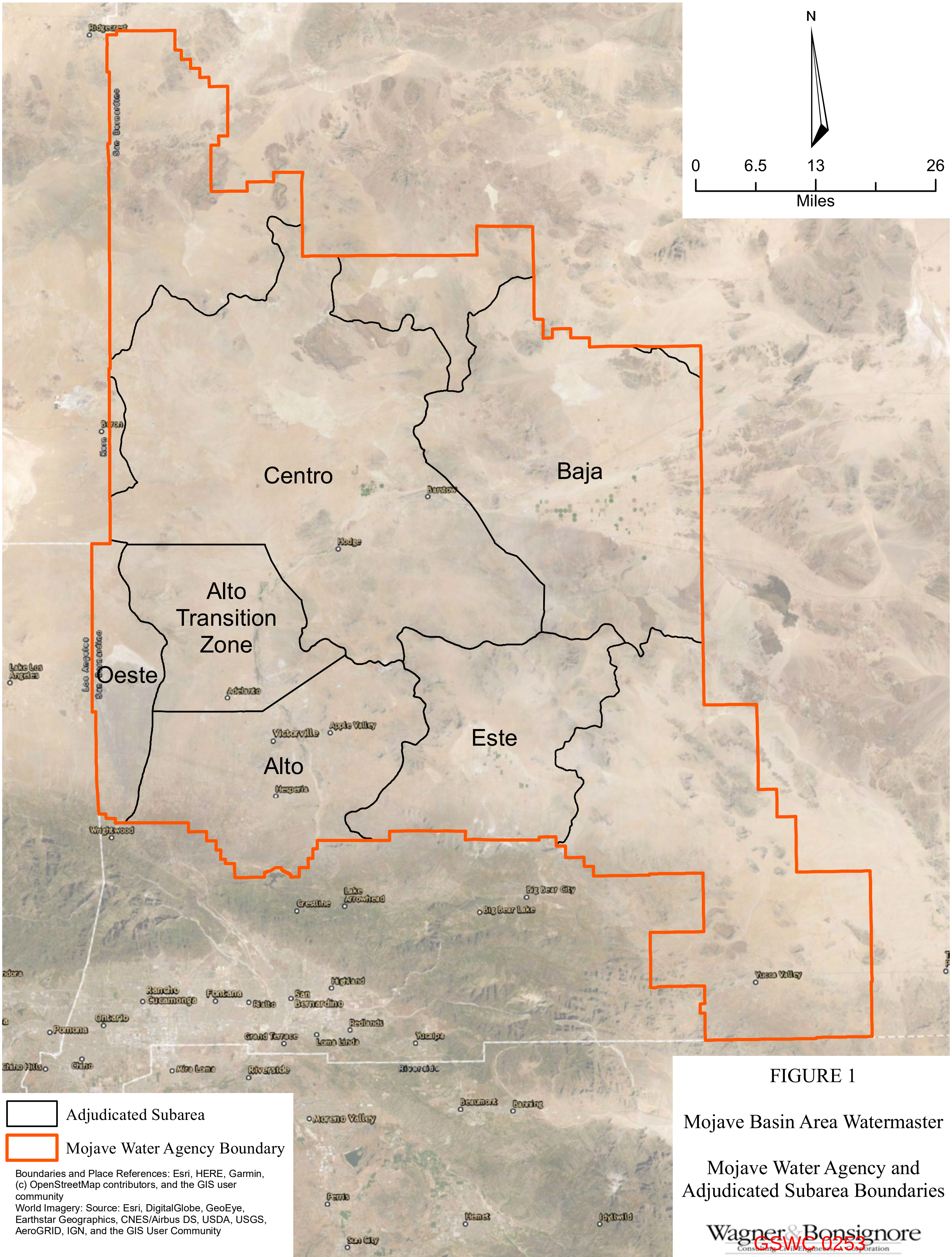


FIGURE 1

Mojave Basin Area Watermaster

Mojave Water Agency and Adjudicated Subarea Boundaries

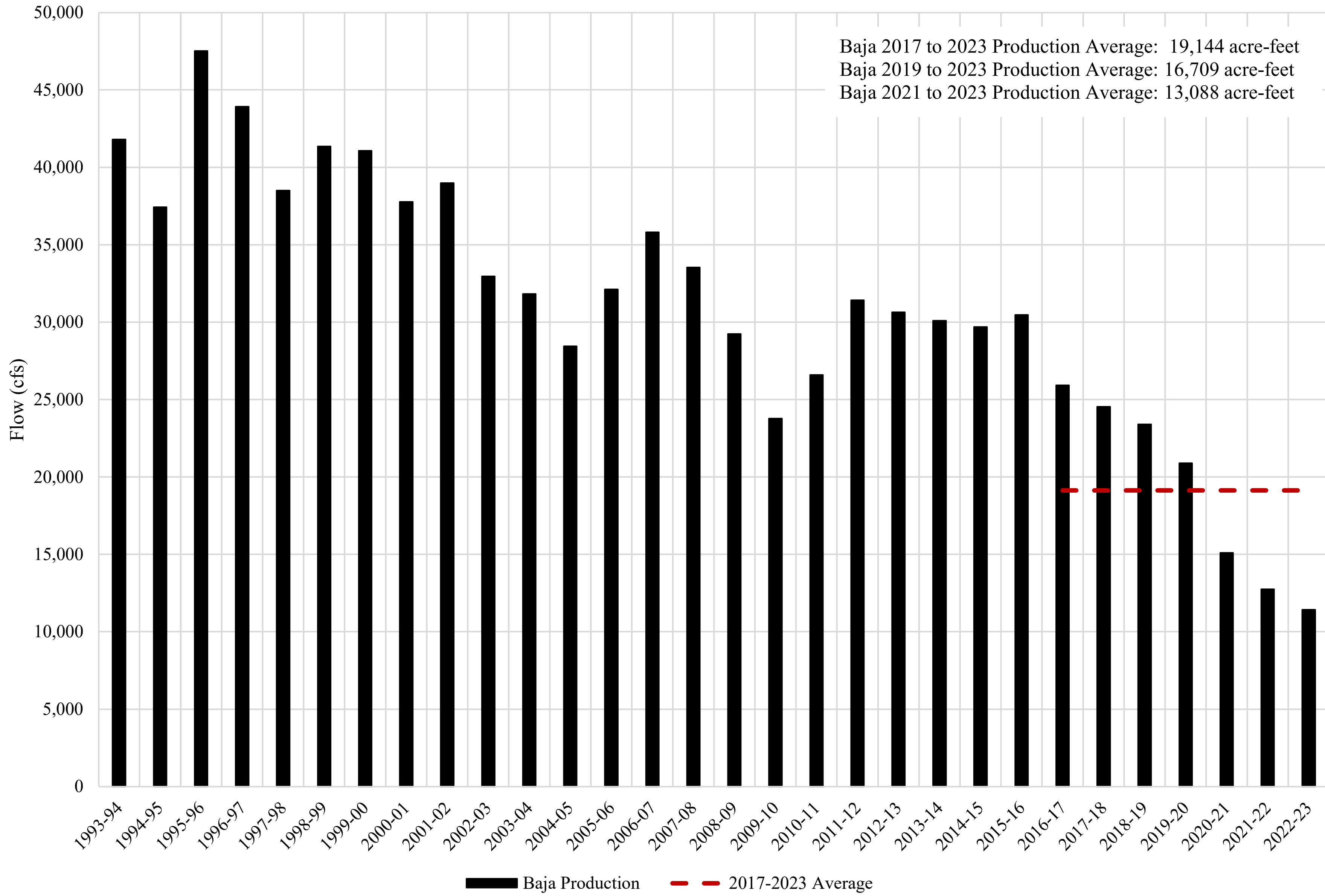
Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

GSWC 0253

Q:\Drawings\Mojave Water Agency\Este Subarea\Este Water Supply - FIGURE 1 - Location Map.mxd

June 2020

FIGURE 3
Baja Production
2016 to 2023



Mojave Water Agency

Data Sources:
MWA, US Census,
USGS/ NWIS,
DWR Bulletin 84 1967
Date: January 2024
Mojave Water Agency
Water Resources Department

- Graphed Wells
- MWA Monitoring Program Wells
- Exhibit H Riparian Habitat Area
- CA Geologic Faults (CGS, USGS)
- MWA Recharge Pipeline
- MWA Recharge Site

Baja Subarea Hydrographs 2024

- Recent record
- Long-term record (begins ~1950 to ~ 1980)
- Very long-term record (begins ~1920)

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FIGURE 4

GSWC 0255

TABLE 1

TABLE 5-1 (1931-1990)
BAJA SUBAREA HYDROLOGICAL INVENTORY BASED ON LONG TERM AVERAGE NATURAL WATER SUPPLY AND OUTFLOW AND 2021-22 IMPORTS AND CONSUMPTIVE USE

(ALL AMOUNTS IN ACRE-FEET)

		Baja
WATER SUPPLY		
Surface Water Inflow		17,358 [1]
Subsurface Inflow		1,581 [2]
Deep Percolation of Precipitation		100
Tributary Inflow		3,571 [3]
	TOTAL	**22,610**
CONSUMPTIVE USE AND OUTFLOW		
Surface Water Outflow		6,066 [4]
Subsurface Outflow		0
Consumptive use		
Agriculture		6,092 [5]
Urban		6,657
Phreatophytes		2,000
	TOTAL	**20,815**
Surplus / (Deficit)		1,795
Total Estimated Production		12,749
PRODUCTION SAFE YIELD		**14,544**

[1] Estimated from reported flows at USGS gaging station, Mojave River at Barstow. Includes 16,406 af of Mojave River surface flow across the Waterman Fault estimated by "Evaluations of Potential Mojave River Recharge Losses between Barstow and Waterman Fault", Wagner & Bonsignore, 2012 (see Appendix A, Table 6), and 747 af of local surface inflow from Kane Wash and Boom Creek, and 205 af from washes (Wagner, 2011).

[2] Stamos, 2001 (USGS).

[3] Stamos page 15, 2001 (USGS).

[4] Based on USGS station Mojave River at Afton, CA (10263000) reported discharge for 1953-1990. Water Years 1979 and 1980 estimated by Mojave Basin Area Watermaster. Water year 1932-1952 estimated by Hardt, William, USGS

[5] 2022 Consumptive Use Analysis, Watermaster.

DRAFT

TABLE 2

TABLE 5-1 (Based on 2001-2020)

BAJA SUBAREA HYDROLOGICAL INVENTORY BASED ON VARIOUS SUPPLY ASSUMPTIONS AND 2021-22 CONSUMPTIVE USE, RETURN FLOW AND IMPORTS

(ALL AMOUNTS IN ACRE-FEET)

Water Supply	**Baja**
Gaged Inflow[(1)]	7,500
Tributary Inflow[(2)]	1,568
Subsurface Inflow[(3)]	1,751
Mountain Front Recharge[(4)]	647
Barstow Treatment Plan [(5)]	2,455
Return Flow[(6)]	554
Deep Percolation of Precipitation[(7)]	100
Total	**14,575**
Production and Outflow	
Gaged Outflow [(8)]	2,554
Subsurface Outflow[(3)]	170
Phreatophytes[(9)]	984
Production[(10)(11)]	12,749
Total	**16,457**
Surplus / (Deficit)	(1,883)
Total Estimated Production	12,749
Production Safe Yield	**10,866**

1 Estimated from reported flows at USGS gaging station, Mojave River at Barstow. (2001 - 2020).
2 2001 USGS Stamos, Page 15-16.
3 2001 USGS Stamos, Figure 34.
4 2001 USGS Stamos, Table 11 Page 96.
5 Percolation Pond + Return Flow from Irrigation. Barstow data per Barstow Water Treatment Plan Matthew Franklin Lead Operator.
6 2022 Consumptive Use Analysis.
7 City of Barstow et al, v. City of Adelanto et al, Judgment. (1996)
8 Estimated from reported flows at USGS gaging station, Mojave River at Afton. (2001-2020) minus stream flows at Afton when Barstow was zero.
9 Area of Camp Cady * Evapotranspiration (Open ET eeMetric yearly average 2019-22).
10 2022 Watermaster.
11 Includes consumptive use of "Minimals Pool" (estimated Minimal's production is 2,228 acre-feet)

Mojave Basin Area Watermaster

Appendix F

Consumptive Use Update

Prepared by:

Wagner & Bonsignore, Engineers

Robert C. Wagner, PE

Watermaster Engineer

David Wong, EIT

February 28, 2024

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

Nicholas F. Bonsignore, P.E.
Robert C. Wagner, P.E.
Paula J. Whealen

Martin Berber, P.E.
Patrick W. Ervin, P.E.
David P. Lounsbury, P.E.
Vincent Maples, P.E.
Leah Orloff, Ph.D, P.E.
David H. Peterson, C.E.G., C.H.G.
Ryan E. Stolfus

MEMORANDUM

To: Mojave Basin Area Watermaster

From: Robert C. Wagner, P.E. & David Wong

Date: February 28, 2024

Re: **Consumptive Use Analysis**

Introduction

The purpose of this update to the consumptive water use values for the Mojave Basin Area Watermaster for the 2021-22 water year is to refine estimates of consumptive use and return flow and ultimately re-calculate Production Safe Yield (PSY). The area of study is the five subareas of the Mojave Basin Area as identified in the Judgment After Trial - January 10, 1996. Consumptive water use for all the water production in the Mojave Basin Area was estimated based on the water use type and location.

Some portion of the water applied to beneficial uses is lost to the water supply system. Consumptive Water Use is the evapotranspiration and the evaporation of water applied to beneficial uses. This is the water permanently removed from the system. The difference between water produced (pumped from the ground) and water consumed is return flow; return flow is considered part of the supply to the extent that it returns to the groundwater basin.

The consumptive use crop unit values for irrigated acres are estimated using the Consumptive Use Program Plus (CUP+) from the California Department of Water Resources (DWR). The climate data used for CUP+ is from the California Irrigation Management Information System (CIMIS) for the Victorville and Newberry Springs stations and the crop coefficients for various crop types are from the Food and Agriculture Organization of the United Nations 56 (FAO 56). CUP+ in conjunction with CIMIS data utilized the Penman-Monteith equation to calculate a reference evapotranspiration value along with an applied water use value for each crop type.

Reference evapotranspiration calculated by CIMIS differs from the output of DWR's CUP+. CIMIS uses a modified Penman equation (referred to as the "CIMIS Penman equation"), while CUP+ uses a modified Penman-Monteith equation to calculate reference evapotranspiration. In addition, in order to complete the monthly climatological record, missing daily climate values were manually computed as the average of the previous day and the following day. On occasions when

2151 River Plaza Drive • Suite 100 • Sacramento, CA 95833-4133
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there was missing climatological data for many consecutive days, climate data was filled with data from the nearest CIMIS station.

For agriculture, a land use study using CUP+ applied water values and aerial photography were used to determine how much water should have been used if a crop is 100% efficient and is being irrigated to obtain optimal yield and coverage. For much of the Mojave Basin Area, crops are under-irrigated, and this can be seen by the quality of the crop where there may be poor coverage (dead spots) or a crop may be fallowed during certain times of the year. This is especially true for the Baja subarea where many crops may be grown for only one quarter of the year or where orchards may appear under-irrigated to the point where many trees may have died. For this report, the assumptions made for orchards are that the trees are mature, that the coverage of trees is optimal, and that the size and quality of the fruit (or nut) is high. If any of these conditions are not met, the orchard is most likely being under-irrigated, and therefore, does not contribute to any return flow.

Consumptive Use of Municipal Production

Consumptive use of municipal production is determined by separating indoor use from outdoor use. For the purposes of this study, indoor domestic use is assumed to be 100% return flow and outdoor use is considered to be 100% consumed. High rates of evaporation in the desert, conservation, restrictions on outdoor uses, changes in landscaping to desert landscapes, ordinances preventing over irrigation, and improved leak detection all support the assumption of 100% outdoor consumptive use. Indoor consumptive use is difficult to measure, and whether water is discharged to sewer or septic, it is assumed to be returned to the system. Municipal leaks in distribution systems are assumed to not contribute to return flow. Leaks are assumed to be repaired timely and thus do not contribute to return flow.

To determine indoor use, the Victor Valley Wastewater Reclamation Authority's (VVWRA) 2009 Flow Projection Analysis was used to estimate gallons per capita per day (gpcd). For a single-family residence (SFR), the sewer generation rate is 57.5 gpcd and for a multi-family residence (MFR), the sewer generation rate is 46.7 gpcd. Total indoor use is determined by population from census data. Resident population estimates for individual municipalities was determined by using census data and Beacon Economics Growth Forecast (2015). SFR and MFR population numbers were determined by extrapolating total single-family homes versus total multi-family homes. The VVWRA Flow Projection Analysis estimated an average of 3.50 persons per edu, and assumed that the average occupancy of a SFR is the same as the average occupancy of a MFR. Sewered and septic parcels are determined using GIS data for sewer laterals & manholes and 2020 census block data. Population numbers for the sewered parcels were obtained by extrapolating population data from census blocks bounded by water purveyor boundary and containing both a census block(s) and sewer later/manhole see Figure 1.

The municipal production is broken down into different categories including SFR, MFR, commercial, industrial, irrigation, other, and system losses. Since the municipal producers do not report this information to the Watermaster, the values were extrapolated using the 2015 and 2020 Urban Water Management Plans for each municipality, where these values were reported to the State.

The average consumptive use for municipal producers varies by subarea. In the Upper Alto region, the average 2022 municipal consumptive use was 48%. In the Transition Zone, the average 2022 municipal consumptive use was 65%. In the Centro subarea, the average 2022 municipal consumptive use was 22%. In the Baja subarea, the average 2018 municipal consumptive use was 66%. In the Este subarea, the average 2022 municipal consumptive use was 61%. In Oeste, the average municipal consumptive use was 68%.

Commercial water use values for Alto Subarea were calculated by multiplying the total commercial area by a standard Industrial/Commercial unit flow factor of 0.25 gallons per square foot per day (gal/sf/day). The commercial square footage for Apple Valley, Hesperia and Victorville were obtained from the VVWRA Flow Projection Analysis with values updated to present time based on average population growth from Beacon Economics (2015). In all other subareas, commercial water use is assumed to be 100% consumptively used.

Consumptive use for domestic production uses the average indoor production estimates for each subarea. It is assumed that the production for single family residences with a well is comparable to single family residences on municipal water. This is done for each subarea including the Transition Zone separate from the Upper Alto region.

Dairy production is assumed to be 100% consumptively used. The water used for dairy operations is either consumed by the cows or evaporated after a wash down of the dairy facilities.

Consumptive use for golf courses is estimated in the same manner as other irrigated lands. Irrigated areas classified as grass, sod, and park were assumed to have the same consumptive use factor as golf courses.

Industrial production is assumed to be 100% consumptively use.

Consumptive use for recreational lakes is calculated at 100% of verified production. For recreational lakes, the quantification of consumptive use corresponds to the losses due to evaporation. Aquaculture consumptive use is considered the same as a recreational lake.

See Table 1 for a Summary of Production, Consumptive Use, and Return Flow by Subarea and Table 2 for Production and Consumptive Use from 2018 to 2023.

In the Judgment, a Minimal Producer is defined as a producer who used less than 10 acre-feet during the 1986-90 base period. Minimal producer total production is assumed to be the same as reported by Albert A. Webb Associates in February 2000. The consumptive use for minimal producers is treated the same as domestic use and is calculated based on the average indoor use for single family residences. The only exception is for Baja subarea where minimal producer population was used to estimate consumptive use. Baja minimal producer consumptive use was calculated differently because several of the minimal producers have private lakes and small orchards and therefore, use water differently than minimal producers in the other subareas.

FIGURE 1

Mojave Water Agency
Map Showing
Alto Subarea
Sewered and Septic Areas

San Bernardino County, California

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

September 2023

Aerial Imagery Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community, April 27, 2020.
Roads and City's per San Bernardino county open data, accessed September 6 2023, https://main.sbcounty.gov/open-government/, freeway data published June 24, 2016, and updated August 25, 2016. City's published May 5, 2021, and updated March 15, 2023.
U.S. Census Bureau 2020. Decentenial Census 2020. Decentenial Census, and UC Riverside School of Business.

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GSWC 0263

Numbered Water Purveyors

1 Apple Valley Foothill County Water District
2 Apple Valley Heights County Water District
3 Apple Valley View Mutual Water Company
4 Bar H Mutual Water Company
5 Bighorn-Desert View Water Agency
6 Center Water Company
7 Chamisal Mutual Water Company
8 City of Adelanto Water District
9 County Service Area 42
10 County Service Area 64
11 County Service Area 70 J
12 County Service Area 70 W4
13 Daggett Community Services District
14 Desert Dawn Mutual Water Company
15 Desert Springs Mutual Water Company
16 Golden State Water Company Apple Valley North System
17 Golden State Water Company Apple Valley South System
18 Golden State Water Company Barstow System
19 Golden State Water Company Desert View System
20 Golden State Water Company Lucerne Valley System
21 Gordon Acres Water Company
22 Helendale Community Services District
23 Hesperia Water District
24 Hi-Desert Water District
25 Hi Desert Mutual Water Company
26 Indian Wells Valley Water District
27 Joshua Basin Water District
28 Jubilee Mutual Water Company
29 Juniper-Riviera County Water District
30 Liberty Utilities Apple Valley
31 Liberty Utilities Yermo
32 Lucerne Valley Mutual Water Company
33 Lucerne Vista Mutual Water Company
34 Mariana Ranchos County Water District
35 Navajo Mutual Water Company
36 Phelan Pinon Hills Community Services District
37 Rancheritos Mutual Water Company
38 Rand Communities Water District
39 Sheep Creek Water Company
40 Thunderbird County Water District
41 Victorville Water District
42 West End Mutual Water Company

Purveyor Population Breakdown According to Sewer Service

Purveyor	*Population*	*Sewered Population*	*Septic Population*	*Percent of Sewered Population*
County Service Area 70J	10,666	0	10,666	0%
County Service Area 64	10,372	10,372	0	100%
Golden State Water South	6,027	717	5,310	12%
Hesperia	102,757	41,102	61,655	40%
Liberty Utilities	63,327	31,482	31,845	50%
Victorville	149,820	124,268	25,552	83%
Adelanto	-	-	-	-

FIGURE 1

Mojave Water Agency
Map Showing
Alto Subarea
Sewered and Septic Areas

San Bernardino County, California

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

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September 2023

TABLE 1

Summary of Production, Consumptive Use, and Return Flow by Subarea

2022

	Alto	TZ	Alto Total	Baja	Centro	Este	Oeste
Agricultural Production (af)	30	1,210	1,240	6,092	5,863	2,514	2
Agricultural Consumptive Use (af)	30	919	949	6,092	5,863	2,514	2
Agricultural Return Flow (af)	0	291	291	0	0	0	0
Agricultural Return Flow (% of Agricultural Production)	0%	24%	23%	0%	0%	0%	0%
Municipal Production (af)	54,291	4,325	58,616	306	5,756	536	2,790
Municipal Consumptive Use (af)	25,303	1,611	26,914	203	2,789	326	1,897
Municipal Return Flow (af)	29,134	2,721	31,855	103	2,970	210	893
Municipal Return Flow (% of Municipal Production)	54%	63%	54%	34%	52%	39%	32%
Domestic Production (af)	1,544	710	2,254	3,224	1,619	1,110	242
Domestic Consumptive Use (af)	696	702	1,398	2,820	388	734	74
Domestic Return Flow (af)	848	8	856	404	1,231	376	168
Domestic Return Flow (% of Domestic Production)	55%	1%	38%	13%	76%	34%	69%
Golf Course Production (af)	3,279	1,014	4,293	0	2	0	0
Golf Course Consumptive Use (af)	2,529	875	3,404	0	0	0	0
Golf Course Return Flow (af)	750	139	889	0	2	0	0
Golf Course Return Flow (% of Golf Course Production)	23%	14%	21%	0	100%	0	0
Industrial Production (af)	3,091	1,380	4,471	1,180	3,444	810	7
Industrial Consumptive Use (af)	3,091	1,380	4,471	1,180	3,444	810	7
Industrial Return Flow (af)	0	0	0	0	0	0	0
Industrial Return Flow (% of Industrial Production)	0%	0%	0%	0%	0%	0%	0%
Parks Production (af)	150	35	185	54	0	62	0
Parks Consumptive Use (af)	150	35	185	8	0	0	0
Parks Return Flow (af)	0	0	0	46	0	62	0
Parks Return Flow (% of Parks Production)	0%	0%	0%	84%	0%	100%	0
Recreational Lakes Production (af)	4,827	2,240	7,067	1,701	35	36	0
Recreational Lakes Consumptive Use (af)	1,926	1,853	3,779	1,701	0	5	0
Recreational Lakes Return Flow (af)	2,901	387	3,288	0	35	31	0
Recreational Lakes Return Flow (% of Recreational Lakes Production)	60%	17%	47%	0%	100%	87%	0
Aquaculture Production (af)	20	0	20	6	0	0	0
Aquaculture Consumptive Use (af)	20	0	20	4	0	0	0
Aquaculture Return Flow (af)	0	0	0	2	0	0	0
Aquaculture Return Flow (% of Aquaculture Production)	0%	0	0%	27%	0	0	0
Dairy Production (af)	0	0	0	16	264	0	66
Dairy Consumptive Use (af)	0	0	0	16	264	0	66
Dairy Return Flow (af)	0	0	0	0	0	0	0
Dairy Return Flow (% of Dairy Production)	0	0	0	0%	0%	0	0%
Total Production (incl. Minimals) (af)	67,232	10,914	78,146	12,579	16,983	5,068	3,107
Total Consumptive Use (af)	33,745	7,375	41,120	12,025	12,748	4,388	2,046
Total Return Flow (af)	33,633	3,546	37,179	554	4,238	680	1,061
Total Return Flow (% of Total Production)	50%	0	48%	4%	0	0	0

TABLE 2

Pumping & Consumptive Use by Subarea
2018 - 2023
Values are in Acre-Feet

Pumping

	2018	2019	2020	2021	2022	2023	Average
Alto Pumping	64,986	61,033	64,129	69,593	67,232	62,354	64,888
TZ Pumping	12,700	11,939	12,618	11,809	10,914	10,039	11,670
Alto Total Pumping	77,686	72,972	76,747	81,402	78,146	72,393	76,558
Baja Pumping	24,524	23,389	20,912	15,095	12,579	11,343	17,974
Centro Pumping	20,665	19,784	18,309	19,685	16,983	16,392	18,636
Este Pumping	5,055	4,983	5,181	5,258	5,068	4,501	5,008
Oeste Pumping	3,944	3,618	3,677	3,798	3,107	2,845	3,498
Total	131,874	124,746	124,826	125,238	115,883	107,474	121,673

Consumptive Use

	2018	2019	2020	2021	2022	2023	Average
Alto Consumptive Use	34,001	30,386	33,489	37,871	33,745	31,927	33,570
TZ Consumptive Use	7,913	7,294	8,052	7,301	7,375	6,859	7,466
Alto Total Consumptive Use	41,914	37,680	41,541	45,172	41,120	38,786	41,035
Baja Consumptive Use	24,002	22,611	20,144	13,589	12,025	10,834	17,201
Centro Consumptive Use	16,451	15,094	14,044	14,035	12,748	12,279	14,108
Este Consumptive Use	3,827	3,634	4,116	4,377	4,388	3,812	4,026
Oeste Consumptive Use	2,931	2,572	2,528	2,574	2,046	1,869	2,420
Total	89,125	81,591	82,372	79,746	72,328	67,579	78,790

Mojave Basin Area Watermaster

Appendix G

Upper Mojave River Basin Groundwater Model

Prepared by:

Mojave Water Agency Water Resources

Kapo Coulibaly PhD, P.G

February 28, 2024

1.0 Introduction

The Upper Mojave River Basin (UMRB) was originally developed in 2007 (SWS, 2007) for the Mojave Water Agency (MWA) as a predictive tool for the Regional Recharge and recovery (R3) project. The current UMRB model is an expanded and updated version of the 2007 version of the model, which was calibrated from water year 1997 to water year 2005. The original model was more groundwater-focused and had limited surface water features. The model presented in this technical memorandum (TM) extends the spatial boundaries of the original UMRB model to include the upper basin (the watersheds of Deep Creek and West Fork) and is a fully integrated groundwater/surface-water numerical model. The calibration period was also extended and covers water years from 1951 to water year 2020. This model is intended to be used as a management tool to support the groundwater banking program, conjunctive use, the optimization of existing water supply project, and potential future water resources projects. This technical memorandum summarizes the model design, calibration process results, and preliminary scenario runs

2.0 Model Overview

The updated UMRB model domain and active area is shown on Figure 1. The United State Geological Survey (USGS) finite difference code MODFLOW-NWT (Niswonger et al., 2011) was used to design the UMRB model. The model has 6 layers, 900 rows, and 1600 columns. The cell size is 200 feet by 200 feet. The layering is based on the hydraulic behaviour from existing production wells where available and hydrostratigraphic markers otherwise. Hydraulic parameters (hydraulic conductivity and storativity) are distributed by zones based on the USGS model (Stamos et al, 2001). Aquifer production estimate prior to 1995 are derived from the USGS model (Stamos et al, 2001). The surface water model component of the UMRB model is derived from the California Basin Characterization Model (BCM) which will be presented in more details further in this TM. The BCM and the calibration process will be presented below. More details about the model conceptual model and overall design can be found in Wood's report (Wood, 2021).

2.1 Discussion of the BCM

The BCM is a gridded mathematical computer model that calculates the hydrologic inputs and outputs at a monthly time step for the whole State of California. Specific climate data inputs, such as precipitation and air temperature, are combined with soils type and topography data to calculate the water balance for each cell. Model calculations include potential evapotranspiration, calculated from solar radiation with topographic shading and cloudiness; contributions from snow based on simulated accumulation and melting; and excess water moving through the soil profile, which is used to calculate actual evapotranspiration and climatic water deficit. Soil properties and the permeability of underlying alluvial or bedrock materials embedded in the model are used to estimate recharge and runoff (Flint et al, 2013). The BCM was calibrated to 159 unimpaired basins across California. The model grid is 270 m by 270 m (889 ft by 889 ft) and it covers the period from 1896 to 2020. An overview of the various components of the BCM are shown on Figure 2 and Figure 3

Output from the BCM model include: PET (potential ET), AET (Actual ET), runoff, recharge, snowmelt, snow sublimation..etc.

A spreadsheet tool provided by the BCM authors allows the recalibration of the BCM to local gages. The inputs for the spreadsheet tool are runoff and recharge from the BCM, observed gage data, and watershed areas. This tool was used to calibrate the BCM output to local gages prior to incorporating them into the UMRB model using the Surface Flow Routing package of MODFLOW-NWT.

2.2 Model Calibration

Calibration of a groundwater flow model is a process through which the model parameters are varied within reasonable and plausible ranges to produce the best fit between the model results and observation values in the real world. Observation values used for this calibration were the groundwater levels at 193 monitoring locations and the river discharges at three stream gages. The calibration process can be either automated or manual. In the automated approach, a parameter estimation tool is used to run the model multiple times to automatically select the best combination of parameter values for optimal matching between measured and observed targets. In the case of the manual calibration, the modeler changes the parameters manually and uses a combination of visual trend matching and a set of statistical parameter to decide whether calibration was achieved. Because of the large size and long runtime of this model, the automatic approach for calibration was impractical, hence the manual calibration approach was used.

As stated in the previous section, a combination of qualitative and quantitative calibration criteria were used to assess the goodness of fit. For the groundwater levels the calibration process was conducted in general accordance with the "Guidelines for Evaluating Ground-Water Flow Models" (Reilly and Harbaugh, 2004). This includes establishing calibration targets, identifying calibration parameters, using history matching, and using both qualitative and quantitative criteria to evaluate model performance. Criteria used included:

- Hydrographs of observed versus model-simulated groundwater levels
- Scatterplots of observed versus model-simulated groundwater levels
- Hydrographs of observed versus model-simulated streamflow
- Scatterplots of observed versus model-simulated streamflow
- Residual statistics, including:
    - Root Mean Square Error (RMSE): Root mean square error provides a measure of the spread of the residuals. Model calibration seeks to minimize RMSE and generally, a lower RMSE indicates a calibration closer to the observed data. Note: the RMSE is the same as the standard deviation of the residuals.
    - Mean Residual: Average of the residuals. Mean residual can help to identify bias in modelsimulated versus observed water level data. Calibration seeks to minimize mean residual. A value close to zero is ideal but the range of the data should also be considered.
    - Relative Error: Relative error is the standard deviation of the residuals or RMSE normalized by the range of observed groundwater levels. Calibration seeks to minimize relative error. A value lower than 10% (0.1) is generally recommended but not an absolute indicator of goodness of fit.
- R^2: Indicates the "goodness of fit" between measured and model-simulated values. For a perfect calibration, all points (observed along the x-axis and model-simulated along the y-axis) would fall on the diagonal line (regression line) with a R^2 value of 1. A greater deviation of points from the diagonal line corresponds with lower R^2 values and poorer model calibration performance. Streamflow was examined in accordance with the R^2 performance criteria suggested by Donigian (2002).

A more detailed discussion of the calibration process and the range of the parameters can be found in Wood (2021). A few of the updated calibration assessment criteria are shown on Figure 4 to Figure 6. Figure 4 shows the model simulated groundwater heads vs the observed values. The scatter observed is typical for regional groundwater models of this size. However a low value for the residual mean means that the model isn't under or over predicting the groundwater heads and the adjusted root mean square (RMS) is below the 0.1 (10%) recommended upper limit. Also the bulk of the values are within one standard deviation of the residuals (red dashed line) which also suggests a good calibration to the observed data. Figure 5 shows hydrographs of observed and simulated water levels at selected monitoring locations.

Figure 6 shows the annual surface water calibration results (Observed vs simulated) at three gages: Deep Creek, West Fork and the Lower Narrows. With R^2 varying from

3.0 Water Budget

3.1 Water Budget Spatial Discretization

The water budget was extracted from the UMRB model results using the USGS Zonebudget program (). The water budget was restricted to the actual UMRB area excluding the upper basin (Deep Creek and West Fork watersheds). This domain is shown on Figure 7. The water budget was further divided into subareas. The subareas combined with the active model domain for water budget estimation purposes is shown in Figure 8. It should be noted that only a portion of the Transition Zone is covered by the model, hence the area termed "Transition Zone" on Figure 8 is only the southern portion of the legal extent of the Transition Zone. Similarly, the area termed "Este" is actually Fifteen Miles Valley which is the Western portion of the legal extent of the Este Subarea.

3.2 Mountain Front Recharge

A detail discussion of the inflows and outflow in the UMRB area can be found in the model calibration report published by Wood (2021). In the previous model (Wood, 2021) values for the mountain front recharge were extracted from the USGS model (Stamos et al, 2001). For this update effort, the Mountain Front recharge for Alto, Oeste, and Este (Fifteen Mile Valley) were derived from the BCM, hence the need to discuss the mountain front recharge in this technical memorandum (TM). By definition, Mountain Front recharge (MFR) is all water that enters a basin-fill aquifer with its source in the mountain block. It is composed of two components. Surface MFR is infiltration through the basin fill of mountain-sourced perennial and ephemeral stream water after these streams exit the mountain block. Subsurface MFR is groundwater inflow to a lowland aquifer from an adjacent mountain block (Markovich et al, 2019). For the purpose of this study, It is assumed that recharge and ungagged inflow mainly from the San Bernardino mountains become mountain front recharge on the valley floor. Direct infiltration from precipitation on the valley floor is assumed negligible. The sub-watersheds used for the BCM gridded results tabulation for recharge and runoff are shown on Figure 9. Subwatershed that drain directly into the Mojave river were not included into the mountain front recharge estimate and are shown on Figure 10 in light green. These sub-watersheds shown in light green on Figure 10 are considered tributary to the Mojave River.

3.3 Water Budget and Change in Storage

The water budget for the subareas within the active model doimain are presented in Table 1, Table 2, and Table 3. The change in storage and the cumulative change of storage from water year 1951 to water year 2020 for the Alto subarea is shown on Figure 11. Overall Alto experienced an average change in storage of 15,000 Acre-feet per year (AFY) for the past seventy (70) years. And 17,500 AFY for the past 20 years. The cumulative change of storage shows a continuous decline in storage for the past 70 years.

4.0 Scenario Run

The calibrated and updated UMRB model was used to run a 20-year future scenario. The main objective of this scenario was to assess the impact of importing enough water to off-set the average yearly storage deficit of 17,500 AF. Due to the uncertainty of future hydrology and demand conditions, some assumptions need to be made in order to define future conditions. The assumptions used for these scenarios are listed below:

1. Water year 2020 is used as the current and initial year
2. The hydrology for the last 20 years was used and assumed representative for the next 20 years
3. The production and demand levels for the year 2020 was used for the 20 year-run and maintain constant throughout the 20 years of scenario run
4. The 17,500 AF imported was delivered at the Deep Creek (directly into the river) site and spread over a three month period from June to August
5. A baseline scenario with the same assumptions as above was run without the imported water for comparison purposes.

4.1 Scenario Results

The main focus will be to quantify the change in flow at the lower narrows gage when enough water is imported and delivered at the Deep Creek Site to offset the long term average loss in storage. Table 4 summarizes the difference between the baseline and Scenario 1. Due to the long term storage loss, it takes about four years of continuopus water delivery to see any impact at the lower narrows (Figure 13). On average an increase of 9,800 AFY is observed at the lower narrows over 20 years as a results of importing a total of 380,000 AF. This would increase water availability downstream of the Lower Narrows (i.e. Centro and potentially Baja)

5.0 Conclusion

The current updated and calibrated UMRB model will be used for safe yield estimate and management decision in the near future. Calibrated groundwater models are powerful and flexible tools for water resources management, projects impact assessment and various conceptual analyses. Though only one scenario was assessed in this report and limited output were analyzed, various options can be explored. They include delivery location and temporal distribution, amount delivered, future demand projections, various climate change scenarios…etc. Also the spatial impact of these projects on water levels can also be explored by looking at water level changes at specific times or water level changes over time at specific locations. As more data are being collected, it is anticipated that the model will be updated every five years or so with newly collected data to keep it current and improve future predictions.

6.0 References

Harbaugh, A.W., 1990, A computer program for calculating subregional water budgets using results from the U.S. Geological Survey modular three-dimensional ground-water flow model: U.S. Geological Survey Open-File Report 90-392, 46 p

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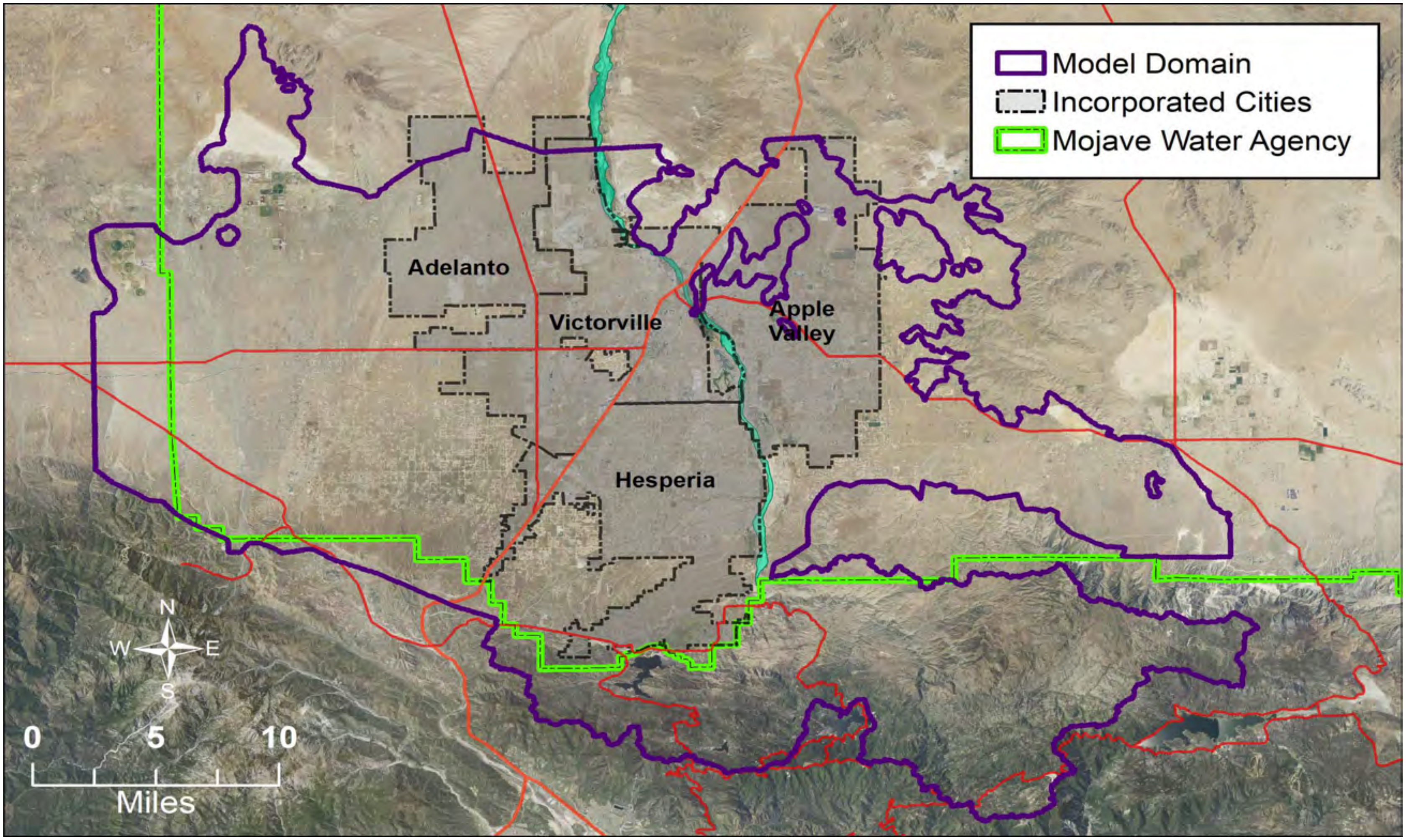
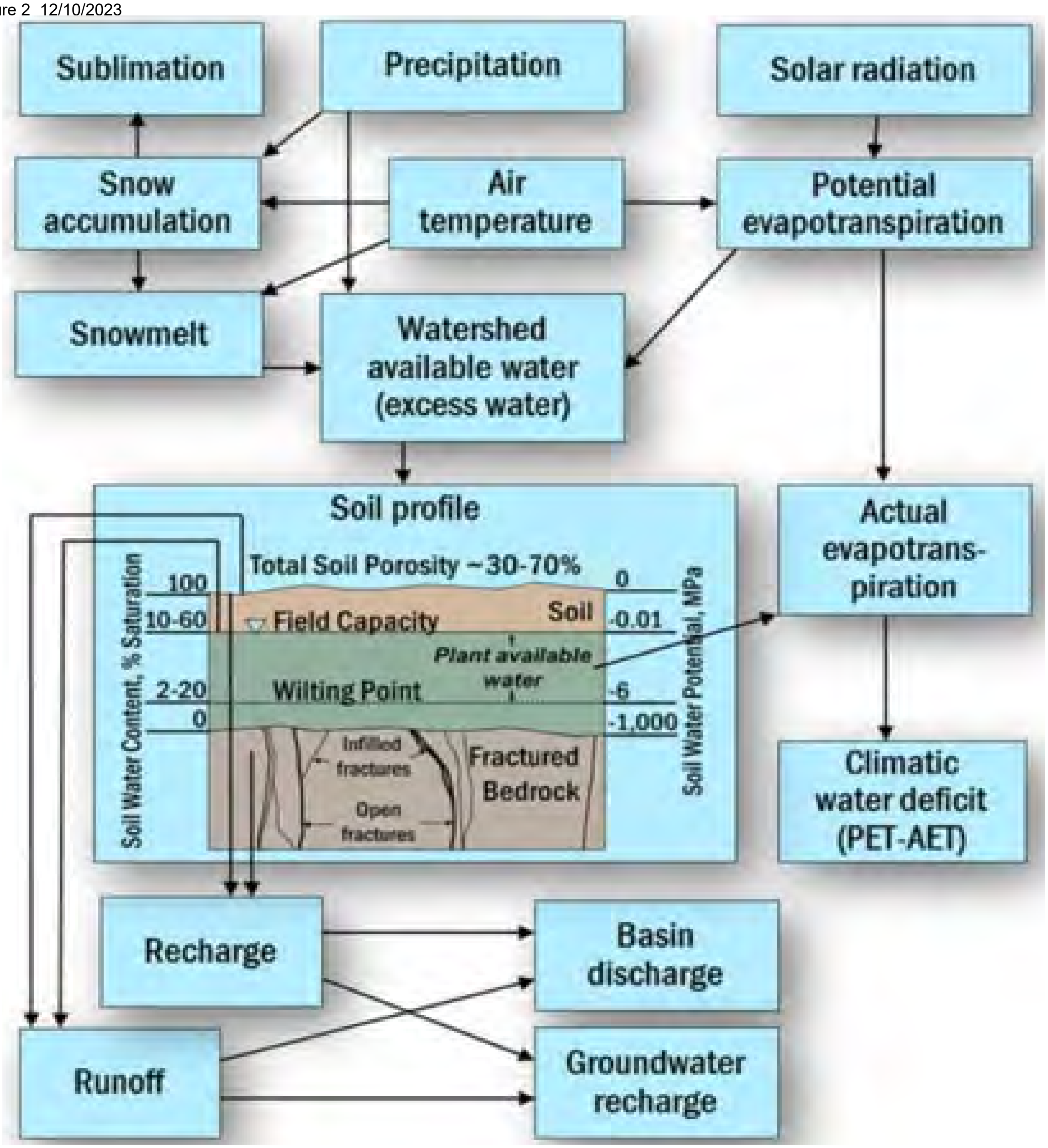
Wood, 2021. Project Completion report, Integrated Surface Water/Groundwater Model, Upper Mojave River Basin Prepared for Mojave Water Agency, dated October 2021.



Model Location

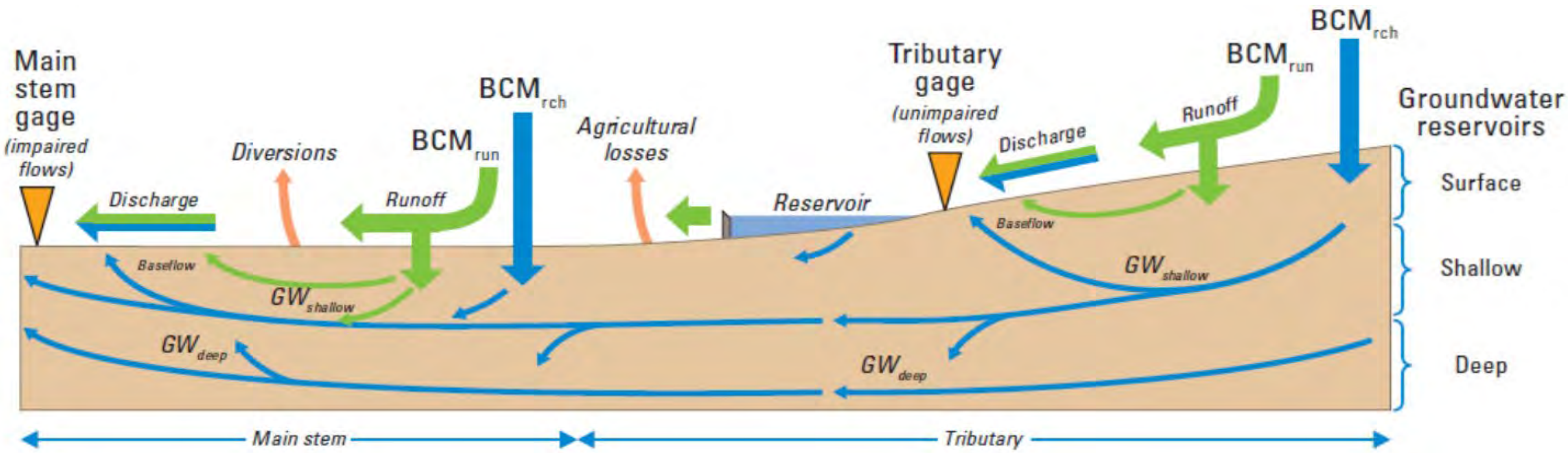
By: KMC	Date: 12/04/2023	Project No.: CM20167800
Mojave Water Agency		Figure 1



Basin Characterization Model Processes

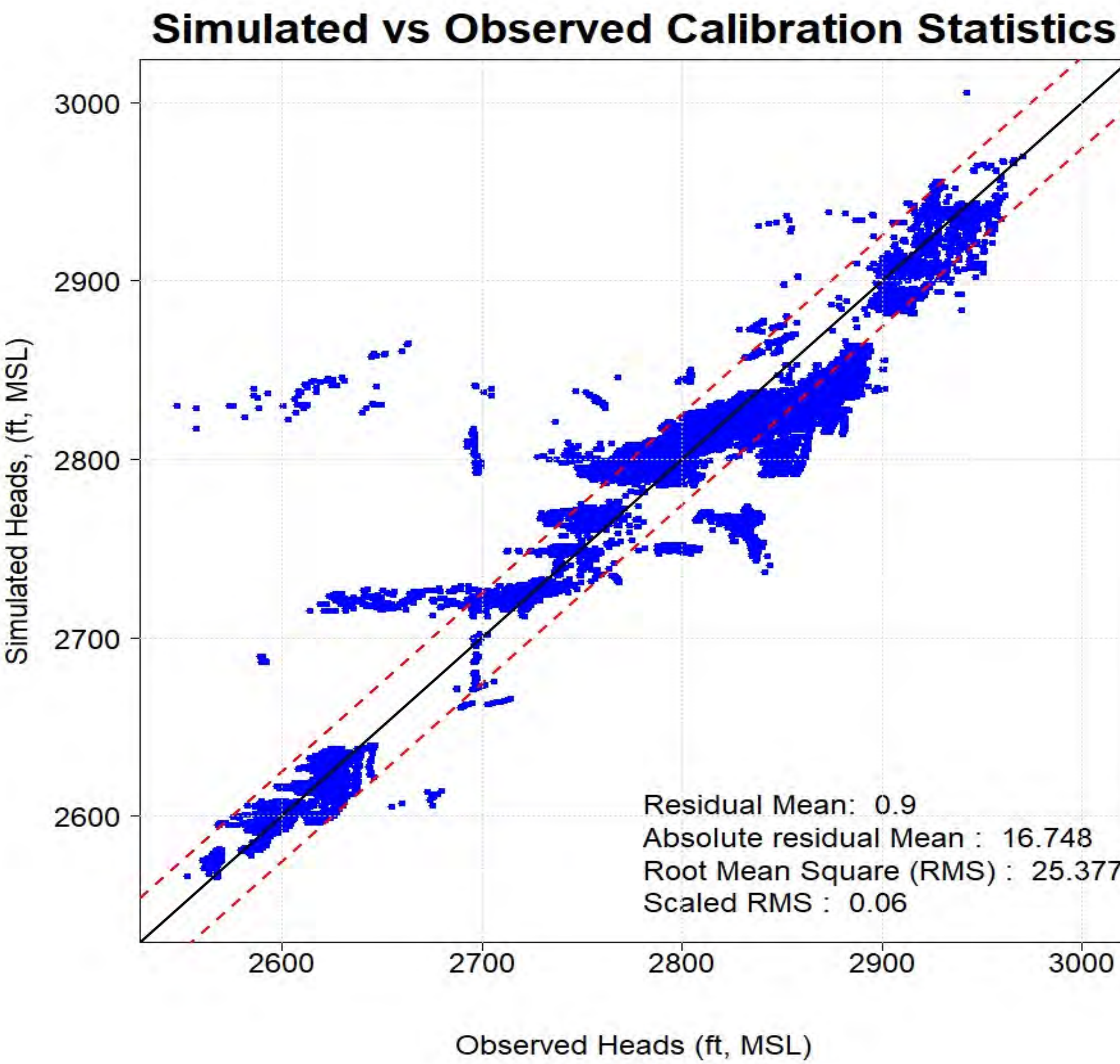
By: KMC	Date: 12/04/2023	Project .:
	Mojave Water Agency	Figure 2

GSWC 0274



BCM Surface Water/Groundwater Conceptual Model

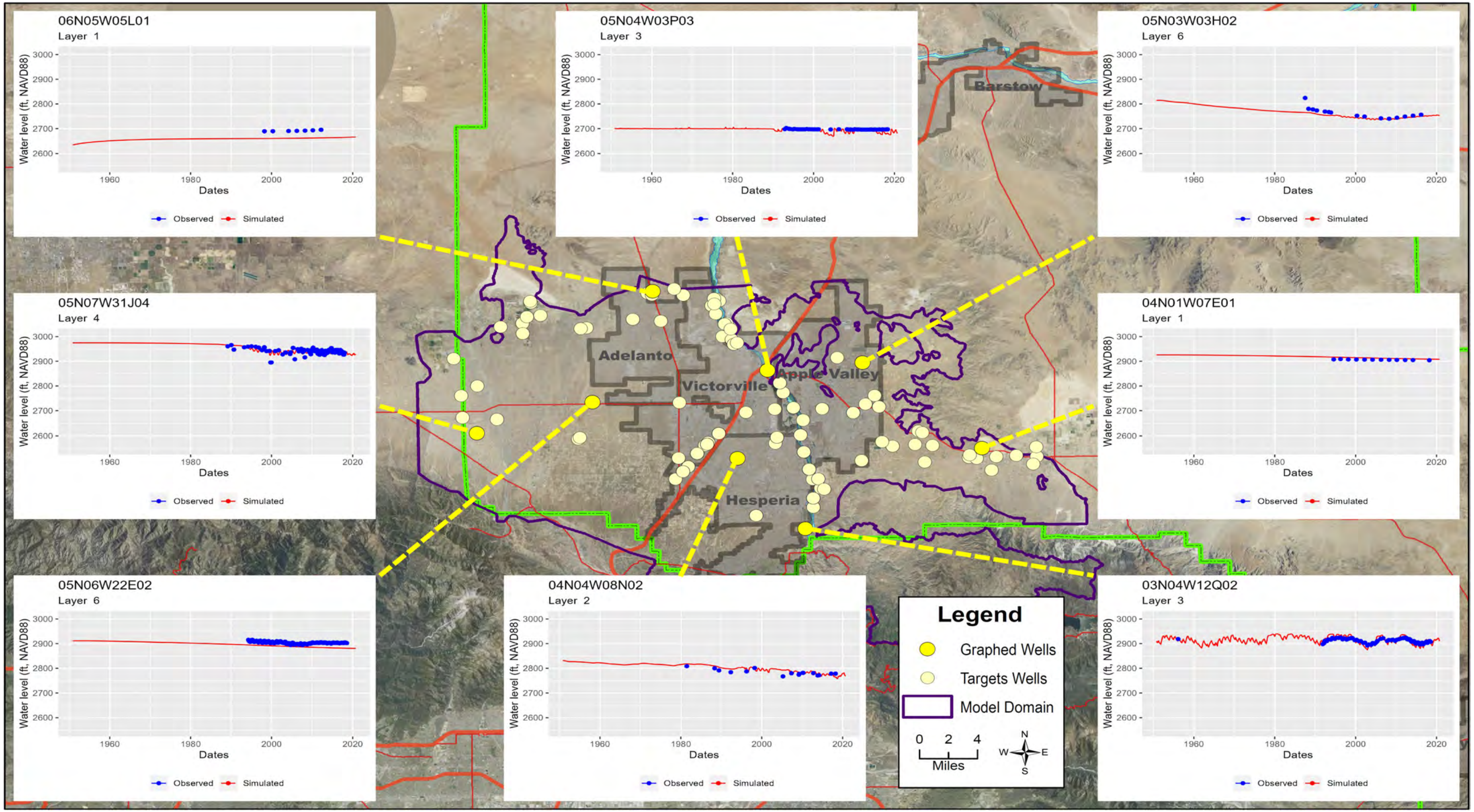
By: KMC	Date: 12/04/2023	Project No.: CM20167800
	Mojave Water Agency	Figure 3



Simulated vs Observed Goundwater Levels

By: KMC	Date: 12/04/2023	Project .:
	Mojave Water Agency	Figure 4

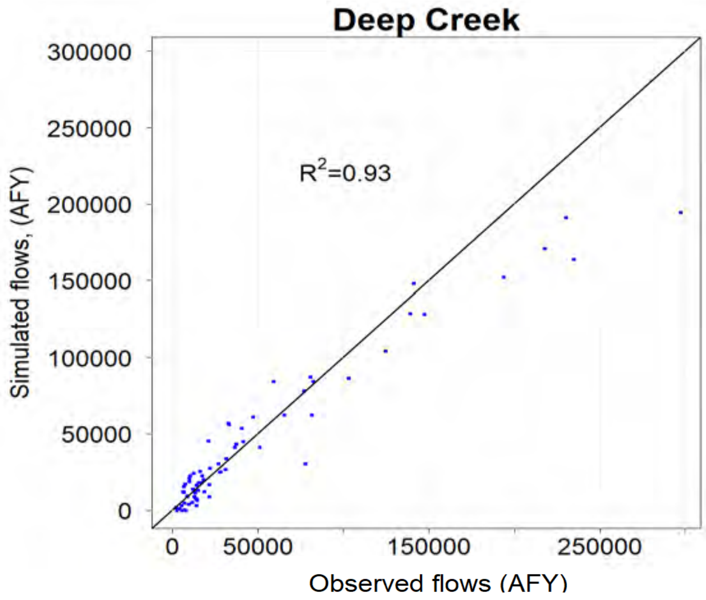
https://mojavewater-my.sharepoint.com/personal/kcoulibaly_mojavewater_org/Documents/Projects/WagnerRequests/PSY_Calc/Figures/ModelingTMFigures.xlsxFigure 5 12/10/2023

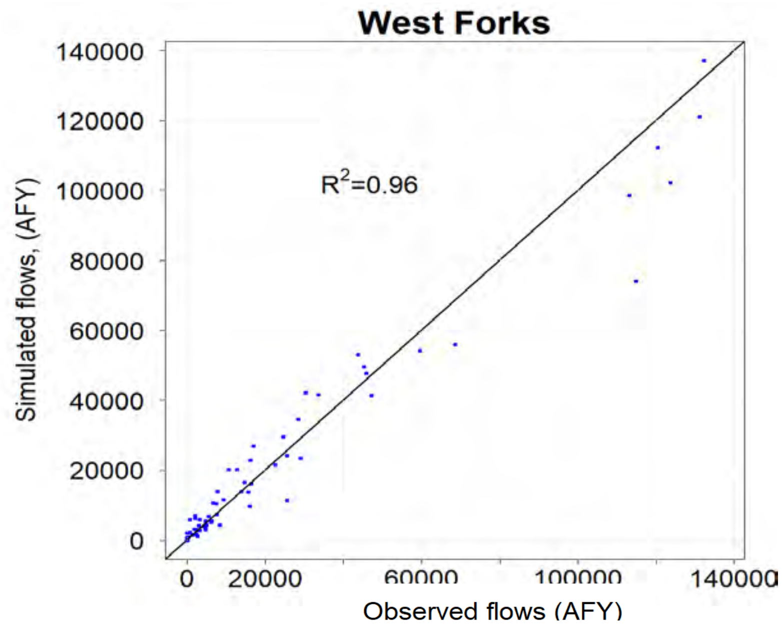


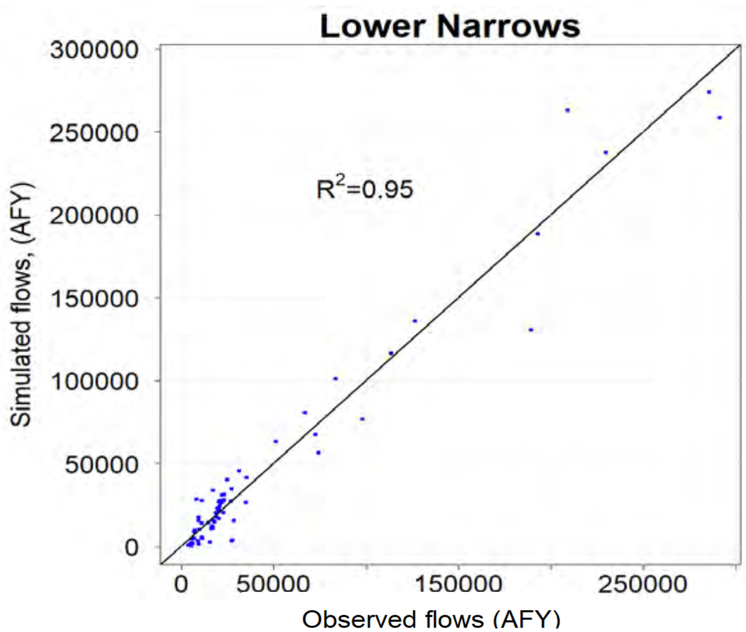
Selected Hydrograph

By: xxx	Date: 01/08/2015	Project No.: IR0000000000
Mojave Water Agency	Figure	5

GSWC 0277



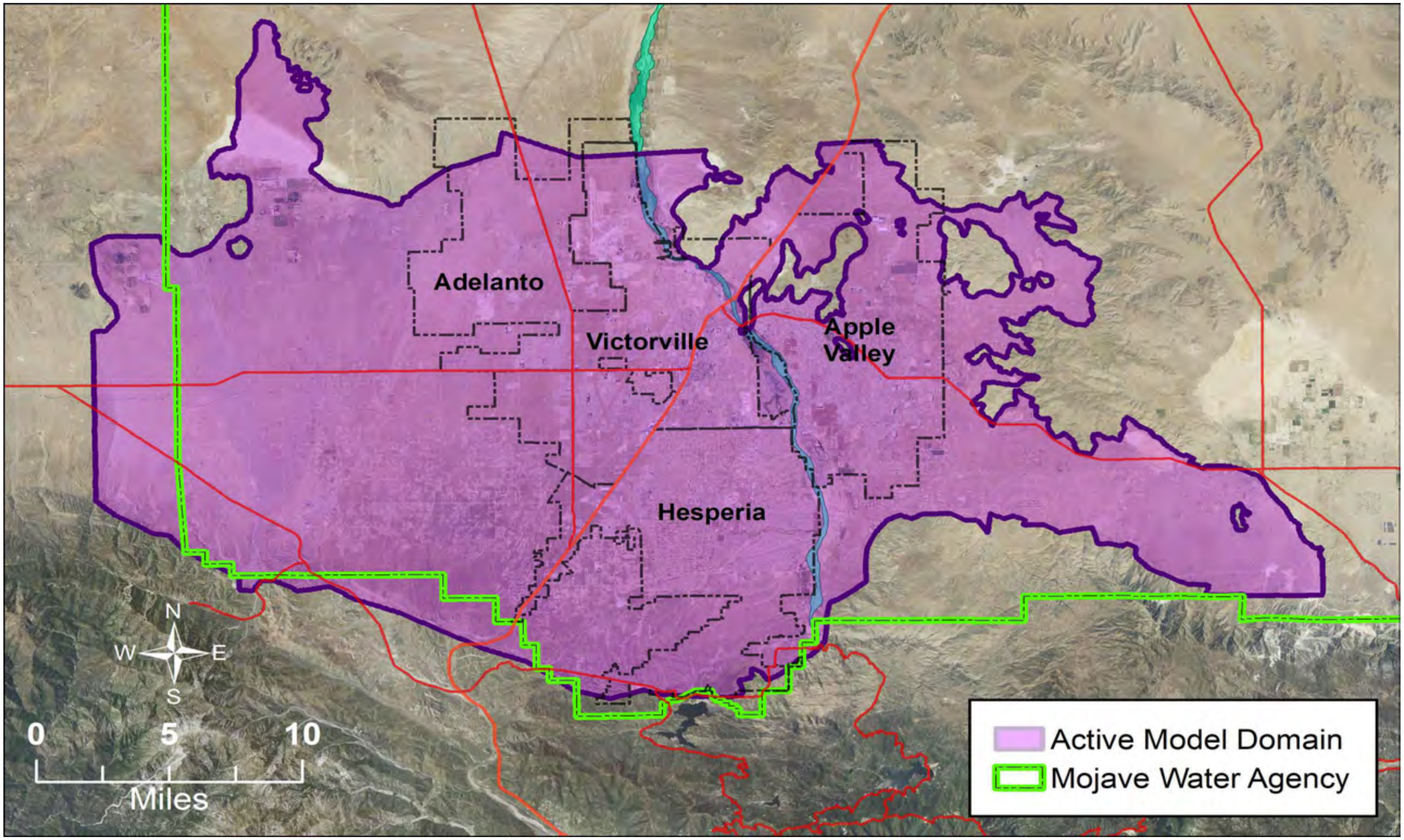




Obserbed vs Simulated Annual Flow

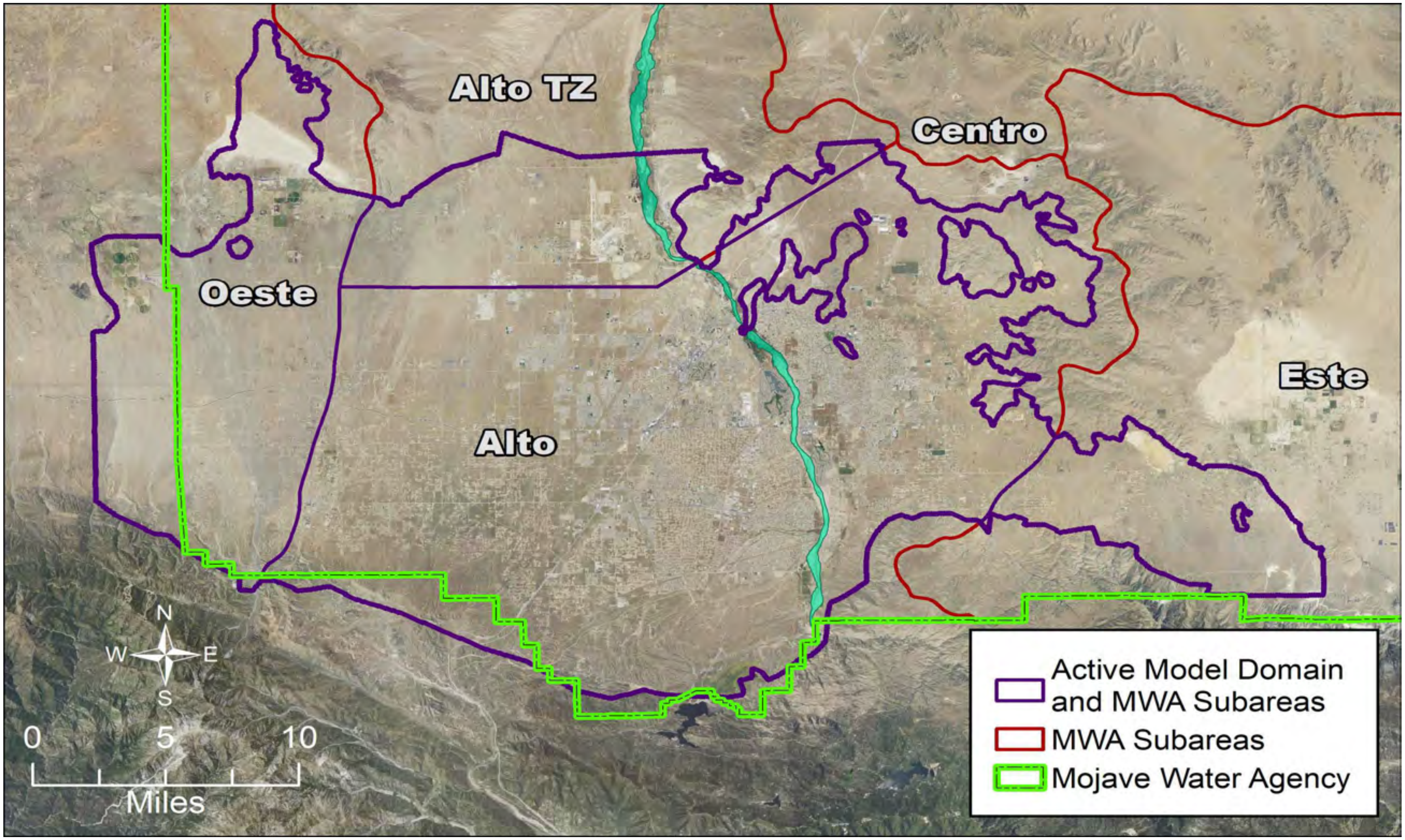
By: KMC	Date: 12/04/2023	Project No.: CM20167800
	Mojave Water Agency	Figure 6

https://mojavewater-my.sharepoint.com/personal/kcoulibaly_mojavewater_org/Documents/Projects/WagnerRequests/PSY_Calc/Figures/ModelingTMFigures.xlsxFigure 7 12/10/2023



Model Water Budget Area

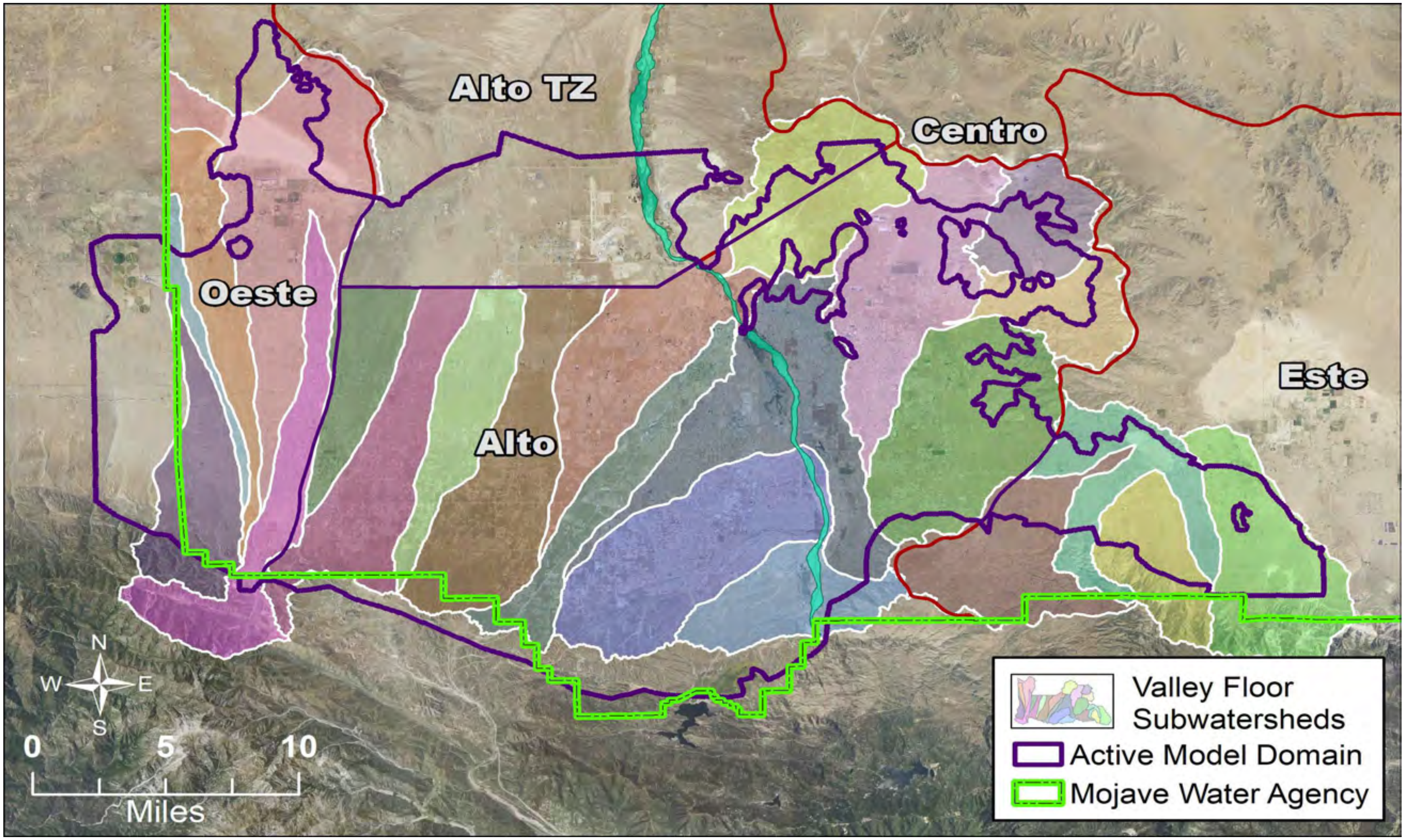
By: KMC	Date: 12/04/2023	Project No.: CM20167800
Mojave Water Agency		Figure 7



Water Budget Subareas

By: KMC	Date: 12/04/2023	Project No.: CM20167800
	Mojave Water Agency	Figure 8

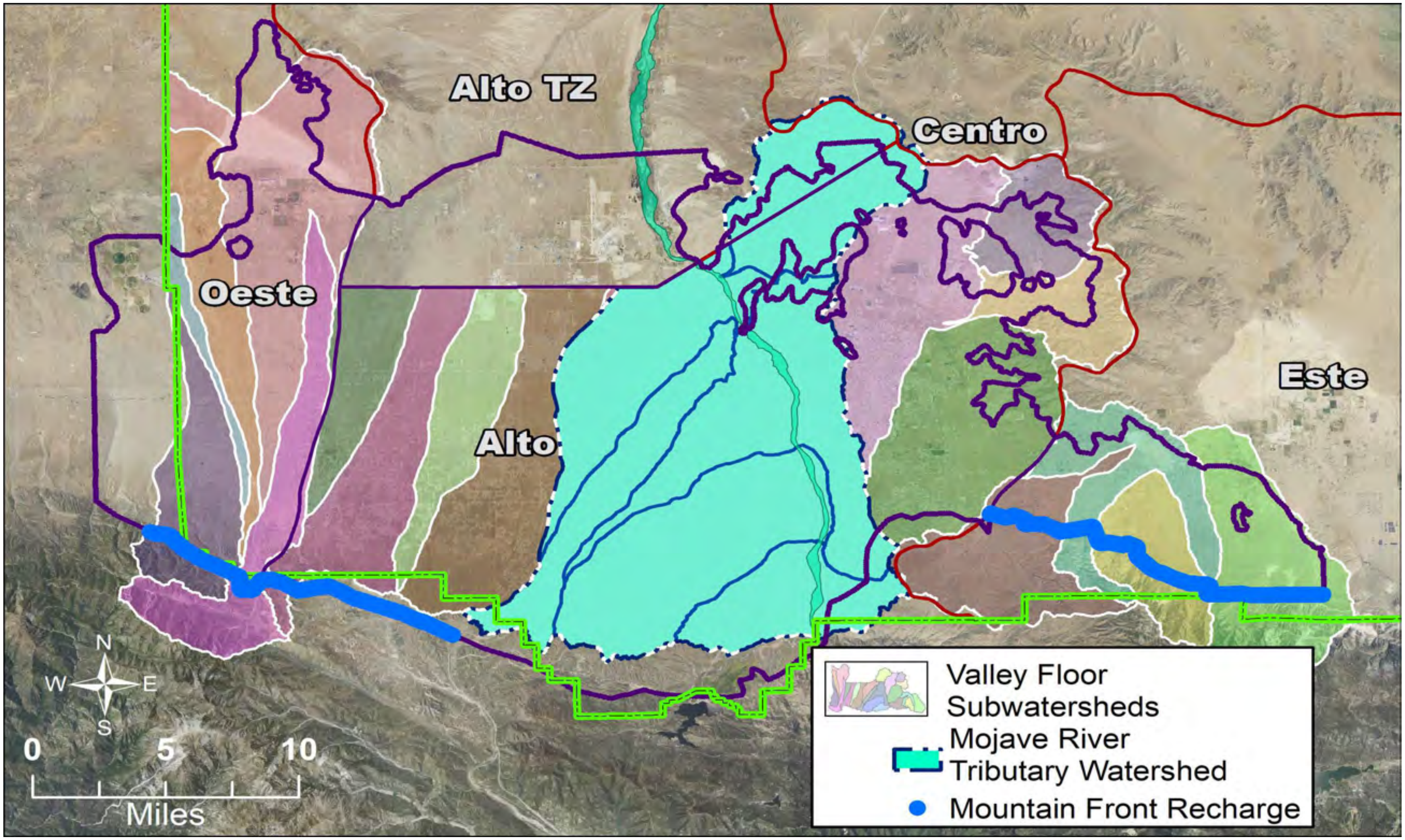
https://mojavewater-my.sharepoint.com/personal/kcoulibaly_mojavewater_org/Documents/Projects/WagnerRequests/PSY_Calc/Figures/ModelingTMFigures.xlsxFigure 9 12/10/2023



Upper Mojave Basin Subwatersheds Used for Mountain Front Recharge Estimates

By: KMC	Date: 12/04/2023	Project No.: CM20167800
Mojave Water Agency		Figure 9

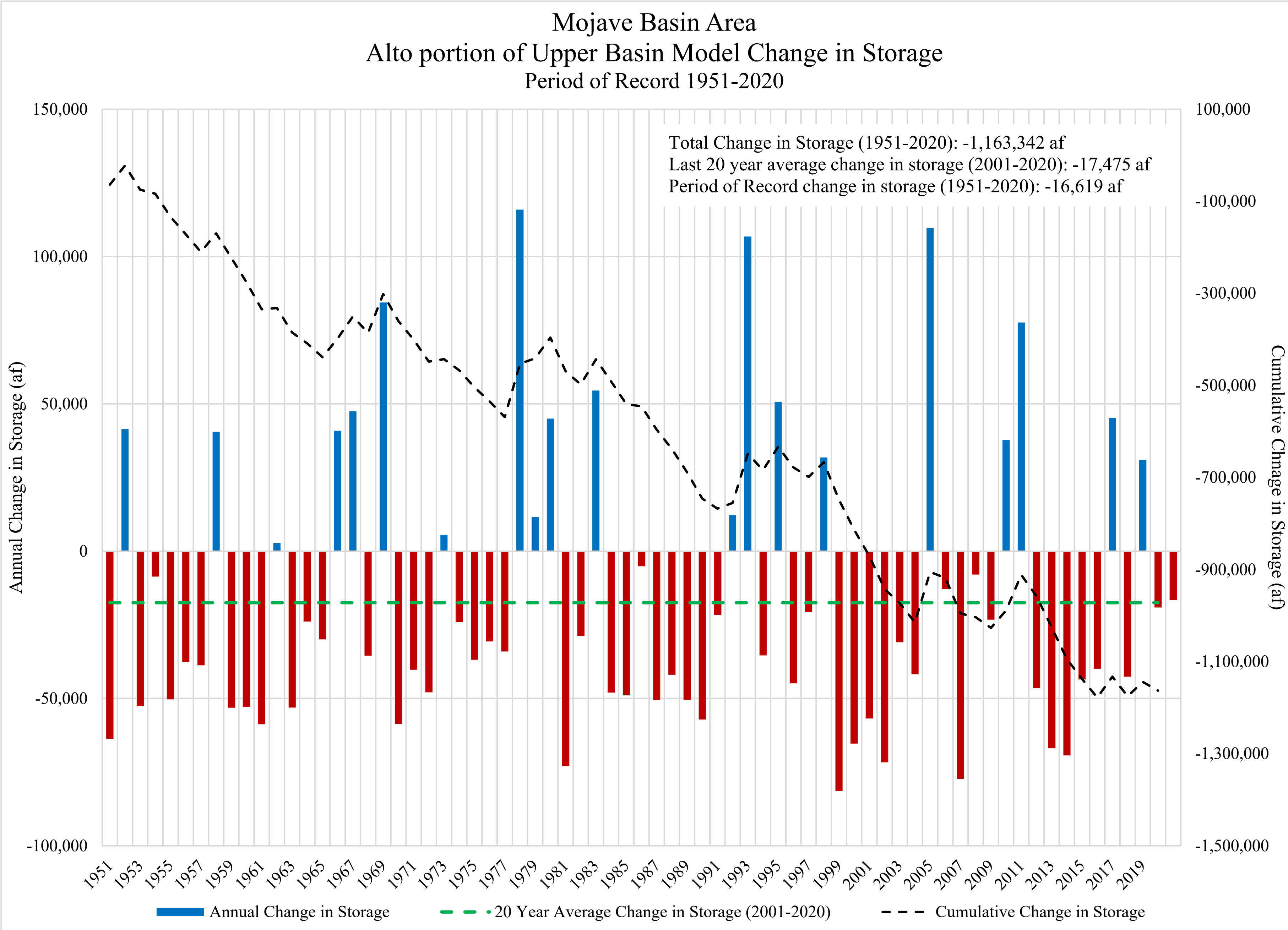
GSWC 0281



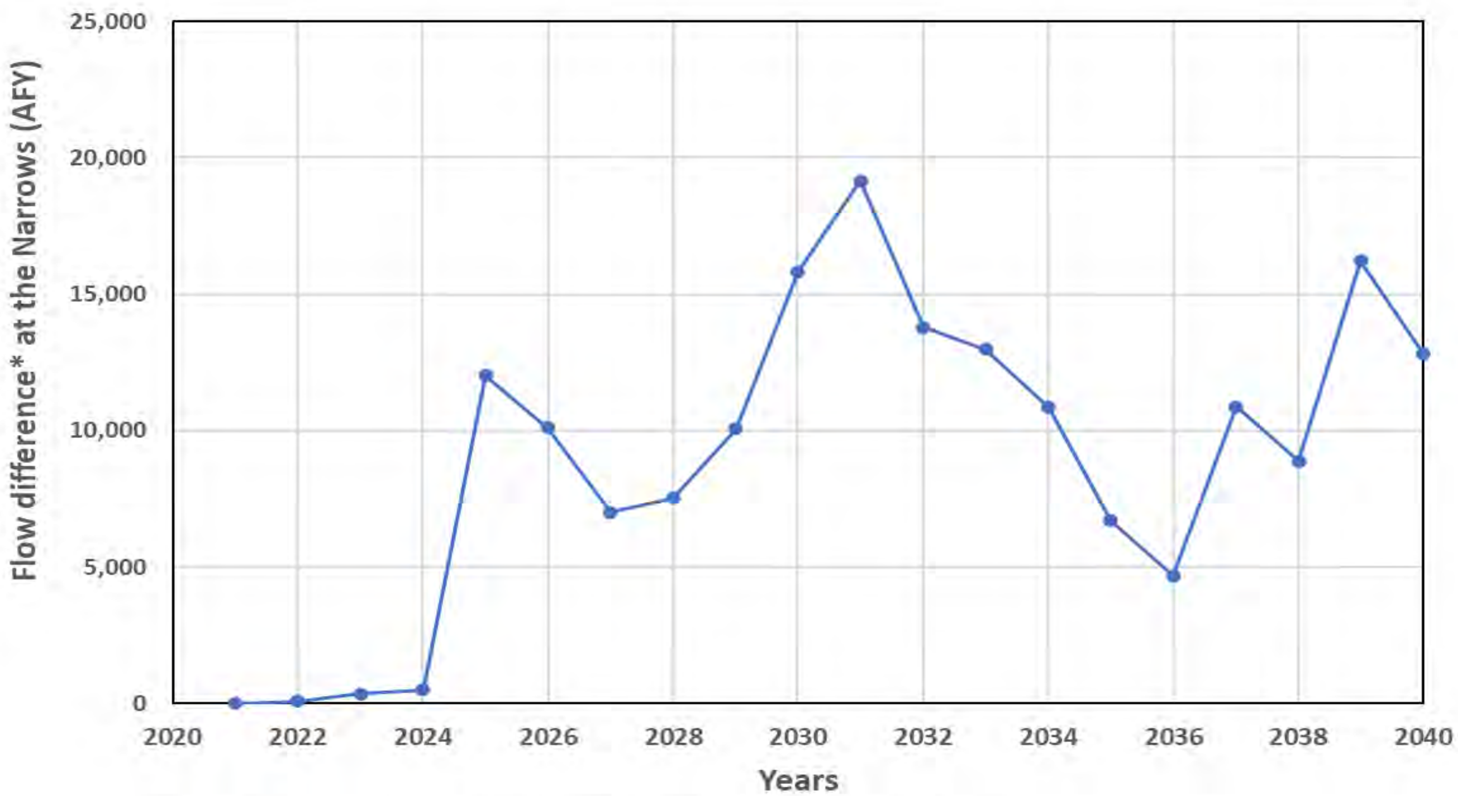
Upper Mojave Basin Subwatersheds Draining in the Mojave River (Tributaries)

By: KMC	Date: 12/04/2023	Project No.: CM20167800
Mojave Water Agency		Figure 10

FIGURE 11



G:\MOJAVE ADJUDICATION - 3020\Analysis\Groundwater Modeling\1-Alto\3020-009M-Table 6.1 Summary of Model Parameters Alto-V4.xlsx



* Difference = Scenario 1 flow - base case flow at the Lower Narrows.
Scenario 1 consists of a 16,000 AFY delivered at Deep Creek.

Change in Flow at the Lower Narrows after Importing 17,500 AFY for 20 Years

By: KMC	Date: 12/04/2023	Project No.: CM20167800
	Mojave Water Agency	Figure 12

Figure 13

Alto Subarea Excluding Transition Zone

Simulated Water Budget Water Year 1951 - 2020
Upper Mojave River Basin Model
San Bernardino, California

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s
	Inflows									Outflows								
Water Year	Art Rech (AF)	Mtn Rech (AF)	Ag Ret (AF)	Jess Ret (AF)	Septic Ret (AF)	Stream Leakage (AF)	Underflow Inflow from Este (AF)	Underflow Inflow Oeste (AF)	Total Inflow (AF)	Min Prod (AF)	Production (AF)	ET (AF)	Dry Lakes (AF)	Underflow Outflow TZ (AF)	Stream Leakage (AF)	Total Outflow	Change in Storage (AF)	Cumulative change in Storage (AF)
1951	0	6,408	17,347	500	556	17,535	1,591	1,829	45,765	-1,381	-59,720	-6,618	0	-9,943	-31,853	-109,515	-63,750	-63,750
1952	0	11,094	22,108	1,327	619	126,956	1,590	1,918	165,611	-1,385	-77,283	-6,905	0	-9,866	-28,680	-124,118	41,493	-22,257
1953	0	7,250	22,619	1,236	683	40,002	1,596	2,003	75,389	-1,381	-81,505	-6,756	0	-9,774	-28,573	-127,988	-52,600	-74,857
1954	0	8,775	21,938	1,021	747	78,836	1,633	2,098	115,047	-1,381	-78,668	-6,785	0	-9,702	-27,195	-123,731	-8,683	-83,540
1955	0	7,073	21,440	1,369	810	36,183	1,658	2,193	70,727	-1,381	-77,153	-6,681	0	-9,643	-26,225	-121,084	-50,356	-133,897
1956	0	7,039	18,972	1,516	874	43,133	1,662	2,289	75,485	-1,385	-71,019	-6,622	0	-9,652	-24,507	-113,185	-37,700	-171,596
1957	0	6,970	18,473	1,756	938	39,179	1,666	2,362	71,343	-1,381	-70,634	-6,597	0	-9,591	-21,882	-110,085	-38,742	-210,338
1958	0	10,417	19,733	2,371	1,002	118,041	1,684	2,437	155,685	-1,381	-74,231	-6,817	0	-9,542	-23,154	-115,124	40,560	-169,778
1959	0	6,852	22,017	2,826	1,065	34,979	1,694	2,507	71,940	-1,381	-83,257	-6,619	0	-9,501	-24,365	-125,124	-53,184	-222,961
1960	0	6,519	23,604	3,455	1,129	35,847	1,696	2,580	74,830	-1,385	-89,129	-6,589	0	-9,477	-21,144	-127,723	-52,893	-275,855
1961	0	6,184	23,675	3,141	1,193	27,319	1,688	2,635	65,834	-1,381	-89,177	-6,562	0	-9,418	-18,111	-124,649	-58,815	-334,670
1962	0	8,505	22,613	2,665	1,256	83,339	1,690	2,694	122,761	-1,381	-85,861	-6,604	0	-9,382	-16,742	-119,969	2,792	-331,878
1963	0	6,200	22,832	3,285	1,320	31,690	1,683	2,749	69,758	-1,381	-89,535	-6,545	0	-9,343	-16,085	-122,889	-53,131	-385,009
1964	0	7,302	23,333	2,834	1,384	58,226	1,685	2,808	97,572	-1,385	-89,654	-6,522	0	-9,353	-14,563	-121,477	-23,905	-408,914
1965	0	6,941	23,784	3,255	1,448	53,507	1,682	2,849	93,467	-1,381	-92,433	-6,522	0	-9,324	-13,723	-123,383	-29,916	-438,830
1966	0	10,227	22,918	2,064	1,511	120,565	1,686	2,894	161,865	-1,381	-87,816	-6,669	0	-9,330	-15,750	-120,946	40,919	-397,911
1967	0	10,016	21,898	2,453	1,575	129,806	1,688	2,935	170,371	-1,381	-85,618	-6,700	0	-9,317	-19,793	-122,809	47,562	-350,349
1968	0	7,425	22,394	2,081	1,639	49,748	1,691	2,982	87,959	-1,385	-85,508	-6,605	0	-9,336	-20,649	-123,482	-35,523	-385,873
1969	0	15,149	23,970	2,105	1,702	167,731	1,686	3,008	215,352	-1,381	-89,563	-7,405	0	-9,256	-23,295	-130,900	84,452	-301,421
1970	0	6,664	21,162	1,049	1,766	31,291	1,681	3,040	66,653	-1,381	-81,885	-6,614	0	-9,225	-26,319	-125,424	-58,771	-360,191
1971	0	7,143	20,708	797	1,830	41,851	1,675	3,068	77,072	-1,381	-76,688	-6,580	0	-9,206	-23,512	-117,366	-40,294	-400,486
1972	0	6,649	19,002	1,353	1,894	33,442	1,676	3,103	67,117	-1,385	-76,894	-6,571	0	-9,201	-21,028	-115,080	-47,963	-448,449
1973	0	7,447	19,504	3,091	1,957	95,468	1,670	3,119	132,256	-1,381	-90,355	-6,589	0	-9,135	-19,234	-126,694	5,563	-442,886
1974	0	7,291	20,085	1,821	2,021	53,825	1,667	3,140	89,850	-1,381	-76,413	-6,555	0	-9,106	-20,577	-114,032	-24,182	-467,068
1975	0	7,147	20,312	1,840	2,085	41,810	1,665	3,159	78,017	-1,381	-78,564	-6,533	0	-9,075	-19,375	-114,928	-36,911	-503,979
1976	0	7,076	20,553	1,859	2,148	55,969	1,668	3,185	92,459	-1,385	-90,002	-6,534	0	-9,070	-16,182	-123,172	-30,714	-534,693
1977	0	7,242	20,752	1,877	2,212	55,741	1,664	3,190	92,678	-1,381	-95,740	-6,526	0	-9,018	-14,029	-126,695	-34,017	-568,709
1978	0	9,645	20,993	1,896	2,488	207,824	1,661	3,201	247,710	-1,381	-97,084	-6,824	0	-8,982	-17,443	-131,715	115,995	-452,715
1979	0	7,559	21,220	1,915	2,818	111,172	1,653	3,211	149,548	-1,381	-97,611	-6,837	0	-8,974	-23,108	-137,910	11,637	-441,077
1980	0	8,896	21,462	1,934	3,149	149,848	1,646	3,227	190,162	-1,385	-100,757	-7,001	0	-8,963	-27,031	-145,136	45,026	-396,051
1981	0	6,787	21,660	1,953	3,479	32,884	1,628	3,222	71,613	-1,381	-98,977	-6,766	0	-8,925	-28,610	-144,659	-73,046	-469,097
1982	0	7,092	21,902	1,972	3,809	73,810	1,616	3,224	113,425	-1,381	-101,608	-6,654	0	-8,896	-23,783	-142,323	-28,898	-497,995
1983	0	8,425	22,129	1,991	4,139	158,942	1,606	3,224	200,455	-1,381	-103,823	-6,837	0	-8,868	-24,984	-145,893	54,562	-443,433
1984	0	7,424	22,371	2,009	4,470	61,985	1,597	3,231	103,088	-1,385	-107,889	-6,806	0	-8,875	-26,172	-151,127	-48,039	-491,471
1985	0	7,758	22,567	1,985	4,800	56,567	1,580	3,219	98,477	-1,381	-109,712	-6,679	0	-8,826	-20,912	-147,510	-49,033	-540,504
1986	0	8,175	22,809	2,239	5,130	92,611	1,571	3,212	135,749	-1,381	-103,345	-6,699	0	-8,802	-20,696	-140,922	-5,173	-545,677
1987	0	7,528	22,371	1,667	5,460	46,920	1,563	3,185	88,694	-1,381	-103,774	-6,627	0	-8,806	-18,672	-139,259	-50,565	-596,242
1988	0	7,580	22,424	1,307	5,790	55,781	1,559	3,147	97,589	-1,385	-107,092	-6,564	0	-8,809	-15,731	-139,581	-41,992	-638,234
1989	0	7,352	23,207	1,304	6,121	49,006	1,547	3,150	91,687	-1,381	-112,094	-6,460	0	-8,736	-13,531	-142,202	-50,515	-688,749
1990	0	7,389	21,271	1,153	6,451	40,460	1,542	3,183	81,450	-1,381	-111,628	-5,982	0	-8,684	-10,967	-138,642	-57,192	-745,941
1991	0	7,944	19,705	2,141	6,543	73,177	1,544	3,212	114,266	-1,381	-110,947	-5,833	0	-8,586	-9,215	-135,963	-21,697	-767,638
1992	0	8,567	18,957	0	6,635	107,799	1,550	3,193	146,701	-1,385	-107,964	-6,252	0	-8,356	-10,475	-134,432	12,269	-755,369
1993	0	10,310	17,995	0	6,727	205,820	1,541	3,202	245,596	-1,381	-106,028	-6,856	0	-8,214	-16,272	-138,751	106,844	-648,524
1994	0	5,891	2,151	0	6,820	62,841	1,537	3,322	82,562	-1,381	-81,775	-6,770	0	-8,193	-19,888	-118,007	-35,445	-683,969
1995	0	7,203	1,828	0	6,912	144,399	1,525	3,289	165,156	-1,381	-74,741	-6,649	0	-8,033	-23,635	-114,439	50,716	-633,253
1996	0	6,084	626	0	7,004	58,397	1,515	3,301	76,927	-1,385	-79,084	-6,877	0	-8,064	-26,428	-121,837	-44,911	-678,163
1997	0	5,936	860	0	7,096	80,612	1,496	3,298	99,297	-1,381	-78,676	-6,887	0	-8,018	-25,035	-119,997	-20,700	-698,863
1998	0	7,808	524	0	7,188	125,160	1,483	3,319	145,483	-1,381	-71,472	-6,292	0	-7,967	-26,510	-113,621	31,861	-667,002
1999	0	6,613	610	0	7,280	20,430	1,469	3,315	39,719	-1,381	-79,245	-6,532	0	-7,929	-26,112	-121,198	-81,480	-748,482

Alto Subarea Excluding Transition Zone

Simulated Water Budget Water Year 1951 - 2020
Upper Mojave River Basin Model
San Bernardino, California

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s
	Inflows										Outflows							
Water Year	**Art Rech (AF)**	**Mtn Rech (AF)**	**Ag Ret (AF)**	**Jess Ret (AF)**	**Septic Ret (AF)**	**Stream Leakage (AF)**	**Underflow Inflow from Este (AF)**	**Underflow Inflow Oeste (AF)**	**Total Inflow (AF)**	**Min Prod (AF)**	**Production (AF)**	**ET (AF)**	**Dry Lakes (AF)**	**Underflow Outflow TZ (AF)**	**Stream Leakage (AF)**	**Total Outflow**	**Change in Storage (AF)**	**Cumulative change in Storage (AF)**
2000	0	7,100	562	0	6,860	34,096	1,476	3,311	53,403	-1,385	-83,462	-6,634	0	-7,928	-19,355	-118,763	-65,360	-813,842
2001	0	7,390	410	0	7,065	33,802	1,481	3,303	53,451	-1,381	-80,266	-6,000	0	-7,772	-14,831	-110,250	-56,798	-870,640
2002	1658	6,869	314	0	7,271	15,572	1,483	3,286	36,453	-1,381	-83,204	-5,546	0	-7,679	-10,363	-108,172	-71,719	-942,359
2003	2940	7,494	248	0	7,477	49,650	1,484	3,265	72,557	-1,381	-82,958	-4,621	0	-7,607	-6,902	-103,469	-30,912	-973,271
2004	1499	7,230	247	0	7,683	43,901	1,486	3,239	65,284	-1,385	-89,462	-4,111	0	-7,484	-4,589	-107,031	-41,747	-1,015,017
2005	2423	9,434	204	0	7,888	194,886	1,485	3,213	219,534	-1,381	-86,263	-5,559	0	-7,056	-9,552	-109,811	109,723	-905,295
2006	1505	7,044	407	0	8,094	86,466	1,484	3,188	108,189	-1,381	-92,688	-6,172	0	-7,379	-13,459	-121,079	-12,890	-918,185
2007	1695	6,298	396	0	8,300	24,175	1,477	3,138	45,479	-1,381	-95,525	-6,014	0	-7,452	-12,451	-122,823	-77,344	-995,529
2008	1010	6,842	520	0	8,506	81,427	1,481	3,157	102,942	-1,361	-86,378	-5,411	0	-7,206	-10,574	-110,930	-7,988	-1,003,518
2009	1453	6,838	480	0	8,712	64,287	1,478	3,205	86,452	-1,357	-84,832	-5,368	0	-7,109	-11,081	-109,748	-23,296	-1,026,814
2010	1395	7,460	283	0	8,917	121,802	1,477	3,289	144,623	-1,357	-79,571	-5,942	0	-7,047	-13,004	-106,922	37,701	-989,112
2011	1234	8,424	138	0	8,997	167,516	1,474	3,365	191,148	-1,357	-77,586	-6,648	0	-6,970	-20,928	-113,490	77,658	-911,454
2012	975	7,066	287	0	9,076	49,999	1,468	3,398	72,270	-1,361	-80,287	-6,829	0	-6,981	-23,394	-118,852	-46,582	-958,037
2013	888	6,829	265	0	9,156	29,370	1,453	3,377	51,337	-1,357	-84,438	-6,714	0	-6,881	-18,885	-118,275	-66,938	-1,024,975
2014	754	6,876	196	0	9,235	23,753	1,448	3,368	45,630	-1,357	-86,951	-6,163	0	-6,791	-13,721	-114,984	-69,354	-1,094,329
2015	779	7,219	125	0	9,315	31,240	1,448	3,392	53,518	-1,357	-74,448	-5,454	0	-6,628	-9,164	-97,051	-43,533	-1,137,862
2016	765	7,181	202	0	9,394	27,074	1,452	3,411	49,480	-1,361	-71,219	-4,804	0	-6,582	-5,479	-89,446	-39,966	-1,177,828
2017	1078	8,023	104	0	9,474	112,277	1,443	3,411	135,810	-1,357	-71,169	-5,242	0	-6,592	-6,181	-90,541	45,269	-1,132,560
2018	0	7,420	27	0	9,474	34,250	1,437	3,426	56,034	-1,357	-79,570	-4,914	0	-6,719	-6,124	-98,684	-42,650	-1,175,210
2019	0	8,104	16	0	9,474	104,335	1,439	3,463	126,831	-1,357	-74,175	-5,548	0	-6,632	-8,071	-95,782	31,048	-1,144,162
2020	0	8,130	13	0	9,502	58,944	1,442	3,479	81,509	-1,361	-78,375	-5,433	0	-6,487	-9,033	-100,689	-19,180	-1,163,342
Entire POR Average	315	7,661	13,326	1,149	4,822	72,961	1,575	3,051	104,859	-1,377	-87,035	-6,349	0	-8,447	-18,270	-121,478	-16,619	
Last 20 Year Average	1,102	7,409	244	0	8,651	67,736	1,466	3,319	89,926	-1,366	-81,968	-5,625	0	-7,053	-11,389	-107,401	-17,475	

Column	**Description**	**Source**
A	Oct 1 to Sept 30, model period of record 1951-2020.	Watermaster
B	Oro Grande + LACSD.	Watermaster
C	Ungaged inflow, deep percolation precipitation and mountain front recharge.	BCM
D	Estimate return flow from agriculture.	Watermaster and USGS (2001)
E	Estimate return flow from Jess Ranch.	Watermaster
F	Estimated portion of indoor water use returned to the aquifer via septic.	MWA
G	Percolation from Mojave River to the aquifer.	Model
H	Subsurface inflow from Este.	Model
I	Subsurface inflow from Oeste.	Model
J	Sum of elements of inflow.	-
K	Estimated production by Minimal Producers.	Watermaster
L	Estimated total pumping within Alto above Lower Narrows.	Watermaster and USGS (2001)
M	Evapotranspiration from riparian vegetation.	Model
N	Evaporation from dry lakes.	Model
O	Subsurface outflow to Transition Zone.	Model
P	Discharge from aquifer to the Mojave River.	Model
Q	Sum of elements of outflow.	-
R	Gains or losses in storage on an annual basis.	-
S	Total accumulation of gains or losses at any point in time.	-

Transition Zone
Modeled Portion

Simulated Water Budget Water Year 1951 - 2020
Upper Mojave River Basin Model
San Bernardino, California

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p
	Inflows							Outflows							
Water Year	**Art Rech (AF)**	**Ag Ret (AF)**	**Septic Ret (AF)**	**Stream Leakage (AF)**	**Underflow Inflow Alto (AF)**	**Underflow Inflow Oeste (AF)**	**Total Inflow (AF)**	**Min Prod (AF)**	**Production (AF)**	**ET (AF)**	**Dry Lakes (AF)**	**Stream Leakage (AF)**	**Total Outflow**	**Change in Storage (AF)**	**Cumulative change in Storage (AF)**
1951	0	1,324	0	7,179	9,943	160	18,607	-93	-3,847	-6,055	0	-6,901	-16,895	1,712	1,712
1952	0	1,716	0	7,259	9,866	162	19,005	-93	-4,775	-6,138	0	-6,838	-17,843	1,162	2,873
1953	0	1,749	0	7,283	9,774	166	18,972	-93	-4,863	-6,077	0	-6,413	-17,445	1,527	4,400
1954	0	1,733	0	7,155	9,702	170	18,760	-93	-4,821	-6,093	0	-6,438	-17,445	1,314	5,714
1955	0	2,512	0	7,473	9,643	174	19,803	-93	-6,524	-6,043	0	-5,432	-18,091	1,712	7,426
1956	0	2,537	0	7,649	9,652	179	20,018	-93	-6,780	-6,028	0	-5,317	-18,217	1,800	9,227
1957	0	2,264	0	7,729	9,591	183	19,767	-93	-6,165	-6,044	0	-6,083	-18,385	1,382	10,609
1958	0	2,014	0	7,784	9,542	185	19,526	-93	-6,064	-6,096	0	-6,428	-18,681	845	11,454
1959	0	1,657	0	8,472	9,501	187	19,818	-93	-5,849	-5,993	0	-3,872	-15,807	4,010	15,464
1960	0	2,003	0	11,506	9,477	188	23,174	-93	-6,793	-5,873	0	-1,687	-14,445	8,728	24,193
1961	0	2,106	0	10,709	9,418	188	22,421	-93	-7,101	-5,889	0	-1,942	-15,025	7,396	31,589
1962	0	2,178	0	8,908	9,382	187	20,654	-93	-7,443	-5,963	0	-4,383	-17,881	2,773	34,362
1963	0	2,287	0	10,706	9,343	185	22,522	-93	-7,872	-5,870	0	-1,717	-15,552	6,970	41,332
1964	0	2,719	0	10,835	9,353	183	23,090	-93	-9,260	-5,711	0	-1,685	-16,749	6,342	47,673
1965	0	2,692	0	10,199	9,324	180	22,395	-93	-9,855	-5,696	0	-2,647	-18,291	4,104	51,778
1966	0	2,260	0	10,927	9,330	177	22,694	-93	-9,896	-5,948	0	-5,452	-21,389	1,305	53,083
1967	0	2,269	0	10,688	9,317	173	22,447	-93	-10,063	-5,961	0	-5,193	-21,310	1,137	54,220
1968	0	2,254	0	10,868	9,336	170	22,628	-93	-10,667	-5,896	0	-3,035	-19,691	2,937	57,157
1969	0	1,860	0	10,829	9,256	165	22,109	-93	-9,294	-6,083	0	-5,162	-20,632	1,477	58,635
1970	0	1,720	0	10,556	9,225	160	21,661	-93	-8,823	-5,907	0	-2,430	-17,253	4,408	63,043
1971	0	1,479	0	12,341	9,206	155	23,181	-93	-8,454	-5,823	0	-1,418	-15,788	7,393	70,436
1972	0	1,426	0	15,519	9,201	150	26,297	-93	-8,257	-5,758	0	-1,188	-15,296	11,001	81,437
1973	0	1,321	0	12,435	9,135	145	23,035	-93	-8,060	-5,894	0	-2,596	-16,644	6,392	87,829
1974	0	1,276	0	10,730	9,106	139	21,252	-93	-8,067	-5,790	0	-1,896	-15,845	5,406	93,235
1975	0	1,265	0	11,629	9,075	133	22,103	-93	-8,139	-5,295	0	-1,064	-14,592	7,512	100,747
1976	0	1,256	0	15,090	9,070	128	25,543	-93	-8,218	-5,667	0	-1,109	-15,088	10,455	111,202
1977	0	1,243	0	13,658	9,018	122	24,041	-93	-8,280	-5,791	0	-1,472	-15,635	8,406	119,608
1978	0	1,234	88	10,574	8,982	116	20,993	-93	-8,358	-6,097	0	-5,307	-19,856	1,138	120,745
1979	0	1,223	100	10,015	8,974	109	20,421	-93	-8,431	-6,027	0	-6,335	-20,886	-464	120,281
1980	0	1,213	112	10,237	8,963	103	20,628	-93	-8,510	-6,075	0	-5,426	-20,103	525	120,807
1981	3	1,201	124	12,132	8,925	97	22,481	-93	-8,571	-5,874	0	-1,810	-16,347	6,134	126,940
1982	430	1,191	135	11,879	8,896	90	22,623	-93	-8,649	-6,003	0	-7,384	-22,130	493	127,433
1983	914	1,180	147	11,719	8,868	84	22,912	-93	-8,722	-6,084	0	-8,146	-23,044	-132	127,301
1984	962	1,171	159	11,768	8,875	77	23,012	-93	-8,801	-6,018	0	-8,073	-22,984	27	127,328
1985	772	1,158	170	12,145	8,826	70	23,142	-93	-8,862	-5,996	0	-7,699	-22,649	492	127,820
1986	576	1,149	182	11,718	8,802	62	22,489	-93	-8,941	-5,978	0	-7,051	-22,063	426	128,246
1987	345	1,307	194	12,361	8,806	55	23,067	-93	-9,575	-5,917	0	-5,191	-20,776	2,291	130,537
1988	463	1,526	206	11,585	8,809	48	22,636	-93	-10,002	-5,666	0	-4,372	-20,132	2,504	133,041
1989	829	1,308	217	7,913	8,736	42	19,045	-93	-9,064	-4,432	0	-4,545	-18,134	911	133,952
1990	69	1,335	229	6,399	8,684	36	16,753	-93	-8,696	-3,468	0	-4,825	-17,082	-329	133,623
1991	70	1,385	232	6,859	8,586	30	17,163	-93	-8,675	-3,556	0	-6,687	-19,011	-1,847	131,776
1992	702	1,398	236	8,444	8,356	26	19,161	-93	-8,593	-4,131	0	-6,900	-19,717	-556	131,220
1993	569	1,522	239	12,690	8,214	24	23,258	-93	-8,691	-5,825	0	-7,134	-21,743	1,516	132,735
1994	692	318	242	9,946	8,193	26	19,417	-93	-3,751	-5,929	0	-8,740	-18,513	903	133,639
1995	792	313	245	9,626	8,033	26	19,035	-93	-3,694	-5,984	0	-8,838	-18,608	427	134,066
1996	539	164	249	11,478	8,064	27	20,521	-93	-6,581	-6,125	0	-8,973	-21,773	-1,252	132,814
1997	1,009	178	252	11,391	8,018	21	20,869	-93	-6,513	-6,150	0	-9,164	-21,919	-1,050	131,764
1998	1,147	139	255	10,061	7,967	13	19,583	-93	-5,187	-5,603	0	-9,179	-20,061	-478	131,285
1999	1,409	155	258	10,718	7,929	9	20,479	-93	-6,525	-5,845	0	-8,357	-20,819	-341	130,945

Transition Zone
Modeled Portion

Simulated Water Budget Water Year 1951 - 2020
Upper Mojave River Basin Model
San Bernardino, California

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p
	Inflows							Outflows							
Water Year	Art Rech (AF)	Ag Ret (AF)	Septic Ret (AF)	Stream Leakage (AF)	Underflow Inflow Alto (AF)	Underflow Inflow Oeste (AF)	Total Inflow (AF)	Min Prod (AF)	Production (AF)	ET (AF)	Dry Lakes (AF)	Stream Leakage (AF)	Total Outflow	Change in Storage (AF)	Cumulative change in Storage (AF)
2000	803	160	41	7,949	7,928	7	16,889	-93	-7,061	-5,063	0	-7,458	-19,675	-2,786	128,158
2001	1,072	102	43	6,751	7,772	10	15,748	-93	-6,462	-4,310	0	-7,568	-18,433	-2,685	125,474
2002	2,141	82	44	4,398	7,679	16	14,360	-93	-7,667	-3,357	0	-7,023	-18,139	-3,779	121,694
2003	3,558	83	45	4,201	7,607	22	15,517	-93	-7,191	-3,285	0	-7,371	-17,939	-2,422	119,272
2004	5,222	85	46	2,479	7,484	28	15,345	-93	-6,197	-3,068	0	-7,746	-17,103	-1,758	117,514
2005	5,050	108	47	7,192	7,056	33	19,487	-93	-6,810	-4,245	0	-9,037	-20,184	-698	116,816
2006	2,782	83	49	5,447	7,379	39	15,778	-93	-6,975	-3,892	0	-8,429	-19,389	-3,610	113,206
2007	3,626	81	50	3,984	7,452	44	15,238	-93	-5,556	-3,434	0	-8,264	-17,347	-2,109	111,097
2008	5,065	78	51	3,489	7,206	48	15,937	-93	-5,511	-3,502	0	-9,430	-18,535	-2,598	108,499
2009	4,795	78	52	3,393	7,109	48	15,476	-93	-5,074	-3,502	0	-9,921	-18,590	-3,115	105,384
2010	4,276	36	54	6,123	7,047	48	17,583	-93	-4,480	-4,686	0	-10,372	-19,631	-2,048	103,337
2011	4,939	13	54	8,951	6,970	46	20,973	-93	-4,127	-5,942	0	-10,186	-20,348	625	103,962
2012	4,471	5	55	8,830	6,981	45	20,385	-93	-4,327	-6,295	0	-10,132	-20,847	-462	103,500
2013	6,167	0	55	7,157	6,881	49	20,310	-93	-4,065	-6,036	0	-10,117	-20,311	-1	103,499
2014	7,602	6	56	5,686	6,791	66	20,206	-93	-4,072	-5,434	0	-11,308	-20,906	-700	102,799
2015	6,514	1	56	4,739	6,628	83	18,020	-93	-3,526	-5,160	0	-10,961	-19,739	-1,719	101,080
2016	7,219	8	57	3,273	6,582	97	17,236	-93	-3,678	-4,794	0	-10,424	-18,988	-1,752	99,328
2017	5,601	7	57	4,300	6,592	108	16,666	-93	-3,571	-4,945	0	-10,183	-18,792	-2,126	97,202
2018	7,358	0	57	2,475	6,719	117	16,725	-93	-3,767	-4,390	0	-9,950	-18,200	-1,474	95,728
2019	8,432	0	57	4,571	6,632	126	19,818	-93	-3,676	-4,901	0	-11,035	-19,705	113	95,840
2020	7,053	0	57	4,800	6,487	134	18,532	-93	-3,850	-5,213	0	-11,055	-20,212	-1,679	94,161
Entire POR Average	1,658	1,056	76	8,828	8,447	99	20,163	-93	-6,932	-5,395	0	-6,399	-18,818	1,345	
Last 20 Year Average	5,147	43	52	5,112	7,053	60	17,467	-93	-5,029	-4,520	0	-9,526	-19,167	-1,700	

Column	Description	Source
A	Oct 1 to Sept 30, model period of record 1951-2020.	Watermaster
B	VVWRA discharge to percolation ponds.	Watermaster
C	Estimate return flow from agriculture.	Watermaster and USGS (2001)
D	Estimated portion of indoor water use returned to the aquifer via septic.	MWA
E	Percolation from Mojave River to the aquifer.	Model
F	Subsurface inflow from Alto.	Model
G	Subsurface inflow from Oeste.	Model
H	Sum of elements of inflow.	-
I	Estimated production by Minimal Producers.	Watermaster
J	Estimated total pumping within Alto below Lower Narrows.	Watermaster and USGS (2001)
K	Evapotranspiration from riparian vegetation.	Model
L	Evaporation from dry lakes.	Model
M	Percolation from Mojave River to the aquifer.	Model
N	Sum of elements of outflow.	-
O	Gains or losses in storage on an annual basis.	-
P	Total accumulation of gains or losses at any point in time.	-

Este Subarea
Fifteen Mile Valley Portion

Simulated Water Budget Water Year 1951 - 2020
Upper Mojave River Basin Model
San Bernardino, California

a	b	c	d	e	f	g	h	i	j	k	l
	Inflows				Outflows						
Water Year	Mtn Rech (AF)	Ag Ret (AF)	Septic Ret (AF)	Total Inflow (AF)	Min Prod (AF)	Production (AF)	Dry Lakes (AF)	Underflow Outflow to Alto	Total Outflow	Change in Storage (AF)	Cumulative change in Storage (AF)
1951	2,690	0	0	2,690	-899	0	-692	-1,650	-3,241	-550	-550
1952	2,696	0	0	2,696	-901	0	-641	-1,656	-3,199	-502	-1,053
1953	2,689	0	0	2,689	-899	0	-639	-1,667	-3,206	-516	-1,569
1954	2,689	0	0	2,689	-899	0	-579	-1,706	-3,183	-494	-2,063
1955	2,689	0	0	2,689	-899	0	-535	-1,732	-3,166	-477	-2,540
1956	2,697	0	0	2,697	-901	0	-497	-1,741	-3,139	-442	-2,982
1957	2,690	0	0	2,690	-899	0	-456	-1,747	-3,103	-413	-3,394
1958	2,689	0	0	2,689	-899	0	-419	-1,767	-3,086	-397	-3,791
1959	2,690	0	0	2,690	-899	0	-397	-1,779	-3,075	-385	-4,176
1960	2,698	0	0	2,698	-901	0	-370	-1,785	-3,056	-358	-4,534
1961	2,690	0	0	2,690	-899	0	-356	-1,780	-3,035	-345	-4,879
1962	2,689	0	0	2,689	-899	0	-323	-1,785	-3,007	-317	-5,196
1963	2,691	0	0	2,691	-899	0	-302	-1,782	-2,983	-293	-5,489
1964	2,696	0	0	2,696	-901	0	-284	-1,788	-2,973	-277	-5,765
1965	2,689	0	0	2,689	-899	0	-267	-1,788	-2,954	-265	-6,030
1966	2,689	0	0	2,689	-899	0	-253	-1,795	-2,947	-258	-6,288
1967	2,689	0	0	2,689	-899	0	-237	-1,799	-2,935	-246	-6,534
1968	2,697	0	0	2,697	-901	0	-223	-1,804	-2,928	-232	-6,766
1969	2,689	0	0	2,689	-899	0	-207	-1,799	-2,905	-216	-6,981
1970	2,690	0	0	2,690	-899	0	-193	-1,794	-2,886	-196	-7,177
1971	2,689	0	0	2,689	-899	0	-178	-1,788	-2,866	-176	-7,353
1972	2,697	0	0	2,697	-901	0	-166	-1,789	-2,856	-159	-7,513
1973	2,689	0	0	2,689	-899	0	-153	-1,782	-2,834	-145	-7,658
1974	2,690	4	0	2,694	-899	-38	-141	-1,780	-2,858	-164	-7,823
1975	2,690	9	0	2,699	-899	-89	-129	-1,777	-2,895	-197	-8,019
1976	2,698	14	0	2,712	-901	-141	-118	-1,781	-2,942	-230	-8,249
1977	2,689	19	0	2,708	-899	-191	-106	-1,777	-2,973	-265	-8,514
1978	2,689	25	4	2,718	-899	-243	-95	-1,775	-3,011	-294	-8,807
1979	2,689	30	5	2,723	-899	-294	-83	-1,767	-3,043	-320	-9,127
1980	2,697	35	5	2,737	-901	-345	-73	-1,760	-3,080	-343	-9,470
1981	2,691	40	6	2,736	-899	-395	-63	-1,741	-3,099	-362	-9,832
1982	2,690	45	6	2,741	-899	-447	-53	-1,728	-3,126	-385	-10,217
1983	2,689	51	7	2,746	-899	-498	-42	-1,716	-3,156	-409	-10,626
1984	2,696	56	7	2,760	-901	-549	-32	-1,707	-3,190	-430	-11,056
1985	2,689	61	8	2,758	-899	-599	-21	-1,689	-3,209	-451	-11,507
1986	2,689	66	8	2,764	-899	-651	-12	-1,679	-3,241	-477	-11,985
1987	2,689	68	9	2,766	-899	-651	-3	-1,671	-3,224	-458	-12,442
1988	2,696	68	9	2,774	-901	-681	0	-1,667	-3,249	-476	-12,918
1989	2,690	68	10	2,767	-899	-717	0	-1,656	-3,272	-504	-13,423
1990	2,690	61	11	2,762	-899	-676	0	-1,651	-3,227	-465	-13,887
1991	2,690	53	11	2,753	-899	-600	0	-1,654	-3,153	-400	-14,287
1992	2,697	44	11	2,751	-901	-536	0	-1,661	-3,099	-347	-14,635
1993	2,689	35	11	2,735	-899	-524	0	-1,653	-3,076	-341	-14,975

Este Subarea
Fifteen Mile Valley Portion

Simulated Water Budget Water Year 1951 - 2020
Upper Mojave River Basin Model
San Bernardino, California

a	b	c	d	e	f	g	h	i	j	k	l
	Inflows					Outflows					
Water Year	Mtn Rech (AF)	Ag Ret (AF)	Septic Ret (AF)	Total Inflow (AF)	Min Prod (AF)	Production (AF)	Dry Lakes (AF)	Underflow Outflow to Alto	Total Outflow	Change in Storage (AF)	Cumulative change in Storage (AF)
1994	2,690	34	11	2,735	-899	-413	0	-1,649	-2,961	-226	-15,201
1995	2,689	30	11	2,730	-899	-326	0	-1,636	-2,861	-131	-15,332
1996	2,697	13	11	2,722	-901	-418	0	-1,625	-2,944	-222	-15,555
1997	2,689	3	12	2,704	-899	-399	0	-1,604	-2,902	-197	-15,752
1998	2,689	9	12	2,710	-899	-402	0	-1,589	-2,890	-180	-15,932
1999	2,692	14	12	2,718	-899	-409	0	-1,573	-2,881	-163	-16,095
2000	2,698	14	240	2,952	-901	-448	0	-1,576	-2,925	27	-16,068
2001	2,691	10	247	2,948	-899	-440	0	-1,577	-2,916	32	-16,036
2002	2,693	9	255	2,957	-899	-446	0	-1,578	-2,923	34	-16,003
2003	2,690	4	262	2,955	-899	-414	0	-1,578	-2,891	64	-15,939
2004	2,697	4	269	2,971	-901	-478	0	-1,582	-2,961	9	-15,929
2005	2,689	4	276	2,969	-899	-400	0	-1,581	-2,880	89	-15,840
2006	2,690	3	283	2,976	-899	-530	0	-1,580	-3,009	-32	-15,873
2007	2,693	7	291	2,990	-899	-527	0	-1,573	-2,999	-8	-15,881
2008	2,697	10	298	3,005	-886	-492	0	-1,576	-2,954	51	-15,830
2009	2,690	7	305	3,002	-884	-478	0	-1,572	-2,933	69	-15,761
2010	2,689	7	312	3,009	-884	-407	0	-1,570	-2,861	148	-15,613
2011	2,689	7	315	3,011	-884	-363	0	-1,566	-2,813	198	-15,415
2012	2,698	7	318	3,022	-886	-358	0	-1,559	-2,804	219	-15,196
2013	2,692	7	321	3,019	-884	-349	0	-1,543	-2,776	243	-14,953
2014	2,692	6	323	3,021	-884	-342	0	-1,536	-2,762	259	-14,694
2015	2,690	6	326	3,022	-884	-319	0	-1,535	-2,738	284	-14,410
2016	2,698	19	329	3,046	-886	-348	0	-1,540	-2,774	272	-14,138
2017	2,689	31	332	3,052	-884	-386	0	-1,531	-2,800	252	-13,886
2018	2,691	36	332	3,058	-884	-419	0	-1,526	-2,828	230	-13,655
2019	2,689	33	332	3,054	-884	-471	0	-1,527	-2,882	172	-13,483
2020	2,697	29	333	3,058	-886	-550	0	-1,530	-2,966	92	-13,391
Average	2,692	17	93	2,802	-897	-289	-133	-1,674	-2,993	-191	
L20 Year Average	2,692	12	303	3,007	-890	-426	0	-1,558	-2,874	134	

Column	Description	Source
A	Oct 1 to Sept 30, model period of record 1951-2020.	Watermaster
B	Ungaged inflow, deep percolation precipitation and mountain front recharge.	BCM
C	Estimate return flow from agriculture.	Watermaster and USGS (2001)
D	Estimated portion of indoor water use returned to the aquifer via septic.	MWA
E	Sum of elements of inflow.	-
F	Estimated production by Minimal Producers.	Watermaster
G	Estimated total pumping within Este.	Watermaster and USGS (2001)
H	Evaporation from dry lakes.	Model
I	Subsurface outflow to Alto.	Model
J	Sum of elements of outflow.	-
K	Gains or losses in storage on an annual basis.	-
L	Total accumulation of gains or losses at any point in time.	-

Oeste Subarea

Simulated Water Budget Water Year 1951 - 2020
Upper Mojave River Basin Model
San Bernardino, California

a	b	c	d	e	f	g	h	i	j	k	l	m
	Inflows				Outflows							
Water Year	Mtn Rech (AF)	Ag Ret (AF)	Septic Ret (AF)	Total Inflow (AF)	Min Prod (AF)	Production (AF)	Dry Lakes (AF)	Oeste to Alto	Outflow to TZ	Total Outflow	Change in Storage (AF)	Cumulative change in Storage (AF)
1951	4,627	0	0	4,627	-117	0	-515	-1,829	-160	-2,622	2,005	2,005
1952	4,670	0	0	4,670	-118	0	-521	-1,918	-162	-2,719	1,951	3,957
1953	4,680	0	0	4,680	-117	0	-534	-2,003	-166	-2,820	1,860	5,817
1954	4,699	0	0	4,699	-117	0	-545	-2,098	-170	-2,931	1,768	7,584
1955	4,714	0	0	4,714	-117	0	-558	-2,193	-174	-3,044	1,671	9,255
1956	4,742	29	0	4,771	-118	-154	-570	-2,289	-179	-3,311	1,460	10,715
1957	4,742	68	0	4,810	-117	-360	-571	-2,362	-183	-3,593	1,217	11,932
1958	4,756	107	0	4,862	-117	-566	-566	-2,437	-185	-3,872	990	12,922
1959	4,769	145	0	4,915	-117	-772	-564	-2,507	-187	-4,148	766	13,688
1960	4,796	184	0	4,980	-118	-979	-556	-2,580	-188	-4,422	559	14,247
1961	4,797	223	0	5,020	-117	-1,184	-545	-2,635	-188	-4,669	351	14,598
1962	4,812	262	0	5,073	-117	-1,390	-528	-2,694	-187	-4,916	157	14,755
1963	4,826	300	0	5,126	-117	-1,596	-516	-2,749	-185	-5,164	-37	14,718
1964	4,854	339	0	5,193	-118	-1,804	-497	-2,808	-183	-5,410	-217	14,500
1965	4,855	377	0	5,232	-117	-2,007	-477	-2,849	-180	-5,630	-398	14,102
1966	4,869	416	0	5,285	-117	-2,214	-455	-2,894	-177	-5,857	-572	13,530
1967	4,883	455	0	5,338	-117	-2,421	-434	-2,935	-173	-6,080	-742	12,788
1968	4,909	494	0	5,403	-118	-2,628	-412	-2,982	-170	-6,309	-906	11,882
1969	4,908	532	0	5,441	-117	-2,831	-385	-3,008	-165	-6,506	-1,066	10,816
1970	4,920	571	0	5,491	-117	-3,039	-365	-3,040	-160	-6,721	-1,230	9,586
1971	4,930	610	0	5,541	-117	-3,245	-338	-3,068	-155	-6,923	-1,383	8,203
1972	4,954	649	0	5,603	-118	-3,453	-308	-3,103	-150	-7,132	-1,529	6,674
1973	4,950	687	0	5,637	-117	-3,654	-271	-3,119	-145	-7,306	-1,669	5,005
1974	4,956	726	0	5,683	-117	-3,863	-239	-3,140	-139	-7,498	-1,816	3,189
1975	4,963	765	0	5,728	-117	-4,069	-211	-3,159	-133	-7,689	-1,961	1,228
1976	4,982	804	0	5,787	-118	-4,278	-177	-3,185	-128	-7,885	-2,098	-870
1977	4,973	842	0	5,815	-117	-4,478	-140	-3,190	-122	-8,047	-2,232	-3,102
1978	4,977	881	0	5,858	-117	-4,687	-114	-3,201	-116	-8,235	-2,377	-5,479
1979	4,979	920	0	5,899	-117	-4,893	-74	-3,211	-109	-8,404	-2,505	-7,984
1980	4,993	960	0	5,952	-118	-5,102	-42	-3,227	-103	-8,592	-2,640	-10,624
1981	4,978	997	0	5,974	-117	-5,301	-24	-3,222	-97	-8,762	-2,788	-13,411
1982	4,976	1,036	0	6,013	-117	-5,511	-13	-3,224	-90	-8,956	-2,943	-16,354
1983	4,972	1,075	0	6,047	-117	-5,717	-5	-3,224	-84	-9,148	-3,100	-19,455
1984	4,981	1,115	0	6,096	-118	-5,927	-2	-3,231	-77	-9,355	-3,259	-22,714
1985	4,962	1,152	0	6,114	-117	-6,125	0	-3,219	-70	-9,531	-3,417	-26,131
1986	4,954	1,191	0	6,146	-117	-6,335	0	-3,212	-62	-9,727	-3,581	-29,712
1987	4,960	1,164	0	6,124	-117	-6,629	0	-3,185	-55	-9,986	-3,862	-33,575
1988	4,991	1,157	0	6,148	-118	-6,729	0	-3,147	-48	-10,042	-3,894	-37,469
1989	4,971	1,163	0	6,134	-117	-6,582	0	-3,150	-42	-9,892	-3,758	-41,226
1990	4,978	1,171	0	6,148	-117	-6,857	0	-3,183	-36	-10,194	-4,045	-45,272
1991	4,990	1,181	0	6,171	-117	-6,851	0	-3,212	-30	-10,210	-4,039	-49,311
1992	5,009	1,194	0	6,203	-118	-6,983	0	-3,193	-26	-10,320	-4,117	-53,428
1993	5,019	1,204	0	6,222	-117	-6,626	0	-3,202	-24	-9,970	-3,748	-57,175

Oeste Subarea

Simulated Water Budget Water Year 1951 - 2020
Upper Mojave River Basin Model
San Bernardino, California

a	b	c	d	e	f	g	h	i	j	k	l	m
	Inflows				Outflows							
Water Year	Mtn Rech (AF)	Ag Ret (AF)	Septic Ret (AF)	Total Inflow (AF)	Min Prod (AF)	Production (AF)	Dry Lakes (AF)	Oeste to Alto	Outflow to TZ	Total Outflow	Change in Storage (AF)	Cumulative change in Storage (AF)
1994	5,108	1,199	0	6,307	-117	-6,433	0	-3,322	-26	-9,899	-3,591	-60,767
1995	5,023	973	0	5,996	-117	-5,277	0	-3,289	-26	-8,709	-2,713	-63,480
1996	5,174	469	0	5,643	-118	-6,091	0	-3,301	-27	-9,536	-3,893	-67,373
1997	5,195	478	0	5,674	-117	-6,329	0	-3,298	-21	-9,765	-4,091	-71,464
1998	5,125	316	0	5,442	-117	-5,191	0	-3,319	-13	-8,641	-3,199	-74,663
1999	5,114	166	0	5,280	-117	-5,110	0	-3,315	-9	-8,551	-3,271	-77,934
2000	5,149	143	790	6,082	-118	-4,891	0	-3,311	-7	-8,327	-2,245	-80,178
2001	5,011	108	813	5,932	-117	-4,377	0	-3,303	-10	-7,807	-1,874	-82,052
2002	5,110	160	837	6,107	-117	-5,131	0	-3,286	-16	-8,550	-2,443	-84,495
2003	5,033	118	861	6,013	-117	-4,653	0	-3,265	-22	-8,058	-2,045	-86,540
2004	5,117	185	885	6,187	-118	-5,234	0	-3,239	-28	-8,619	-2,432	-88,972
2005	4,925	173	908	6,006	-117	-4,667	0	-3,213	-33	-8,031	-2,025	-90,997
2006	5,012	169	932	6,112	-117	-4,912	0	-3,188	-39	-8,256	-2,144	-93,141
2007	5,263	170	956	6,389	-117	-5,622	0	-3,138	-44	-8,921	-2,533	-95,674
2008	5,146	264	979	6,388	-116	-5,415	0	-3,157	-48	-8,736	-2,347	-98,021
2009	5,046	196	1,003	6,245	-115	-5,030	0	-3,205	-48	-8,399	-2,154	-100,175
2010	5,023	174	1,027	6,224	-115	-4,319	0	-3,289	-48	-7,771	-1,547	-101,722
2011	4,964	220	1,036	6,220	-115	-4,371	0	-3,365	-46	-7,897	-1,678	-103,399
2012	4,981	233	1,045	6,259	-116	-4,542	0	-3,398	-45	-8,101	-1,842	-105,241
2013	4,963	145	1,054	6,162	-115	-3,250	0	-3,377	-49	-6,791	-629	-105,870
2014	4,954	159	1,063	6,177	-115	-3,403	0	-3,368	-66	-6,952	-775	-106,645
2015	4,914	177	1,072	6,164	-115	-3,309	0	-3,392	-83	-6,900	-736	-107,381
2016	4,745	253	1,082	6,079	-116	-3,315	0	-3,411	-97	-6,939	-860	-108,241
2017	4,752	146	1,091	5,988	-115	-2,936	0	-3,411	-108	-6,570	-582	-108,823
2018	5,018	0	1,091	6,108	-115	-3,392	0	-3,426	-117	-7,051	-942	-109,765
2019	4,837	0	1,091	5,928	-115	-3,207	0	-3,463	-126	-6,912	-984	-110,749
2020	4,820	0	1,094	5,914	-116	-2,931	0	-3,479	-134	-6,660	-746	-111,495
Entire POR Average	4,939	485	296	5,720	-117	-3,874	-172	-3,051	-99	-7,313	-1,593	-113,088
Last 20 Year Average	4,982	152	996	6,130	-116	-4,201	0	-3,319	-60	-7,696	-1,566	

Column	**Description**	**Source**
A	Oct 1 to Sept 30, model period of record 1951-2020.	Watermaster
B	Ungaged inflow, deep percolation precipitation and mountain front recharge.	BCM
C	Estimate return flow from agriculture.	Watermaster and USGS (2001)
D	Estimated portion of indoor water use returned to the aquifer via septic.	MWA
E	Sum of elements of inflow.	-
F	Estimated production by Minimal Producers.	Watermaster
G	Estimated total pumping within Oeste.	Watermaster and USGS (2001)
H	Evaporation from dry lakes.	Model
I	Subsurface outflow to Alto.	Model
J	Subsurface outflow to Transition Zone.	Model
K	Sum of elements of outflow.	-
L	Gains or losses in storage on an annual basis.	-
M	Total accumulation of gains or losses at any point in time.	-

BROWNSTEIN HYATT FARBER SCHRECK, LLP
Attorneys at Law
1021 Anacapa Street, 2nd Floor
Santa Barbara, CA 93101

PROOF OF SERVICE

I am over the age of eighteen years and not a party to the within-entitled action. I am employed in Santa Barbara County, California. My business address is Brownstein Hyatt Farber Schreck, LLP, 1021 Anacapa Street, 2nd Floor, Santa Barbara, California 93101-2711. My electronic service address is Meldridge@bhfs.com. On September 5, 2024, I served a copy of the following document(s):

GOLDEN STATE WATER COMPANY'S EVIDENCE IN SUPPORT OF MOTION TO ENFORCE JUDGMENT - VOLUME 1

X BY E-MAIL OR ELECTRONIC TRANSMISSION: I caused a copy of the document(s) listed above to be sent to the persons at the e-mail addresses listed below

William J. Brunick, Esq. Leland P. McElhaney, Esq. Brunick, McElhaney & Kennedy, PLC P. O. Box 13130 San Bernardino, CA 92423-3130 Email: bbrunick@bmklawplc.com lmcelhaney@bmklawplc.com	Attorneys for Defendant/Cross-Complainant Mojave Water Agency
Valerie Wiegenstein Jeffrey D. Ruesch Watermaster Services Managers Mojave Basin Area Watermaster Mojave Water Agency 13846 Conference Center Drive Apple Valley, CA 92307 Email: vwiegenstein@MojaveWater.org jruesch@mojavewater.org	Mojave Basin Area Watermaster

I declare under penalty of perjury under the laws of the State of California that the above is true and correct. Executed on September 5, 2024, at Santa Barbara, California.

Melissa Eldridge

30883973.2

PROOF OF SERVICE

STATE OF CALIFORNIA }
COUNTY OF SAN BERNARDINO}

I am employed in the County of the San Bernardino, State of California. I am over the age of 18 and not a party to the within action; my business address is 13846 Conference Center Drive, Apple Valley, California 92307.

On September 6, 2024, the document(s) described below were served pursuant to the Mojave Basin Area Watermaster's Rules and Regulations paragraph 8.B.2 which provides for service by electronic mail upon election by the Party or paragraph 10.D, which provides that Watermaster shall mail a postcard describing each document being served, to each Party or its designee according to the official service list, a copy of which is attached hereto, and which shall be maintained by the Mojave Basin Area Watermaster pursuant to Paragraph 37 of the Judgment. Served documents will be posted to and maintained on the Mojave Water Agency's internet website for printing and/or download by Parties wishing to do so.

Document(s) filed with the court and served herein are described as follows:

GOLDEN STATE WATER COMPANY'S EVIDENCE IN SUPPORT OF MOTION TO ENFORCE JUDGMENT – VOLUME 1 (Pages GSWC 0001 to GSWC 0292)

_X_ (STATE) I declare under penalty of perjury under the laws of the State of California that the above is true and correct.

Executed on September 6, 2024 at Apple Valley, California.

Jeffrey D. Ruesch

Mojave Basin Area Watermaster Service List as of September 06, 2024

Attn: Roberto Munoz
35250 Yermo, LLC
11273 Palms Blvd., Ste. D.
Los Angeles, CA 90066-2122

Attn: John McCallum
Abshire, David V.
PO Box # 2059
Lucerne Valley, CA 92356-2059

Attn: Dwayne Oros
Adelanto, City Of
11600 Air Expressway
Adelanto, CA 92301-1914

(adesdevon@gmail.com)
Ades, John and Devon (via email)

Attn: Pedro Dumaua
(pdumaua@ducommun.com)
Aerochem, Inc. (via email)
4001 El Mirage Rd.
Adelanto, CA 92301-9489

Attn: Lori Clifton (lclifton@robar.com)
Agcon, Inc. (via email)
17671 Bear Valley Road
Hesperia, CA 92345-4902

Attn: Chun Soo and Wha Ja Ahn
(chunsooahn@naver.com)
Ahn Revocable Living Trust (via email)
P. O. Box 45
Apple Valley, CA 92307-0001

Attn: Simon Ahn (ssahn58@gmail.com)
Ahn Revocable Trust (via email)
29775 Hunter Road
Murrieta, CA 92563-6710

Attn: Chun Soo Ahn
(davidahnmd@gmail.com,
chunsooahn@naver.com;
davidahn0511@gmail.com)
Ahn, Chun Soo and David (via email)
P. O. Box 45
Apple Valley, CA 92307-0001

Attn: Chun Soo Ahn
(chunsooahn@naver.com)
Ahn, Chun Soo and Wha Ja (via email)
P. O. Box 45
Apple Valley, CA 92307-0001

Ake, Charles J. and Marjorie M.
2301 Muriel Drive, Apt. 67
Barstow, CA 92311-6757

Attn: Paul Tsai (paul@ezzlife.com)
America United Development, LLC (via email)
19625 Shelyn Drive
Rowland Heights, CA 91748-3246

Attn: Ana Chavez
American States Water Company
160 Via Verde, Ste. 100
San Dimas, CA 91773-5121

Anderson, Ross C. and Betty J.
13853 Oakmont Dr.
Victorville, CA 92395-4832

Attn: Daniel B. Smith (avfcwd@gmail.com)
Apple Valley Foothill County Water District (via email)
22545 Del Oro Road
Apple Valley, CA 92308-8206

Attn: Matthew Patterson
Apple Valley Heights County Water District
P. O. Box 938
Apple Valley, CA 92308-0938

Attn: Matthew Schulenberg
Apple Valley Unified School District
12555 Navajo Road
Apple Valley, CA 92308-7256

Attn: Emely and Joe Saltmeris
Apple Valley View Mutual Water Company
P. O. Box 3680
Apple Valley, CA 92307-0072

Attn: Tina Kuhns
Apple Valley, Town Of
14955 Dale Evans Parkway
Apple Valley, CA 92307-3061

(ArchibekFarms@gmail.com;
Sandi.Archibek@gmail.com)
Archibek, Eric (via email)
41717 Silver Valley Road
Newberry Springs, CA 92365-9517

Avila, Angel and Evalia
1523 S. Visalia
Compton, CA 90220-3946

Attn: Sheré R. Bailey
(LegalPeopleService@gmail.com)
Bailey 2007 Living Revocable Trust, Sheré R. (via email)
10428 National Blvd
Los Angeles, CA 90034-4664

Attn: Daniel Shaw (barhwater@gmail.com)
Bar H Mutual Water Company (via email)
P. O. Box 844
Lucerne Valley, CA 92356-0844

Barber, James B.
43774 Cottonwood Road
Newberry Springs, CA 92365

Attn: John Munoz
(barlenwater@hotmail.com;)
Bar-Len Mutual Water Company (via email)
P. O. Box 77
Barstow, CA 92312-0077

Attn: Curtis Palmer
Baron, Susan and Palmer, Curtis
141 Road 2390
Aztec, NM 87410-9322

Attn: Jennifer Riley (hriley@barstowca.org)
Barstow, City of (via email)
220 East Mountain View Street -Suite A
Barstow, CA 92311

Mojave Basin Area Watermaster Service List as of September 06, 2024

Bartels, Gwendolyn J.
156 W 100 N
Jerome, ID 83338-5256

Attn: Barbara Davisson
Bass Trust, Newton T.
14924 Chamber Lane
Apple Valley, CA 92307-4912

Attn: Remo E. Bastianon
Bastianon Revocable Trust
9484 Iroquois Rd.
Apple Valley, CA 92308-9151

Attn: Mike Beinschroth
(Beinschroth@gmail.com)
Beinschroth Family Trust (via email)
18794 Sentenac Road
Apple Valley, CA 92307-5342

Beinschroth, Andy Eric
6719 Deep Creek Road
Apple Valley, CA 92308-8711

Attn: Chuck Bell (Chuckb193@outlook.com; Chuckb193@outlook.com)
Bell, Charles H. Trust dated March 7, 2014 (via email)
P. O. Box 193
Lucerne Valley, CA 92356-0193

Best, Byron L.
21461 Camino Trebol
Lake Forest, CA 92630-2011

Attn: Deborah Stephenson
(stephenson@dmsnaturalresources.com; Jason.Murray@bnsf.com; Blaine.Bilderback@bnsf.com)
BNSF Railway Company (via email)
602 S. Ferguson Avenue, Suite 2
Bozeman, MT 59718-

Attn: Deborah Stephenson
(stephenson@dmsnaturalresources.com)
BNSF Railway Company (via email)
602 S. Ferguson Avenue, Suite 2
Bozeman, MT 59718-6483

Borja, Leonil T. and Tital L.
20784 Iris Canyon Road
Riverside, CA 92508-

Box, Geary S. and Laura
P. O. Box 402564
Hesperia, CA 92340-2564

Attn: Marvin Brommer
Brommer House Trust
9435 Strathmore Lane
Riverside, CA 92509-0941

Attn: Valeria Brown
Brown Family Trust Dated August 11, 1999
26776 Vista Road
Helendale, CA 92342-9789

Brown, Jennifer
10001 Choiceana Ave.
Hesperia, CA 92345

Bruneau, Karen
19575 Bear Valley Rd.
Apple Valley, CA 92308-5104

(irim@aol.com)
Bryant, Ian (via email)
15434 Sequoia Avenue - Office
Hesperia, CA 92345-1667

(bubierbear@msn.com)
Bubier, Diane Gail (via email)
46263 Bedford Rd.
Newberry Springs, CA 92365-9819

Attn: Noah Furie
Budget Finance Company
PO BOX 641339
Los Angeles, CA 90064-6339

Bunnell, Dick
8589 Volga River Circle
Fountain Valley, CA 92708-5536

(kjbco@yahoo.com)
Bush, Kevin (via email)
7768 Sterling Ave.
San Bernardino, CA 92410-4741

Attn: Kristie Wright
(Kristie.Wright@associa.us)
Calico Lakes Homeowners Association (via email)
11860 Pierce Street, Suite 100
Riverside, CA 92505-5178

Attn: William DeCoursey
(michael.lemke@dot.ca.gov; William.Decoursey@dot.ca.gov)
California Department Of Transportation (via email)
175 W. Cluster
San Bernardino, CA 92408-1310

Attn: Robert W. Bowcock
CalMat Company
405 N. Indian Hill Blvd.
Claremont, CA 91711-4614

Attn: Catalina Fernandez-Moores
(celias@calportland.com)
CalPortland Company - Agriculture (via email)
P. O. Box 146
Oro Grande, CA 92368-0146

Attn: Catalina Fernandez-Moores
(cfernandez@calportland.com)
CalPortland Company - Oro Grande Plant (via email)
P. O. Box 146
Oro Grande, CA 92368-0146

Attn: Tony Camanga
Camanga, Tony and Marietta
2309 Highland Heights Lane
Carrollton, TX 75007-2033

Attn: Myron Campbell II
Campbell, M. A. and Dianne
19327 Cliveden Ave
Carson, CA 90746-2716

Mojave Basin Area Watermaster Service List as of September 06, 2024

Carlton, Susan
445 Via Colusa
Torrance, CA 90505-

Attn: Denise Parra
Casa Colina Foundation
P.O. Box 1760
Lucerne Valley, CA 92356

Attn: Danielle Stewart (danielle.stewart@wildlife.ca.gov; Richard.Kim@wildlife.ca.gov; Alisa.Ellsworth@wildlife.ca.gov)
CDFW - Camp Cady (via email)
4775 Bird Farm Road
Chino Hills, CA 91709-3175

Attn: Jared Beyeler
CDFW - Mojave Narrows Regional Park
222 W. Hospitality Lane, 2nd Floor
San Bernardino, CA 92415-0023

Attn: Paco Cabral (paco.cabral@wildlife.ca.gov; askregion6@wildlife.ca.gov; aaron.johnson@wildlife.ca.gov)
CDFW - Mojave River Fish Hatchery (via email)
12550 Jacaranda Avenue
Victorville, CA 92395-5183

Attn: Environmental (valorie.moore@cemex.com)
Cemex, Inc. (via email)
16888 North E. Street
Victorville, CA 92394-2999

Attn: Jennifer Cutler
Center Water Company
P. O. Box 616
Lucerne Valley, CA 92356-0616

Attn: Nancy Ryman
Chamisal Mutual Water Company
P. O. Box 1444
Adelanto, CA 92301-2779

Attn: Carl Pugh (talk2betty@aol.com; cpugh3@aol.com)
Cheyenne Lake, Inc. (via email)
44658 Valley Center Rd.
Newberry Springs, CA 92365-

Attn: Micahel Chisram
Chisram, et al.
414 S. Lincoln Ave.
Monterey Park, CA 91775-3323

Choi, Yong Il and Joung Ae
34424 Mountain View Road
Hinkley, CA 92347-9412

(joan.chong7@gmail.com; joancksp@hotmail.com)
Chong, Joan (via email)
10392 Shady Ridge Drive
Santa Ana, CA 92705-7509

Christison, Joel
P. O. Box 2635
Big River, CA 92242-2635

Attn: Hwa-Yong Chung
Chung, et al.
11446 Midway Ave.
Lucerne Valley, CA 92356-8792

Clark, Arthur
P. O. Box 4513
Blue Jay, CA 92317-4513

Attn: Manoucher Sarbaz
Club View Partners
9903 Santa Monica Blvd., PMB #541
Beverly Hills, CA 90212-1671

Attn: Jaehwan Lee
Come Mission, Inc.
9965 Baker Road
Lucerne Valley, CA 92365-8490

Conner, William H.
11535 Mint Canyon Rd.
Agua Dulce, CA 91390-4577

Contratto, Ersula
13504 Choco Road
Apple Valley, CA 92308-4550

Attn: George Starke
Corbridge, Linda S.
8743 Vivero St
Rancho Cucamonga, CA 91730-

Cross, Sharon I.
P. O. Box 922
Lucerne Valley, CA 92356

Attn: Jay Hooper (jayho123@gmail.com)
Crown Cambria, LLC (via email)
9860 Gidley St.
El Monte, CA 91731-1110

Attn: Alessia Morris
Crystal Lakes Property Owners Association
P. O. Box 351
Yermo, CA 92398-0351

(dacostadean@gmail.com)
DaCosta, Dean Edward (via email)
32307 Foothill Road
Lucerne Valley, CA 92356-8526

Attn: Shanna Mitchell (daggettcsd@aol.com; daggettcsd@outlook.com; daggettwater427@gmail.com)
Daggett Community Services District (via email)
P. O. Box 308
Daggett, CA 92327-0308

Attn: Steve and Dana Rivett
Daggett Ranch, LLC
P. O. Box 112
Daggett, CA 92327-0112

Attn: James Kelly (James.Kelly@clearwayenergy.com)
Daggett Solar Power 3 LLC (via email)
5780 Fleet Street, Suite 130
Carlsbad, CA 92008-4715

Mojave Basin Area Watermaster Service List as of September 06, 2024

(ron@dadcopowerandlights.com)
Dahlquist, George R. (via email)
8535 Vine Valley Drive
Sun Valley, CA 91352-

Darr, James S.
40716 Highway 395
Boron, CA 93516

Attn: Alan L. De Jong
De Jong Family Trust
46561 Fairview Road
Newberry Springs, CA 92365-9230

Attn: Randy Wagner
Dennison, Quentin D. - Clegg, Frizell and Joke
44579 Temescal Street
Newberry Springs, CA 92365

Attn: Marie McDaniel
Desert Dawn Mutual Water Company
P. O. Box 392
Lucerne Valley, CA 92356-0392

Attn: Penny Zaritsky
(pennyzaritsky2000@yahoo.com)
Desert Girlz LLC (via email)
P. O. Box 709
Lucerne Valley, CA 92356-0709

Attn: Denise Courtney
Desert Springs Mutual Water Company
P. O. Box 396
Lucerne Valley, CA 92356-0396

Attn: Debby Wyatt
DLW Revocable Trust
13830 Choco Rd.
Apple Valley, CA 92307-5525

Attn: Judith Dolch-Partridge, Trustee
Dolch Living Trust Robert and Judith
4181 Kramer Lane
Bellingham, WA 98226-7145

Donaldson, Jerry and Beverly
16736 B Road
Delta, CO 81416-8501

Attn: Jeffery Lidman
Dora Land, Inc.
P. O. Box 1405
Apple Valley, CA 92307-0026

Attn: David Dorrance
Dorrance, David W. and Tamela L.
118 River Road Circle
Wimberley, TX 78676-5060

Attn: David Looper
Douglass, Tina
P.O. Box 1730
Lucerne Valley, CA 92356-

Dowell, Leonard
345 E Carson St.
Carson, CA 90745-2709

Evenson, Edwin H. and Joycelaine C.
P. O. Box 66
Oro Grande, CA 92368-0066

Attn: Stephanie L. Evert
(severt2166@aol.com)
Evert Family Trust (via email)
19201 Parker Circle
Villa Park, CA 92861-1302

Attn: David Dittenmore
(d2dittemore@bop.gov; rslayman@bop.gov)
Federal Bureau of Prisons, Victorville (via email)
P. O. Box 5400
Adelanto, CA 92301-5400

Fejfar, Monica Kay
34080 Ord Street
Newberry Springs, CA 92365-9791

(wwcc0626@gmail.com)
Feng, Jinbao (via email)
33979 Fremont Road
Newberry Springs, CA 92365-9136

(afc30@yahoo.com)
Fernandez, Arturo (via email)
28 Calle Fortuna
Rancho Santa Margarita, CA 92688-2627

Ferro, Dennis and Norma
1311 1st Ave. N
Jacksonville Beach, FL 32250-3512

(ropingmom3@yahoo.com)
Finch, Jenifer (via email)
9797 Lewis Lane
Apple Valley, CA 92308-8357

Attn: Alex and Jerrica Liu
(alexliu1950@gmail.com; alexroseanneliu@yahoo.com)
First CPA LLC (via email)
46669 Valley Center Rd
Newberry Springs, CA 92365-

Attn: Mike Fischer
(carlsfischer@hotmail.com; fischer@fischercompanies.com)
Fischer Revocable Living Trust (via email)
1372 West 26th St.
San Bernardino, CA 92405-3029

Attn: Paul Johnson
Fisher Trust, Jerome R.
7603 Hazeltine Ave
Van Nuys, CA 91405-1423

Attn: Daisy Cruz
Foothill Estates MHP, LLC
9454 Wilshire Blvd., Ste. 920
Beverly Hills, CA 90212-2925

(cfrates@renewablegroup.com)
Frates, D. Cole (via email)
113 S La Brea Ave., 3rd Floor
Los Angeles, CA 90036-2998

Attn: Deborah A. Friend
Friend, Joseph and Deborah
P. O. Box 253
Barstow, CA 92312-0253

Attn: Mark Asay (bettybrock@ironwood.org; waltbrock@ironwood.org)
Fundamental Christian Endeavors, Inc. (via email)
49191 Cherokee Road
Newberry Springs, CA 92365

Gabrych, Eugene
2006 Old Highway 395
Fallbrook, CA 92028

Gabrych, Eugene
2006 Old Highway 395
Fallbrook, CA 92028-8816

Gaeta, Miguel and Maria
9366 Joshua Avenue
Lucerne Valley, CA 92356-8273

Attn: Jay Storer
Gaeta, Trinidad
10551 Dallas Avenue
Lucerne Valley, CA 92356

Garcia, Daniel
223 Rabbit Trail
Lake Jackson, TX 77566-3728

Attn: Sang Hwal Kim
Gardena Mission Church, Inc.
P. O. Box 304
Lucerne Valley, CA 92356-0304

Garg, Om P.
358 Chorus
Irvine, CA 92618-1414

Attn: Brent Peterson
Gayjikian, Samuel and Hazel
34534 Granite Road
Lucerne Valley, CA 92356-

Attn: Jeffrey Edwards
(jedwards@fbremediation.com)
GenOn California South, LP (via email)
P. O. Box 337
Daggett, CA 92327-0337

(Nereida.Gonzalez@gswater.com,
ana.chavez@gswater.com)
Golden State Water Company (via email)
160 Via Verde, Ste. 100
San Dimas, CA 91773-5121

Attn: Nereida Gonzalez
(ana.chavez@gswater.com,
Nereida.Gonzalez@gswater.com)
Golden State Water Company (via email)
160 Via Verde, Ste. 100
San Dimas, CA 91773-5121

Attn: Scot Gasper
Gordon Acres Water Company
P. O. Box 1035
Lucerne Valley, CA 92356-1035

Gray, George F. and Betty E.
975 Bryant
Calimesa, CA 92320-1301

Attn: Brian E. Bolin
Green Acres Estates
P. O. Box 29
Apple Valley, CA 92307-0001

Attn: Eric Archibek
Green Hay Packers LLC
41717 Silver Valley Road
Newberry Springs, CA 92365-9517

Attn: Nick Grill (terawatt@juno.com)
Grill, Nicholas P. and Millie D. (via email)
35350 Mountain View Rd
Hinkley, CA 92347-9613

Gubler, Hans
P. O. Box 3100
Landers, CA 92285

Attn: Tamara J Skoglund
(TamaraMcKenzie@aol.com)
Gulbranson, Merlin (via email)
511 Minnesota Ave W
Gilbert, MN 55741-

Gutierrez, Jose and Gloria
24116 Santa Fe
Hinkley, CA 92347

Attn: Bryan C. Haas and Mary H. Hinkle
(resrvc4you@aol.com)
Haas, Bryan C. and Hinkle, Mary H. (via email)
14730 Tigertail Road
Apple Valley, CA 92307-5249

(hackbarthoffice@gmail.com)
Hackbarth, Edward E. (via email)
12221 Poplar Street, Unit #3
Hesperia, CA, CA 92344-9287

Attn: Doug and Cheryl Hamilton
Hamilton Family Trust
19945 Round Up Way
Apple Valley, CA 92308-8338

Attn: William Handrinos
Handrinos, Nicole A.
1140 Parkdale Rd.
Adelanto, CA 92301-9308

Hang, Phu Quang
645 S. Shasta Street
West Covina, CA 91791-2818

Attn: Donald F. Hanify
Hanify, Michael D., dba - White Bear Ranch
PO BOX 1021
Yermo, CA 92398-1021

Attn: Matt Wood
(Matthew.wood@martinmarietta.com)
Hanson Aggregates WRP, Inc. (via email)
P. O. Box 1115
Corona, CA 92878-1115

Attn: Mary Jane Hareson
Hareson, Nicholas and Mary
1737 Anza Avenue
Vista, CA 92084-3236

Attn: Kenny Harmsen (harmsencow@aol.com)
Harmsen Family Trust (via email)
23920 Community Blvd.
Hinkley, CA 92347-9721

Harter, Joe and Sue
10902 Swan Lake Road
Klamath Falls, OR 97603-9676

(harveyl.92356@gmail.com)
Harvey, Lisa M. (via email)
P. O. Box 1187
Lucerne Valley, CA 92356-

Haskins, James J.
11352 Hesperia Road, #2
Hesperia, CA 92345-2165

Hass, Pauline L.
P. O. Box 273
Newberry Springs, CA 92365-

Attn: Craig Carlson (kcox@helendalecsd.org; ccarlson@helendalecsd.org)
Helendale Community Services District (via email)
P. O. Box 359
Helendale, CA 92342-0359

Attn: Joshua Maze
Helendale School District
P. O. Box 249
Helendale, CA 92342-0249

Attn: Jeff Gallistel
Hendley, Rick and Barbara
P. O. Box 972
Yermo, CA 92398-0972

Hensley, Mark P.
35523 Mountain View Rd
Hinkley, CA 92347-9613

Attn: Jeremy McDonald (jmcdonald@cityofhesperia.us)
Hesperia - Golf Course, City of (via email)
9700 Seventh Avenue
Hesperia, CA 92345-3493

Attn: Janie Martines (janiemartines@gmail.com)
Hesperia Venture I, LLC (via email)
10 Western Road
Wheatland, WY 82201-8936

Attn: Jeremy McDonald (jmcdonald@cityofhesperia.us)
Hesperia Water District (via email)
9700 7th Avenue
Hesperia, CA 92345-3493

Attn: Jeremy McDonald (tsouza@cityofhesperia.us)
Hesperia, City of (via email)
9700 Seventh Avenue
Hesperia, CA 92345-3493

Attn: Carabeth Carter ()
Hettinga Revocable Trust (via email)
P. O. Box 455
Ehrenberg, AZ 84334-0455

Attn: Lisset Sardeson
Hi Desert Mutual Water Company
23667 Gazana Street
Barstow, CA 92311

(leehiett@hotmail.com)
Hiett, Harry L. (via email)
P. O. Box 272
Daggett, CA 92327-0272

Attn: Robert W. Bowcock
High Desert Associates, Inc.
405 North Indian Hill Blvd.
Claremont, CA 91711-4614

Attn: Lori Clifton (lclifton@robar.com)
Hi-Grade Materials Company (via email)
17671 Bear Valley Rd
Hesperia, CA 92345-4902

Attn: Lori Clifton (lclifton@robar.com)
Hi-Grade Materials Company (via email)
17671 Bear Valley Road
Hesperia, CA 92345-4902

Attn: Frank Hilarides
Hilarides 1998 Revocable Family Trust
37404 Harvard Road
Newberry Springs, CA 92365

Attn: Katherine Hill (Khill9@comcast.net)
Hill Family Trust and Hill's Ranch, Inc. (via email)
84 Dewey Street
Ashland, OR 97520-

Attn: Anne Roark
Hitchin Lucerne, Inc.
P. O. Box 749
Lucerne Valley, CA 92356-0749

Ho, Ting-Seng and Ah-Git
P.O. Box 20001
Bakersfield, CA 93390-0001

Attn: Joan Rohrer
Hollister, Robert H. and Ruth M.
22832 Buendia
Mission Viejo, CA 92691-

Attn: Jeffrey R Holway and Patricia Gage (patricia.gage@yahoo.com)
Holway Jeffrey R and Patricia Gage (via email)
1401 Wewatta St. #1105
Denver, CO 80202-1348

Holway, Jeffrey R
1401 Wewatta St. #1105
Denver, CO 80202-1348

Attn: Katherine K. Hsu
Holy Heavenly Lake, LLC
1261 S. Lincoln Ave.
Monterey Park, CA 91755-5017

Attn: Paul Hong
Hong, Paul B. and May
P. O. Box #1432
Covina, CA 91722-0432

Attn: Sandra D. Hood
Hood Family Trust
2142 W Paseo Del Mar
San Pedro, CA 90732-4557

Attn: Barry Horton
Horton Family Trust
47716 Fairview Road
Newberry Springs, CA 92365-9258

Attn: Ester Hubbard
Hubbard, Ester and Mizuno, Arlean
47722 Kiloran St.
Newberry Springs, CA 92365-9529

Attn: Paul Johnson
Huerta, Hector
25684 Community Blvd
Barstow, CA 92311-

(hconnie630@gmail.com)
Hunt, Connie (via email)
39392 Burnside Loop
Astoria, OR 97103-8248

Attn: Ralph Hunt
Hunt, Ralph M. and Lillian F.
P. O. Box 603
Yermo, CA 92398-0603

Attn: Daniel and Karen Gray
(calivolunteer@verizon.net)
Hyatt, James and Brenda (via email)
31726 Fremont Road
Newberry Springs, CA 92365

(econorx@yahoo.com)
Im, Nicholas Nak-Kyun (via email)
23329 Almarosa Ave.
Torrance, CA 90505-3121

Irvin, Bertrand W.
3224 West 111th Street
Inglewood, CA 90303-

Attn: James Jackson Jr.
Jackson, James N. Jr Revocable Living Trust
1245 S. Arlington Avenue
Los Angeles, CA 90019-3517

Attn: Lawrence Dean
Jackson, Ray Revocable Trust No. 45801
P.O. Box 8250
Redlands, CA 92375-1450

Attn: Audrey Goller
(audrey.goller@newportpacific.com)
Jamboree Housing Corporation (via email)
15940 Stoddard Wells Rd - Office
Victorville, CA 92395-2800

Attn: Gary A. Ledford
(gleddream@gmail.com)
Jess Ranch Water Company (via email)
906 Old Ranch Road
Florissant, CO 80816-

Attn: Cynthia Mahoney
(cyndisue87@yahoo.com)
Johnson, Carlean F. Trust Dated 10/29/2004 (via email)
8626 Deep Creek Road
Apple Valley, CA 92308-8769

Attn: Paul Johnson
(johnsonfarming@gmail.com)
Johnson, Paul - Industrial (via email)
10456 Deep Creek Road
Apple Valley, CA 92308-8330

Johnson, Ronald
1156 Clovis Circle
Dammeron Valley, UT 84783-5211

Attn: Lawrence W. Johnston
Johnston, Harriet and Johnston, Lawrence W.
P. O. Box 401472
Hesperia, CA 92340-1472

Attn: Magdalena Jones
(mygoldenbiz9@gmail.com)
Jones Trust dated March 16, 2002 (via email)
35424 Old Woman Springs Road
Lucerne Valley, CA 92356-7237

Attn: Paul Jordan
Jordan Family Trust
1650 Silver Saddle Drive
Barstow, CA 92311-2057

Attn: Ray Gagné
Jubilee Mutual Water Company
P. O. Box 1016
Lucerne Valley, CA 92356

Attn: Lee Logsdon
Juniper Riviera County Water District
P. O. Box 618
Lucerne Valley, CA 92356-0618

Attn: Ash Karimi
Karimi, Hooshang
1254 Holmby Ave
Los Angeles, CA 90024-

Attn: Robert R. Kasner
(Robertkasner@aol.com)
Kasner Family Limited Partnership (via email)
11584 East End Avenue
Chino, CA 91710-

(Robertkasner@aol.com)
Kasner, Robert (via email)
11584 East End Avenue
Chino, CA 91710-1555

Attn: Martin A and Mercedes Katcher
Katcher, August M. and Marceline
12928 Hyperion Lane
Apple Valley, CA 92308-4565

Kemp, Robert and Rose
48441 National Trails Highway
Newberry Springs, CA 92365

Attn: Peggy Shaughnessy
Kemper Campbell Ranch
10 Kemper Campbell Ranch Road - Office
Victorville, CA 92395-3357

Kim, Jin S. and Hyun H.
6205 E Garnet Circle
Anaheim, CA 92807-4857

Attn: Alan and Annette De Jong
Kim, Joon Ho and Mal Boon Revocable Trust
46561 Fairview Road
Newberry Springs, CA 92365-9230

(juskim67@yahoo.com)
Kim, Ju Sang (via email)
1225 Crestview Dr
Fullerton, CA 92833-2206

Kim, Seon Ja
34981 Piute Road
Newberry Springs, CA 92365-9548

Attn: Richard Koering
Koering, Richard and Koering, Donna
40909 Mountain View Road
Newberry Springs, CA 92365-9414

Attn: Catherine Cerri
(ccerri@lakearrowheadcsd.com)
Lake Arrowhead Community Services District (via email)
P. O. Box 700
Lake Arrowhead, CA 92352-0700

Attn: Claire Cabrey
(HandleWithClaire@aol.com; mjaynes@mac.com)
Lake Jodie Property Owners Association (via email)
8581 Santa Monica Blvd., #18
West Hollywood, CA 90069-4120

Attn: Nancy Lan
Lake Waikiki
230 Hillcrest Drive
La Puente, CA 91744-4816

Attn: c/o J.C. UPMC, Inc. Lori Rodgers
(ljm9252@aol.com; timrohmbuilding@gmail.com)
Lake Wainani Owners Association (via email)
2812 Walnut Avenue, Suite A
Tustin, CA 92780-7053

(PhillipLam99@Yahoo.com)
Lam, Phillip (via email)
864 Sapphire Court
Pomona, CA 91766-5171

(jlangley@kurschgroup.com)
Langley, James (via email)
12277 Apple Valley Road, Ste. #120
Apple Valley, CA 92308-1701

Attn: Vanessa Laosy
Lavanh, et al.
18203 Yucca St.
Hesperia, CA 92345-

Attn: Robert Lawrence Jr.
Lawrence, William W.
P. O. Box 98
Newberry Springs, CA 92365

Lawson, Ernest and Barbara
20277 Rock Springs Road
Apple Valley, CA 92308-8740

Attn: Anna K. Lee (aklee219@gmail.com)
Lee, Anna K. and Eshban K. (via email)
10979 Satsuma St
Loma Linda, CA 92354-6113

Lee, Doo Hwan
P. O. Box 556
Lucerne Valley, CA 92356-0556

Attn: Sepoong & Woo Poong Lee
Lee, et al., Sepoong and Woo Poong
#6 Ensueno East
Irvine, CA 92620-

Lee, Vin Jang T.
42727 Holcomb Trl
Newberry Springs, CA 92365

Attn: Virginia Janovsky
(virginiajanovsky@yahoo.com)
Lem, Hoy (via email)
17241 Bullock St.
Encino, CA 91316-1473

Lenhert, Ronald and Toni
4474 W. Cheyenne Drive
Eloy, AZ 85131-3410

Attn: Brad Francke
LHC Alligator, LLC
P. O. Box 670
Upland, CA 91785-0670

Attn: Billy Liang
Liang, Yuan - I and Tzu - Mei Chen
4192 Biscayne St
Chino, CA 91710-3196

Attn: Eric Larsen
(eric.larsen@libertyutilities.com; tony.pena@libertyutilities.com)
Liberty Utilities (Apple Valley Ranchos Water) Corp. (via email)
P. O. Box 7005
Apple Valley, CA 92307

Attn: James Lin
Lin, Kuan Jung and Chung, Der-Bing
2026 Turnball Canyon
Hacienda Heights, CA 91745-

Attn: Manshan Gan
Lo, et al.
5535 N Muscatel Ave
San Gabriel, CA 91776-1724

Attn: Neal Davies (ndavies@terra-gen.com; dkelly@terra-gen.com)
Lockhart Land Holding, LLC (via email)
43880 Harper Lake Road
Hinkley, CA 92347-

Attn: Patricia Miranda
Lopez, Baltazar
12318 Post Office Rd
Lucerne Valley, CA 92356-

(lowgo.dean@gmail.com)
Low, Dean (via email)
3 Panther Creek Ct.
Henderson, NV 89052-

Lua, Michael T. and Donna S.
18838 Aldridge Place
Rowland Heights, CA 91748-4890

Attn: Gwen L. Bedics
Lucerne Valley Mutual Water Company
P. O. Box 1311
Lucerne Valley, CA 92356

Attn: Manoucher Sarbaz
Lucerne Valley Partners
9903 Santa Monica Blvd., PMB #541
Beverly Hills, CA 90212-1671

Attn: Marian Walent
(LVVMC677@gmail.com)
Lucerne Vista Mutual Water Company (via email)
P. O. Box 677
Lucerne Valley, CA 92356-0677

Attn: Eugene R. & Vickie R. Bird
M Bird Construction
1613 State Street, Ste. 10
Barstow, CA 92311-4162

Mojave Basin Area Watermaster Service List as of September 06, 2024

Attn: Maria Martinez
M.B. Landscaping and Nursery, Inc.
6831 Lime Avenue
Long Beach, CA 90805-1423

Attn: Robert Saidi
Mahjoubi, Afsar S.
46622 Fairview Road
Newberry Springs, CA 92365

Attn: Jimmy Berry
Manning, Sharon S.
19332 Balan Road
Rowland Heights, CA 91748-4017

Attn: Allen Marcroft
Marcroft, James A. and Joan
P. O. Box 519
Newberry Springs, CA 92365

Attn: James M. Hansen, Jr. (gm@mrcwd.org; gmmrcwd@gmail.com)
Mariana Ranchos County Water District (via email)
9600 Manzanita Street
Apple Valley, CA 92308-8605

Marshall, Charles
32455 Lakeview Road
Newberry Springs, CA 92365-9482

Martin, Michael D. and Arlene D.
32942 Paseo Mira Flores
San Juan Capistrano, CA 92675

Attn: Rod Sexton
McCollum, Charles L.
15074 Spruce St
Hesperia, CA 92345-2950

McKinney, Paula
144 East 72nd
Tacoma, WA 98404-1060

Attn: Olivia L. Mead
Mead Family Trust
31314 Clay River Road
Barstow, CA 92311-2057

Attn: David I. Milbrat
Milbrat, Irving H.
P. O. Box 487
Newberry Springs, CA 92365-0487

Attn: Donna Miller
Miller Living Trust
6124 Parsonage Circle
Milton, FL 32570-8930

Attn: Freddy Garmo (freddy@garmolaw.com)
Minn15 LLC (via email)
5464 Grossmont Center Drive, #300
La Mesa, CA 91942-3035

Attn: David Riddle (driddle@mitsubishicement.com)
Mitsubishi Cement Corporation (via email)
5808 State Highway 18
Lucerne Valley, CA 92356-8179

Attn: Philip Mizrahie
Mizrahie, et al.
4105 W. Jefferson Blvd.
Los Angeles, CA 90048-

Attn: Thomas A. Hrubik (tahgolf@aol.com)
MLH, LLC (via email)
P. O. Box 2611
Apple Valley, CA 92307-0049

Attn: Sarah Bliss
Mojave Desert Land Trust
60124 29 Palms Highway
Joshua Tree, CA 92252-4130

Attn: Mahnas Ghamati (mahnaz.ghamati@atlantica.com)
Mojave Solar, LLC (via email)
42134 Harper Lake Road
Hinkley, CA 92347-9305

Attn: Doug Kerns (aanabtawi@mojavewater.org)
Mojave Water Agency (via email)
13846 Conference Center Drive
Apple Valley, CA 92307-4377

Attn: Doug Kerns (tmccarthy@mojavewater.org)
Mojave Water Agency (via email)
13846 Conference Center Drive
Apple Valley, CA 92307-4377

Attn: Manoucher Sarbaz
Monaco Investment Company
9903 Santa Monica Blvd., PMB #541
Beverly Hills, CA 90212-1671

Attn: Ken Elliot (Billie@ElliotsPlace.com)
Morris Trust, Julia V. (via email)
7649 Cypress Dr.
Lanexa, VA 23089-9320

Moss, Lawrence W. and Helen J.
38338 Old Woman Springs Road Spc# 56
Lucerne Valley, CA 92356-8116

Attn: Bradford Ray Most
Most Family Trust
39 Sundance Circle
Durango, CO 81303-8131

Attn: Dennis Hills
Mulligan, Robert and Inez
35575 Jakobi Street
Saint Helens, OR 97051-1194

Murphy, Jean
46126 Old National Trails Highway
Newberry Springs, CA 92365-9025

(z.music5909@gmail.com; zajomusic@gmail.com)
Music, Zajo (via email)
43830 Cottonwood Rd
Newberry Springs, CA 92365-8510

Attn: James Hansen (gm@marianaranchoscwd.org)
Navajo Mutual Water Company (via email)
21724 Hercules St.
Apple Valley, CA 92308-8490

Attn: Billy Liang (flossdaily@hotmail.com; asaliking@yahoo.com)
New Springs Limited Partnership (via email)
4192 Biscayne St.
Chino, CA 91710-3196

Attn: Jodi Howard
Newberry Community Services District
P. O. Box 220
Newberry Springs, CA 92365-0220

Attn: Jeff Gaastra (jeffgaastra@gmail.com)
Newberry Springs Recreational Lakes Association (via email)
32935 Dune Road, Space 10
Newberry Springs, CA 92365-

Attn: Mary Ann Norris
Norris Trust, Mary Ann
29611 Exeter Street
Lucerne Valley, CA 92356-8261

Attn: Kenton Eatherton (keatherton@verizon.net)
NSSLC, Inc. (via email)
9876 Moon River Circle
Fountain Valley, CA 92708-7312

Nuñez, Luis Segundo
9154 Golden Seal Court
Hesperia, CA 92345-0197

Attn: Pearl or Gail Nunn
Nunn Family Trust
P. O. Box 545
Apple Valley, CA 92307-0010

Attn: Jeff Gaastra (jeffgaastra@gmail.com; andy@seesmachine.com; bbswift4044@cox.net)
O. F. D. L., Inc. (via email)
32935 Dune Road, #10
Newberry Springs, CA 92365-9175

Attn: Chun Soo Ahn (chunsooahn@naver.com)
Oasis World Mission (via email)
P. O. Box 45
Apple Valley, CA 92307-0001

Attn: Kody Tompkins (ktompkins@barstowca.org)
Odessa Water District (via email)
220 E. Mountain View Street, Suite A
Barstow, CA 92311-2888

Attn: Dorothy Ohai
Ohai, Reynolds and Dorothy
13450 Monte Vista
Chino, CA 91710-5149

Attn: Craig Maetzold (craig.maetzold@omya.com)
Omya California, Inc. (via email)
7225 Crystal Creek Rd
Lucerne Valley, CA 92356-8646

Attn: John P. Oostdam
Oostdam Family Trust, John P. and Margie K.
24953 Three Springs Road
Hemet, CA 92545-2246

Attn: Nick Higgs
Oro Grande School District
P. O. Box 386
Oro Grande, CA 92368-0386

Attn: Taghi Shoraka
P and H Engineering and Development Corporation
1423 South Beverly Glen Blvd. Apt. A
Los Angeles, CA 90024-6171

Attn: Jessica Bails (J4Dx@pge.com)
Pacific Gas and Electric Company (via email)
22999 Community Blvd.
Hinkley, CA 92347-9592

Pak, Kae Soo and Myong Hui Kang
P. O. Box 1835
Lucerne Valley, CA 92356-1835

Patino, José
3914 W. 105th Street
Inglewood, CA 90303-1815

(wndrvr@aol.com)
Paustell, Joan Beinschroth (via email)
10275 Mockingbird Ave.
Apple Valley, CA 92308-8303

Pearce, Craig L.
127 Columbus Dr
Punxsutawney, PA 15767-1270

Perko, Bert K.
P. O. Box 762
Yermo, CA 92398-0762

Pettigrew, Dan
285 N Old Hill Road
Fallbrook, CA 92028-2571

Attn: Sean Wright (swright@pphcsd.org; dbartz@pphcsd.org; llowrance@pphcsd.org)
Phelan Piñon Hills Community Services District (via email)
4176 Warbler Road
Phelan, CA 92371-8819

Attn: John Poland
Poland, John R. and Kathleen A.
5511 Tenderfoot Drive
Fontana, CA 92336-1156

Polich, Donna
75 3rd Avenue #4
Chula Vista, CA 91910-1714

Porter, Timothy M.
34673 Little Dirt Road
Newberry Springs, CA 92365-9646

Attn: Carin McKay
Precision Investments Services, LLC
791 Price Street, #160
Pismo Beach, CA 93449-2529

Price, Donald and Ruth
933 E. Virginia Way
Barstow, CA 92311-4027

Pruett, Andrea
P. O. Box 37
Newberry Springs, CA 92365

(s_quakenbush@yahoo.com)
Quakenbush, Samuel R. (via email)
236 Iris Drive
Martinsburg, WV 25404-1338

Attn: Ron Herrmann
Quiros, Fransisco J. and Herrmann, Ronald
35969 Newberry Rd
Newberry Springs, CA 92365-9438

Attn: Elizabeth Murena (waterboy7F8@msn.com; etminav@aol.com)
Rancheritos Mutual Water Company (via email)
P. O. Box 348
Apple Valley, CA 92307

Reed, Mike
9864 Donaldson Road
Lucerne Valley, CA 92356-8105

Attn: Brian C. Vail (bvail@river-west.com)
Reido Farms, LLC (via email)
2410 Fair Oaks Blvd., Suite 110
Sacramento, CA 95825-7666

(LucerneJujubeFarm@hotmail.com)
Rhee, Andrew N. (via email)
11717 Fairlane Rd, #989
Lucerne Valley, CA 92356-8829

Attn: Kelly Rice
Rice, Henry C. and Diana
31823 Fort Cady Rd.
Newberry Springs, CA 92365-

Attn: Ian Bryant
Rim Properties, A General Partnership
15434 Sequoia Road
Hesperia, CA 92345-1667

Attn: Josie Rios
Rios, Mariano V.
P. O. Box 1864
Barstow, CA 92312-1864

Rivero, Fidel V.
612 Wellesley Drive
Corona, CA 92879-0825

(RayRizvi@Yahoo.com)
Rizvi, S.R Ali (via email)
4054 Allyson Terrace
Freemont, CA 94538-4186

Attn: Bill Taylor or Property Mngr (billt@rrmca.com)
Robertson's Ready Mix (via email)
200 S. Main Street, Suite 200
Corona, CA 92882-2212

Attn: Susan Sommers (sommerssqz@aol.com)
Rossi Family Trust, James Lawrence Rossi and Naomi (via email)
P. O. Box 120
Templeton, CA 93465-0120

Attn: Robert Vega
Royal Way
2632 Wilshire Blvd., #480
Santa Monica, CA 90403-4623

Attn: Sam Marich
Rue Ranch, Inc.
P. O. Box 133109
Big Bear Lake, CA 92315-8915

Attn: Dale W. Ruisch
Ruisch Trust, Dale W. and Nellie H.
10807 Green Valley Road
Apple Valley, CA 92308-3690

Attn: Sherwin Shoraka
S and B Brothers, LLC
1423 S. Beverly Glen Blvd., Ste. A
Los Angeles, CA 90024-6171

Attn: Jafar Rashid (jr123realestate@gmail.com)
S and E 786 Enterprises, LLC (via email)
3300 S. La Cienega Blvd.
Los Angeles, CA 90016-3115

Attn: Sara Fortuna (sarajfortuna@gmail.com; fourteengkids@aol.com)
Saba Family Trust dated July 24, 2018 (via email)
212 Avenida Barcelona
San Clemente, CA 92672-5468

Attn: Kanoe Barker (kanoebarker@yahoo.com)
Sagabean-Barker, Kanoeolokelani L. (via email)
42224 Valley Center Rd
Newberry Springs, CA 92365

(BILLU711@Yahoo.com)
Samra, Jagtar S. (via email)
10415 Edgebrook Way
Northridge, CA 91326-3952

San Bernardino Co Barstow - Daggett Airport
268 W. Hospitality Lane, Suite 302
San Bernardino, CA 92415-0831

Attn: Jared Beyeler (waterquality@sdd.sbcounty.gov)
San Bernardino County - High Desert Detention Center (via email)
222 W. Hospitality Lane, 2nd Floor - SDW
San Bernardino, CA 92415-0415

Attn: Trevor Leja (trevor.leja@sdd.sbcounty.gov)
San Bernardino County Service Area 29 (via email)
222 W. Hospitality Lane, 2nd Floor (Spec
San Bernardino, CA 92415-0450

Attn: Jared Beyeler (ssamaras@sdd.sbcounty.gov; jbeyeler@sdd.sbcounty.gov; waterquality@sdd.sbcounty.gov)
San Bernardino County Service Area 42 (via email)
222 W. Hospitality Lane, 2nd Floor - SDW
San Bernardino, CA 92415-0450

Attn: Jared Beyeler (ssamaras@sdd.sbcounty.gov; jbeyeler@sdd.sbcounty.gov; waterquality@sdd.sbcounty.gov)
San Bernardino County Service Area 64 (via email)
222 W. Hospitality Lane, 2nd Floor - SDW
San Bernardino, CA 92415-0450

Attn: Jared Beyeler (ssamaras@sdd.sbcounty.gov; jbeyeler@sdd.sbcounty.gov; waterquality@sdd.sbcounty.gov)
San Bernardino County Service Area 70J (via email)
222 W. Hospitality Lane, 2nd Floor - SDW
San Bernardino, CA 92415-0450

Attn: Michelle Scray (mcscray@gmail.com)
Scray, Michelle A. Trust (via email)
16869 State Highway 173
Hesperia, CA 92345-9381

Attn: Rod Sexton
Sexton, Rodney A. and Sexton, Derek R.
P.O. Box 155
Rim Forest, CA 92378-

Attn: Joseph Tapia
Sheep Creek Water Company
P. O. Box 291820
Phelan, CA 92329-1820

Sheng, Jen
5349 S Sir Richard Dr
Las Vegas, NV 89110-0100

(gloriasheppard14@gmail.com)
Sheppard, Thomas and Gloria (via email)
33571 Fremont Road
Newberry Springs, CA 92365-9520

Short, Jerome E.
P. O. Box 1104
Barstow, CA 92312-1104

Attn: Carlos Banuelos
(maint@silverlakesassociation.com;
fibarra@silverlakesassociation.com)
Silver Lakes Association (via email)
P. O. Box 179
Helendale, CA 92342-0179

Attn: Nepal Singh (NepalSingh@yahoo.com)
Singh, et al. (via email)
4972 Yearling Avenue
Irvine, CA 92604-2956

Attn: Denise Smith
Smith, Denise dba Amerequine Beauty, Inc
P. O. Box 188
Newberry Springs, CA 92365-0188

Smith, Porter and Anita
8443 Torrell Way
San Diego, CA 92126-1254

Attn: Steve Kim (stevekim1026@gmail.com)
Snowball Development, Inc. (via email)
P. O. Box 2926
Victorville, CA 92393-2926

Attn: Chan Kyun Son
Son's Ranch
P. O. Box 1767
Lucerne Valley, CA 92356

Attn: Erika Clement
(Shannon.Oldenburg@SCE.com;
erika.clement@sce.com)
Southern California Edison Company (via email)
2 Innovation Way, 2nd Floor
Pomona, CA 91768-2560

Attn: Maria de Lara Cruz
(maria.delaracruz@mineralstech.com)
Specialty Minerals, Inc. (via email)
P. O. Box 558
Lucerne Valley, CA 92356-0558

Sperry, Wesley
P. O. Box 303
Newberry Springs, CA 92365-0303

Spillman, James R. and Nancy J.
12132 Wilshire
Lucerne Valley, CA 92356-8834

Attn: Eric Miller (emiller@svla.com;
alogan@svla.com;)
Spring Valley Lake Association (via email)
SVL Box 7001
Victorville, CA 92395-5107

Attn: Joe Trombino
Spring Valley Lake Country Club
7070 SVL Box
Victorville, CA 92395-5152

Attn: Father Sarapamon
St. Antony Coptic Orthodox Monastery
P. O. Box 100
Barstow, CA 92311-0100

(chiefgs@verizon.net)
Starke, George A. and Jayne E. (via email)
8743 Vivero Street
Rancho Cucamonga, CA 91730-1152

Storm, Randall
51432 130th Street
Byars, OK 74831-7357

Sudmeier, Glenn W.
14253 Highway 138
Hesperia, CA 92345-9422

Attn: Alexandra Lioanag
(sandra@halannagroup.com)
Summit Valley Ranch, LLC (via email)
220 Montgomery Street, Suite PH-10
San Francisco, CA 94104-3433

Attn: Alex Vienna
Sundown Lakes, Inc.
P. O. Box 364
Newberry Springs, CA 92365-0364

Attn: Stephen H. Douglas
(sdouglas@centaurusenergy.com;
mdoublesin@centcap.net;
cre.notices@clenera.com)
Sunray Land Company, LLC (via email)
1717 West Loop South, Suite 1800
Houston, TX 77027-3049

Attn: Venny Vasquez (lbaroldi@synagro.com)
Synagro-WWT, Inc. (dba Nursury Products, LLC) (via email)
P. O. Box 1439
Helendale, CA 92342-

Attn: Russell Szynkowski
Szynkowski, Ruth J.
46750 Riverside Rd.
Newberry Springs, CA 92365-9738

Attn: Bill and Elizabeth Tallakson
(billtallakson@sbcglobal.net)
Tallakson Family Revocable Trust (via email)
11100 Alto Drive
Oak View, CA 93022-9535

Tapie, Raymond L.
73270 Desert Greens Dr N
Palm Desert, CA 92260-1206

Taylor, Sharon L.
14141 State Hwy 138
Hesperia, CA 92345-9339

(jerryteisan@gmail.com)
Teisan, Jerry (via email)
P. O. Box 2089
Befair, WA 98528-2089

Attn: Daryl or Lucinda Lazenby
Thayer, Sharon
P. O. Box 845
Luceren Valley, CA 92356-

Attn: Stephen Thomas
Thomas, Stephen and Lori
4890 Topanga Canyon Bl.
Woodland Hills, CA 91364-4229

Attn: Lynnette L. Thompson
Thompson Living Trust, James A. and Sula B.
22815 Del Oro Road
Apple Valley, CA 92308

Attn: Rodger Thompson
Thompson Living Trust, R.L. and R.A.
9141 Deep Creek Road
Apple Valley, CA 92308-8351

Thrasher, Gary
14024 Sunflower Lane
Oro Grande, CA 92368-9617

Attn: Doug Heinrichs
Thunderbird County Water District
P. O. Box 1105
Apple Valley, CA 92307-1105

Attn: Jim Hoover
Triple H Partnership
35870 Fir Ave
Yucaipa, CA 92399-9635

Attn: Mike Troeger (mjtroeger@yahoo.com)
Troeger Family Trust, Richard H. (via email)
P. O. Box 24
Wrightwood, CA 92397

Turner, Terry
726 Arthur Lane
Santa Maria, CA, CA 93455-7403

Attn: Aurelio Ibarra (aibarra@up.com; powen@up.com)
Union Pacific Railroad Company (via email)
HC1 Box 33
Kelso, CA 92309-

(druppal@aicdent.com)
Uppal, Gagan (via email)
220 S Owens Drive
Anaheim, CA 92808-1327

(gagevaage23@gmail.com)
Vaage, Gage V. (via email)
47150 Black Butte Road
Newberry Springs, CA 92365-9698

Vaca, Andy and Teresita S.
5550 Avenue Juan Bautista
Riverside, CA 92509-5613

Attn: Dean Van Bastelaar
Van Bastelaar, Alphonse
45475 Martin Road
Newberry Springs, CA 92365-9625

Attn: Glen and Jennifer Van Dam (gvandam@verizon.net)
Van Dam Family Trust, Glen and Jennifer (via email)
3190 Cottonwood Avenue
San Jacinto, CA 92582-4741

Attn: Jacob Bootsma
Van Leeuwen Trust, John A. and Ietie
44128 Silver Valley Road
Newberry Springs, CA 92365-9588

Attn: John Driscoll
Vernola Trust, Pat and Mary Ann
P. O. Box 2190
Temecula, CA 92593-2190

Attn: John Nahlen
Victor Valley Community College District
18422 Bear Valley Road, Bldg 10
Victorville, CA 92395-5850

Attn: Jade Kiphen
Victor Valley Memorial Park
17150 C Street
Victorville, CA 92395-3330

Attn: Arnold Villarreal (avillarreal@victorvilleca.gov; ccun@victorvilleca.gov)
Victorville Water District, ID#1 (via email)
P. O. Box 5001
Victorville, CA 92393-5001

Attn: Arnold Villarreal (avillarreal@victorvilleca.gov; kmetzler@victorvilleca.gov; snawaz@victorvilleca.gov)
Victorville Water District, ID#1 (via email)
P. O. Box 5001
Victorville, CA 92393-5001

Attn: Arnold Villarreal (sashton@victorvilleca.gov; avillarreal@victorvilleca.gov; dmathews@victorvilleca.gov)
Victorville Water District, ID#2 (via email)
PO Box 5001
Victorville, CA 92393-5001

Vogler, Albert H.
17612 Danbury Ave.
Hesperia, CA 92345-7073

Attn: Joan Wagner
Wagner Living Trust
22530 Calvert Street
Woodland Hills, CA 91367-1704

Attn: Christian Joseph Wakula
Wakula Family Trust
11741 Ardis Drive
Garden Grove, CA 92841-2423

(Jlow3367@gmail.com)
Wang, Steven (via email)
2551 Paljay Avenue
Rosemead, CA 91770-3204

Ward, Raymond
P. O. Box 358
Newberry Springs, CA 92365-0358

Weems, Lizzie
9157 Veranda Court
Las Vegas, NV 89149-0480

Weeraisinghe, Maithri N.
P. O. Box 487
Barstow, CA 92312-0487

(andrewwerner11@gmail.com)
Werner, Andrew J. (via email)
1718 N Sierra Bonita Ave
Los Angeles, CA 90046-2231

Attn: James Woody
West End Mutual Water Company
P. O. Box 1732
Lucerne Valley, CA 92356

West, Howard and Suzy
9185 Loma Vista Road
Apple Valley, CA 92308-0557

West, Jimmie E.
P. O. Box 98
Oro Grande, CA 92368-0098

Attn: Nick Gatti ()
Western Development and Storage, LLC (via email)
5701 Truxtun Avenue, Ste. 201
Bakersfield, CA 93309-0402

Attn: Chung Cho Gong
Western Horizon Associates, Inc.
P. O. Box 397
Five Points, CA 93624-0397

Attn: Genaro Zapata
Westland Industries, Inc.
520 W. Willow St.
Long Beach, CA 90806-2800

Attn: Thomas G. Ferruzzo (tferruzzo@ferruzzo.com)
Wet Set, Inc. (via email)
44505 Silver Valley Road, Lot #05
Newberry Springs, CA 92365-9565

Wiener, Melvin and Mariam S.
1626 N. Wilcox Avenue
Los Angeles, CA 90028-6234

Attn: Manoucher Sarbaz
Wilshire Road Partners
9903 Santa Monica Blvd., PMB #541
Beverly Hills, CA 90212-1671

Attn: Connie Tapie (praisethelord77777@yahoo.com)
Withey, Connie (via email)
P. O. Box 3513
Victorville, CA 92393-3513

Witte, E. Daniel and Marcia
31911 Martino Drive
Daggett, CA 92327-9752

Attn: Mark J. Cluff
WLSR, Inc.
3507 N 307th Drive
Buckeye, AZ 85396-6746

Attn: David A. Worsey
Worsey, Joseph A. and Revae
P. O. Box 422
Newberry Springs, CA 92365-0422

(thechelseaco@yahoo.com)
Yang, Zilan (via email)
428 S. Atlantic Blvd #205
Monterey Park, CA 91754-3228

Attn: Christine M. Carson, Esq. (ccarson@awattorneys.com)
Aleshire & Wynder, LLP (via email)
3880 Lemon Street
Suite 520
Riverside, CA 92501-

Attn: Robert Hensley, Esq. (rhensley@awattorneys.com)
Aleshire & Wynder, LLP (via email)
3880 Lemon Street
Suite 520
Riverside, CA 92501-

Attn: Pam Lee, Esq. (plee@awattorneys.com)
Aleshire & Wynder, LLP (via email)
3880 Lemon Street
Suite 520
Riverside, CA 92501-

Attn: Alison Paap (apaap@agloan.com)
American AgCredit (via email)
42429 Winchester Road
Temecula, CA 92590-2504

Attn: Wesley A. Miliband, Esq. (wes.miliband@aalrr.com)
Atkinson, Andelson, Loya, Ruud & Romo (via email)
2151 River Plaza Drive
Suite 300
Sacramento, CA 95833-

Attn: W.W. Miller, Esq. (bmiller@aalrr.com)
Atkinson, Andelson, Loya-Ruud & Romo (via email)
3612 Mission Inn Avenue, Upper Level
Riverside, CA 92501

Attn: Christopher L. Campbell, Esq.
Baker, Manock & Jensen
5260 N. Palm Avenue, 4th Floor
Fresno, CA 93704-2209

Attn: Aloson Toivola, Esq. (alison.toivola@bbklaw.com)
Best, Best & Krieger LLP (via email)
300 South Grand Avenue
25th Floor
Los Angeles, CA 90071

Attn: Eric L. Garner, Esq. (eric.garner@bbklaw.com)
Best, Best & Krieger LLP (via email)
3750 University Avenue
3rd Floor
Riverside, CA 92502-1028

Attn: Piero C. Dallarda, Esq.
(piero.dallarda@bbklaw.com)
Best, Best & Krieger LLP (via email)
P.O. Box 1028
Riverside, CA 92502-

Attn: Christopher Pisano, Esq.
(christopher.pisano@bbklaw.com)
Best, Best & Krieger LLP (via email)
300 South Grand Avenue
25th Floor
Los Angeles, CA 90071

Attn: Stephanie Osler Hastings, Esq.
(SHastings@bhfs.com; mcarlson@bhfs.com)
Brownstein Hyatt Farber Schreck, LLP (via email)
1021 Anacapa Street, 2nd Floor
Santa Barbara, CA 93101-2102

Attn: William J. Brunick, Esq.
(bbrunick@bmklawplc.com)
Brunick, McElhaney & Kennedy PLC (via email)
1839 Commercenter West
P.O. Box 13130
San Bernardino, CA 92423-3130

Attn: Terry Caldwell, Esq.
Caldwell & Kennedy
15476 West Sand Street
Victorville, CA 92392

Attn: Stephen Puccini
(stephen.puccini@wildlife.ca.gov)
California Department of Fish and Wildlife (via email)
,

Attn: Alexander Devorkin, Esq.
California Department of Transportation
100 South Main Street, Suite 1300
Los Angeles, CA 90012-3702

Attn: Nancy McDonough
California Farm Bureau Federation
2300 River Plaza Drive
Sacramento, CA 95833

Attn: Jeffery L. Caufield, Esq.
(Jeff@caufieldjames.com)
Caufield & James, LLP (via email)
2851 Camino Del Rio South, Suite 410
San Diego, CA 92108-

Attn: Andrew L. Jared, Esq.
(ajared@chwlaw.us)
Colantuono, Highsmith & Whatley, PC (via email)
790 E. Colorado Blvd., Suite 850
Pasadena, CA 91101-2109

Attn: Matthew T. Summers, Esq.
(msummers@chwlaw.us)
Colantuono, Highsmith & Whatley, PC (via email)
790 E. Colorado Blvd., Suite 850
Pasadena, CA 91101-2109

Attn: Maria Insixiengmay
(Maria.Insixiengmay@cc.sbcounty.gov)
County of San Bernardino, County Counsel (via email)
385 N. Arrowhead Avenue, 4th Floor
San Bernardino, CA 92415-0140

Attn: Robert E. Dougherty, Esq.
Covington & Crowe
1131 West 6th Street
Suite 300
Ontario, CA 91762

Attn: Ed Dygert, Esq.
Cox, Castle & Nicholson
3121 Michelson Drive, Ste. 200
Irvine, CA 92612-

Attn: Noah GoldenKrasner, Dep
(Noah.GoldenKrasner@doj.ca.gov)
Department of Justice (via email)
300 S. Spring Street, Suite 1700
Los Angeles, CA 90013

Attn: Marilyn Levin, Dep
(Marilyn.Levin@doj.ca.gov)
Department of Justice (via email)
300 S. Spring Street, Suite 1702
Los Angeles, CA 90013

Attn: Diana Carloni, Esq.
(diana@carlonilaw.com)
Diana J. Carloni (via email)
21001 N. Tatum Blvd.
Suite 1630-455
Phoenix, AZ 85050-

Attn: James S. Heiser, Esq.
Ducommun, Inc.
23301 S. Wilmington Avenue
Carson, CA 90745

Attn: Michele Hinton, Ms.
(mhinton@fennemorelaw.com)
Fennemore LLP (via email)
8080 N Palm Ave, Third Floor
Fresno, CA 93711-

Attn: Kelly Ridenour, Ms.
(kridenour@fennemorelaw.com)
Fennemore LLP (via email)
550 East Hospitality Lane
Suite 350
San Bernardino, CA 92408-4206

Attn: Marlene Allen Murray, Esq.
(mallenmurray@fennemorelaw.com)
Fennemore LLP (via email)
550 East Hospitality Lane
Suite 350
San Bernardino, CA 92408-4206

Attn: Derek Hoffman, Esq.
(dhoffman@fennemorelaw.com)
Fennemore LLP (via email)
550 East Hospitality Lane
Suite 350
San Bernardino, CA 92408-4206

Attn: Thomas G. Ferruzzo, Esq.
(tferruzzo@ferruzzo.com)
Ferruzzo & Ferruzzo, LLP (via email)
3737 Birch Street, Suite 400
Newport Beach, CA 92660

Attn: Toby Moore, PhD, PG, CHG
(TobyMoore@gswater.com)
Golden State Water Company (via email)
160 W. Via Verde, Suite 100
San Dimas, CA 91773-

Attn: Andre de Bortnowsky, Esq.
(andre@gblawoffices.com)
Green de Bortnowsky, LLP (via email)
30077 Agoura Court, Suite 210
Agoura Hills, CA 91301-2713

Attn: Michelle McCarron, Esq.
(mmccarron@gdblawoffices.com;
andre@gdblawoffices.com)
Green de Bortnowsky, LLP (via email)
30077 Agoura Court, Suite 210
Agoura Hills, CA 91301-2713

Attn: Calvin R. House, Esq.
Gutierrez, Preciado & House
3020 E. Colorado BLVD
Pasadena, CA 91107-3840

Mojave Basin Area Watermaster Service List as of September 06, 2024

Attn: Curtis Ballantyne, Esq.
Hill, Farrer & Burrill
300 S. Grand Avenue, 37th Floor
1 California Plaza
Los Angeles, CA 90071

Attn: Michael Turner, Esq.
(mturner@kasdancdlaw.com)
Kasdan, LippSmith Weber Turner, LLP (via email)
19900 MacArthur Blvd., Suite 850
Irvine, CA 92612-

Attn: Mitchell Kaufman, Esq.
(mitch@kmcllp.com)
Kaufman McAndrew LLP (via email)
16633 Ventura Blvd., Ste. 500
Encino, CA 91436-1835

Attn: Thomas S. Bunn, Esq.
(TomBunn@lagerlof.com)
Lagerlof, Senecal, Gosney & Kruse, LLP (via email)
301 N. Lake Avenue, 10th Floor
Pasadena, CA 91101-5123

Attn: Peter J. Kiel, Esq.
(pkiel@cawaterlaw.com)
Law Office of Peter Kiel PC (via email)
PO Box 422
Petaluma, CA 94953-0422

Attn: Fred J. Knez, Esq.
Law Offices of Fred J. Knez
6780 Indiana Ave, Ste 150
Riverside, CA 92506-4253

Attn: Robert C. Hawkins, Esq.
Law Offices of Robert C. Hawkins
14 Corporate Plaza, Suite 120
Newport, CA 92660

Attn: Arthur G. Kidman, Esq.
McCormick, Kidman & Behrens
695 Town Center Drive, Suite 400
Costa Mesa, CA 92626-7187

Attn: Jeffrey D Ruesch
(watermaster@mojavewater.org)
Mojave Basin Area Watermaster (via email)
13846 Conference Center Drive
Apple Valley, CA 92307

Attn: Adnan Anabtawi
(aanabtawi@mojavewater.org)
Mojave Water Agency (via email)
13846 Conference Center Drive
Apple Valley, CA 92307

Attn: Frederic A. Fudacz, Esq.
(ffudacz@nossaman.com)
Nossaman LLP (via email)
777 South Figueroa Street, 34th Floor
Los Angeles, CA 90017-

Attn: Kieth Lemieux
(KLemieux@omlolaw.com)
Olivarez Madruga Lemieux O'Neill, LLP (via email)
500 South Grand Avenue, 12th Floor
Los Angeles, CA 90071-2609

Attn: Betsy Brunswick (bmb7@pge.com)
Pacific Gas and Electric Company (via email)
77 Beale Street, B28P
San Francisco, CA 94105-1814

Attn: Joesfina M. Luna, Esq.
(fluna@redwineandsherrill.com)
Redwine and Sherrill (via email)
3890 Eleventh Street
Suite 207
Riverside, CA 92501-

Attn: Steven B. Abbott, Esq.
(sabbott@redwineandsherrill.com; fluna@redwineandsherrill.com)
Redwine and Sherrill (via email)
3890 Eleventh Street
Suite 207
Riverside, CA 92501-

Attn: Todd O. Maiden, Esq.
(TMaiden@ReedSmith.com)
Reed Smith LLP (via email)
101 Second Street
Suite 1800
San Francisco, CA 94105-

Attn: James L. Markman, Esq.
Richards, Watson & Gershon
1 Civic Center Circle
P.O. Box 1059
Brea, CA 92822-1059

Attn: Elizabeth Hanna, Esq.
Rutan & Tucker
P.O. Box 1950
Costa Mesa, CA 92626

Attn: Randall R. Morrow, Esq.
Sempra Energy Law Department
Office of the General Counsel
555 West Fifth Street, Suite 1400
Los Angeles, CA 90013-1011

Attn: Shannon Oldenburg, Esq.
(shannon.oldenburg@sce.com)
Southern California Edison Company
Legal Department (via email)
P.O. Box 800
Rosemead, CA 91770

Attn: ()
Southern California Gas Company
Transmission Environmental Consultant (via email)
,

Attn: Rick Ewaniszyk, Esq.
The Hegner Law Firm
14350 Civc Drive
Suite 270
Victorville, CA 92392

Attn: Agnes Vander Dussen Koetsier
(beppeauk@aol.com)
Vander Dussen Trust, Agnes & Edward (via email)
P.O. Box 5338
Blue Jay, CA 92317-

Attn: Robert C. Wagner, P.E.
(rcwagner@wbecorp.com)
Wagner & Bonsignore
Consulting Civil Engineers (via email)
2151 River Plaza Drive, Suite 100
Sacramento, CA 95833-4133