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

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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 ΔS=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, ΔS=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.

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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

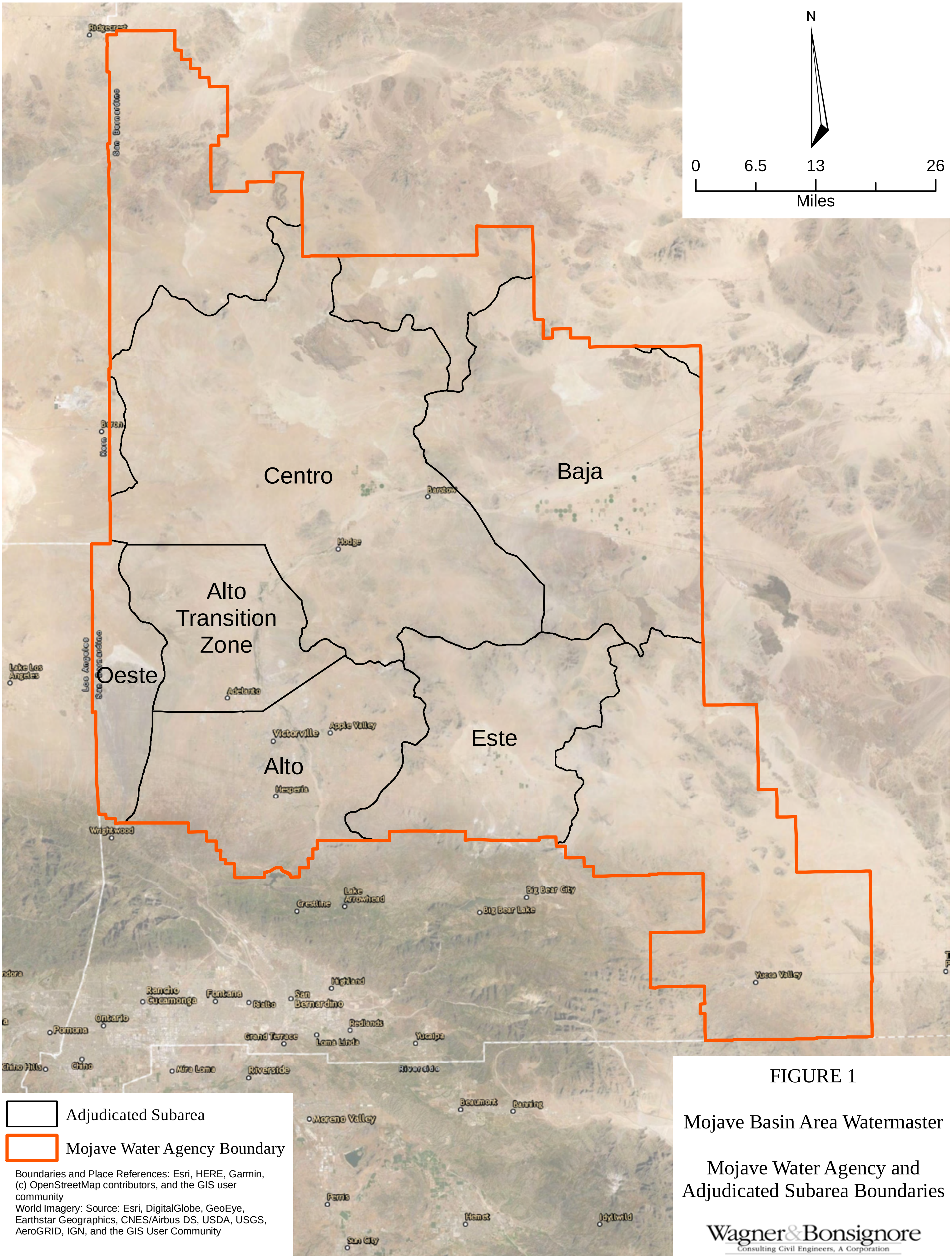

FIGURE 1

Mojave Basin Area Watermaster

Mojave Water Agency and Adjudicated Subarea Boundaries

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

June 2020

Figure 2

Free Body Diagram of Ground Water Model for Mojave Basin Area

San Bernardino County, California

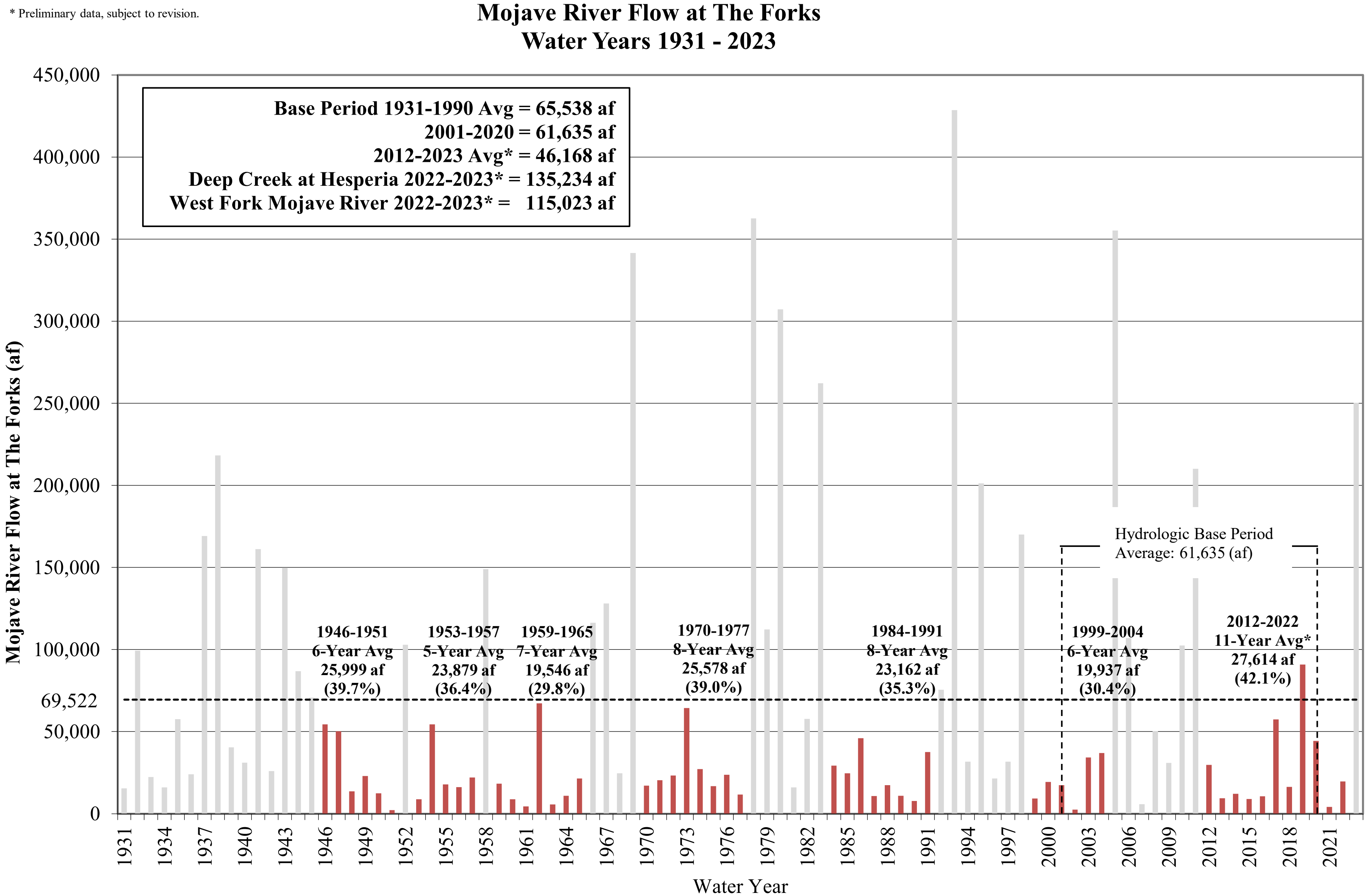
Wagner Bonsignore
Consulting Civil Engineers, A Corporation

February 2024

2/20/2024

Figure 3

* Preliminary data, subject to revision.



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

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Consulting Civil Engineers, A Corporation

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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).

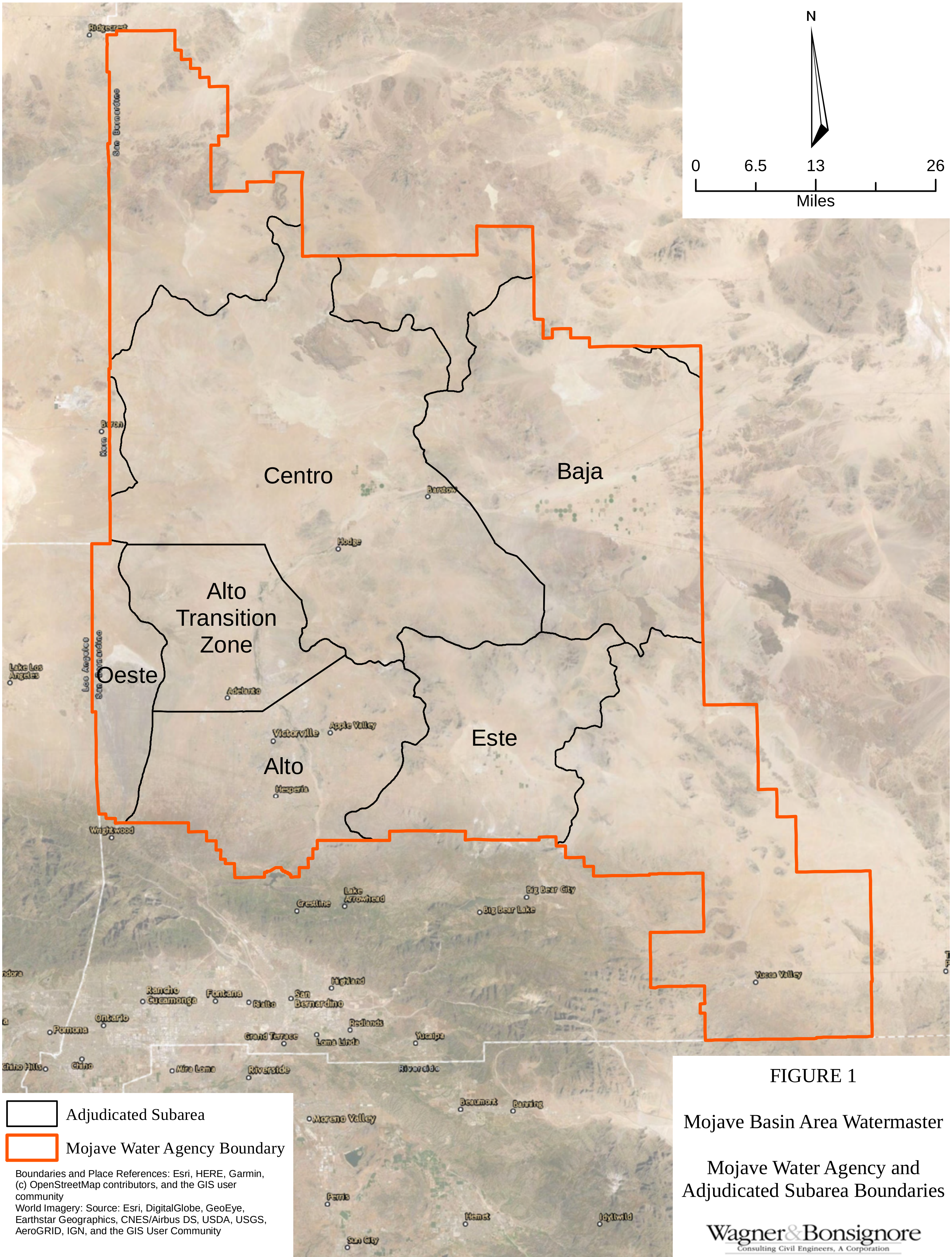
The inflow to Centro is considered to be the outflow from Alto. The outflow from Centro consists of average discharge (2001-2020) at the USGS Barstow gaging station, the net discharge from the Barstow wastewater treatment plant, subsurface discharge to the Baja subarea, water use by phreatophytes and 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
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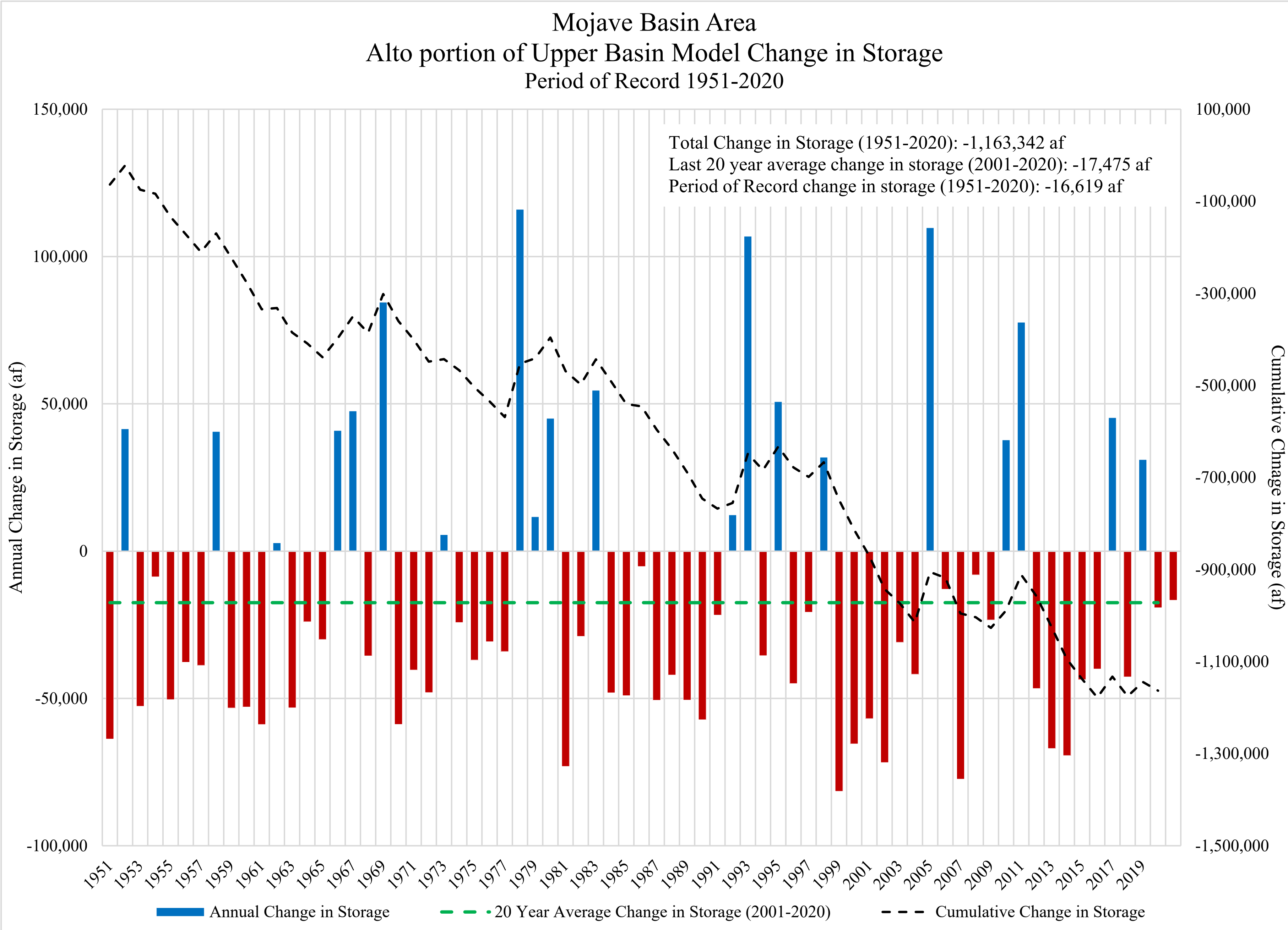
June 2020

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

FIGURE 2



G:\MOJAVE ADJUDICATION - 3020\Analysis\Groundwater Modeling\1-Alto\3020-009M-Table 6.1 Summary of Model Parameters Alto-V4.xlsx

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

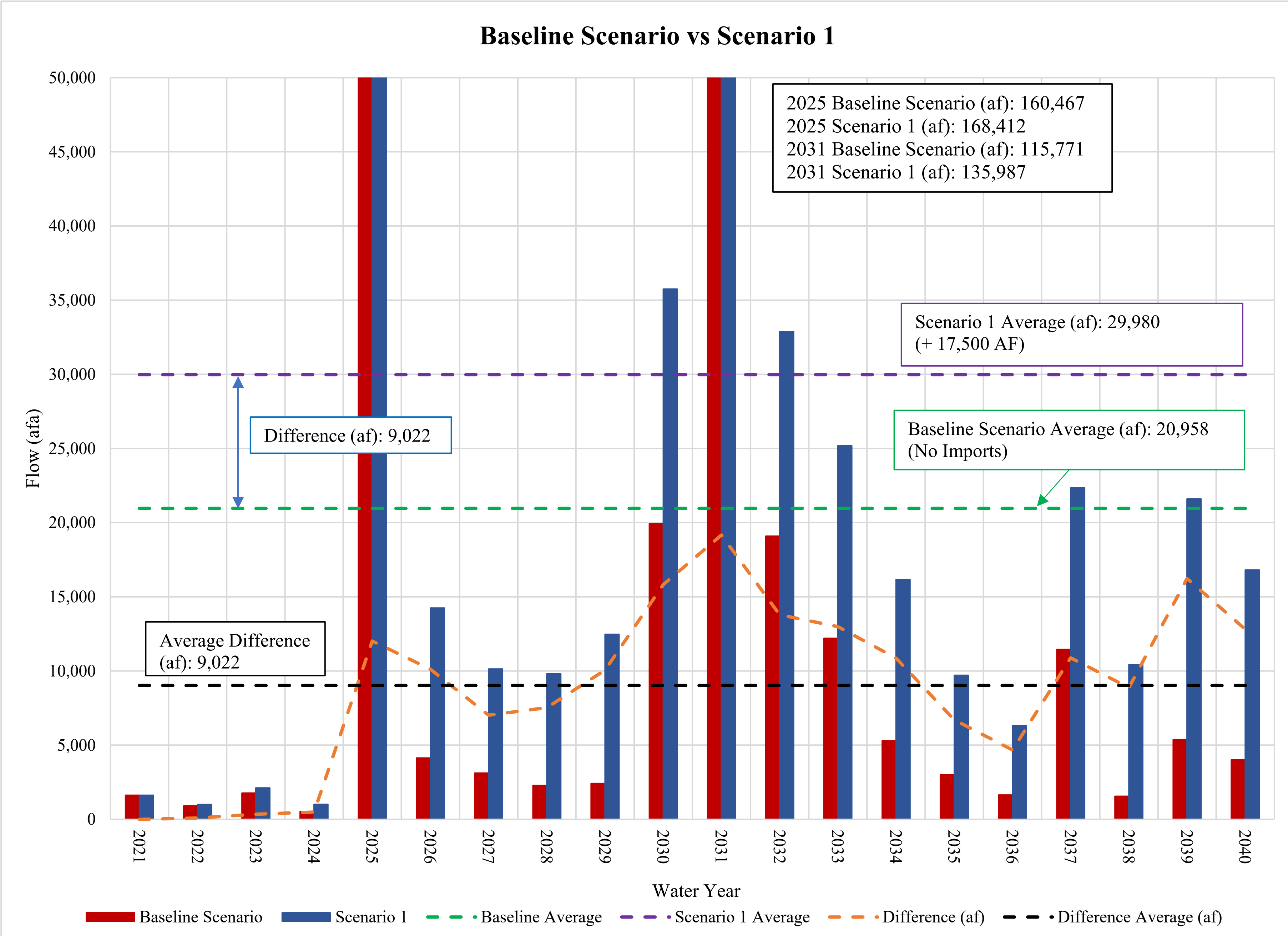


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TABLE 1

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

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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).

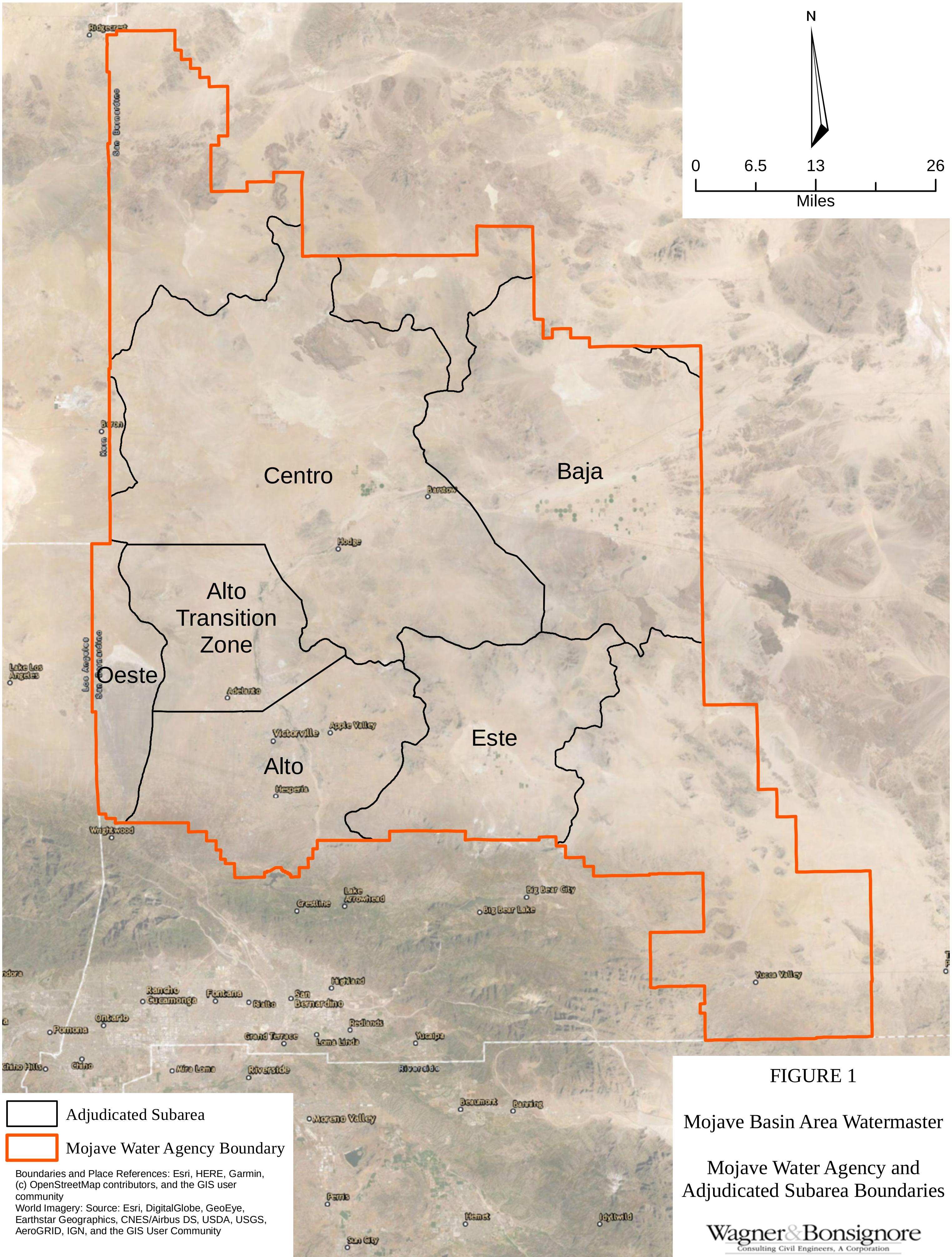
The TZ is the area generally lying between the Lower Narrows, Mojave River, and the Helendale Fault (see Fig 1). Department of Water Resources Bulletin 84, 1967 was a foundational technical document guiding development of the Judgment. The Alto Subarea was drawn to be consistent with the Upper Mojave 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

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

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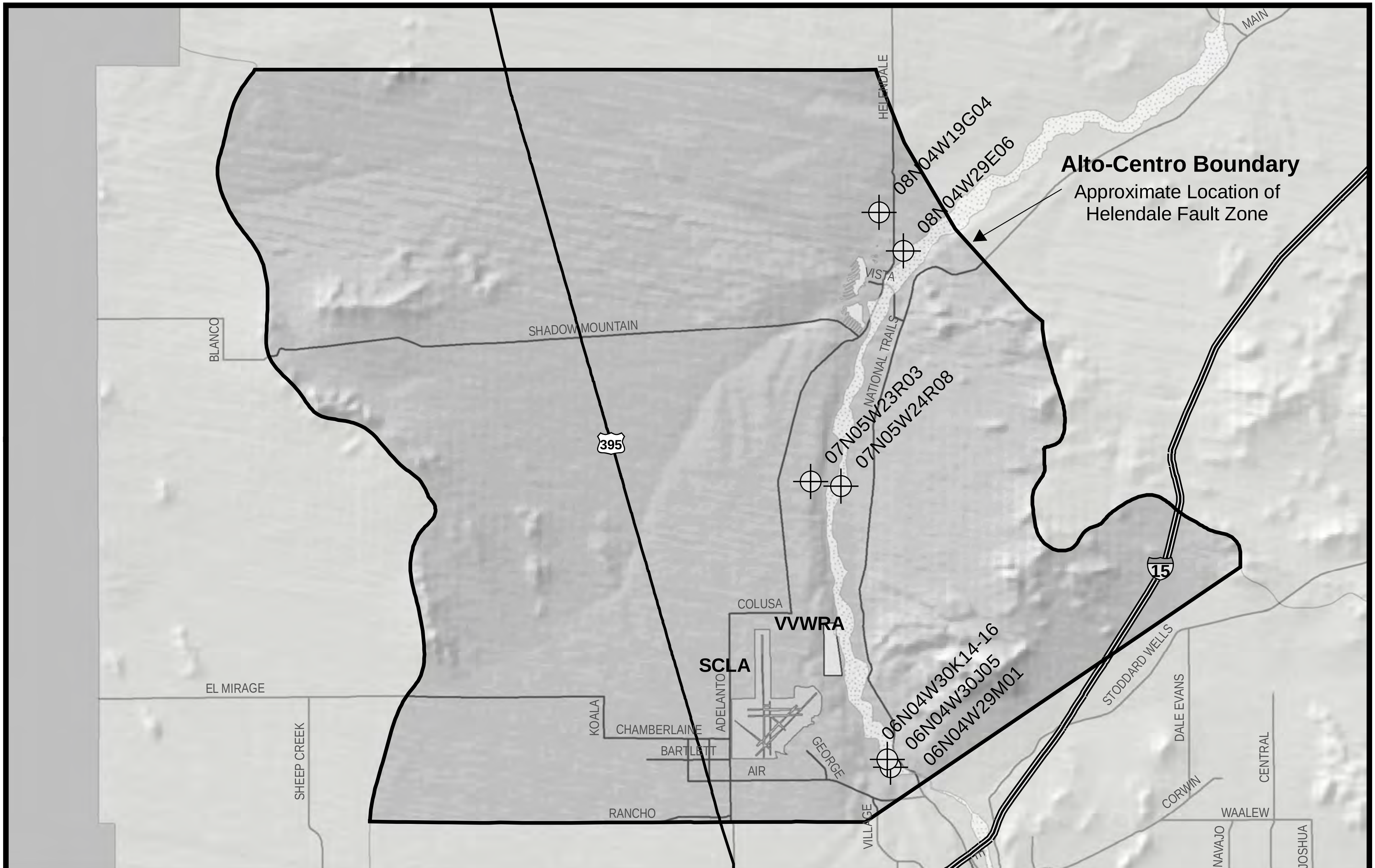
Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

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

June 2020

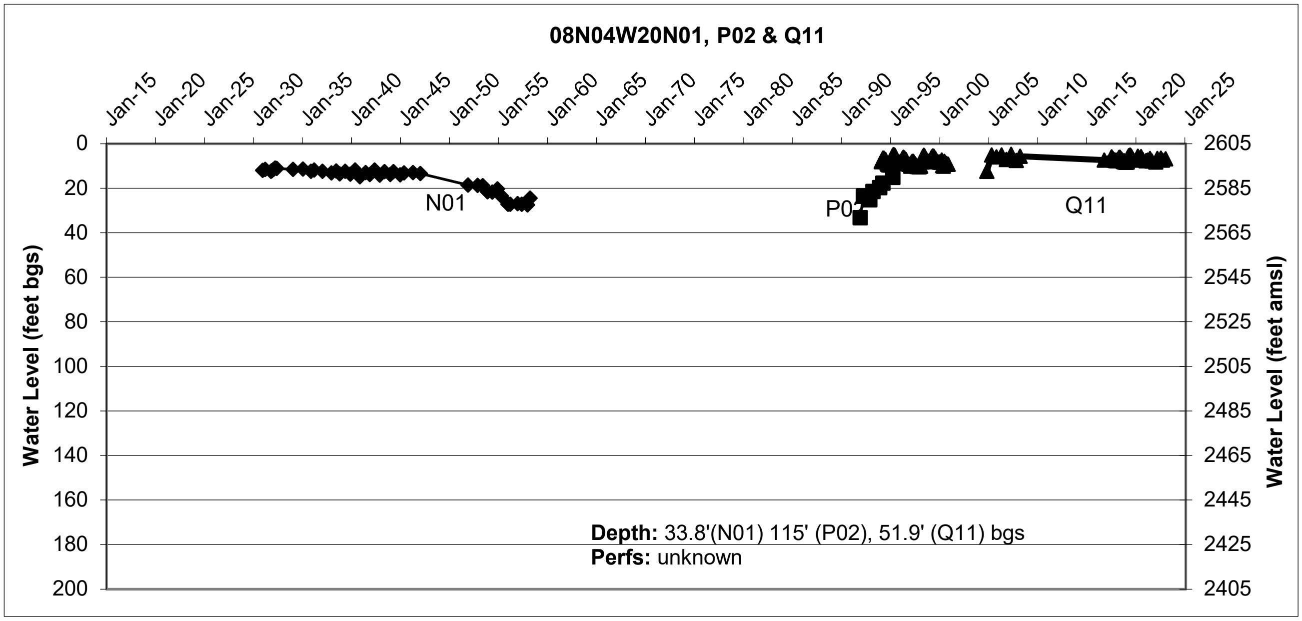
FIGURE 2

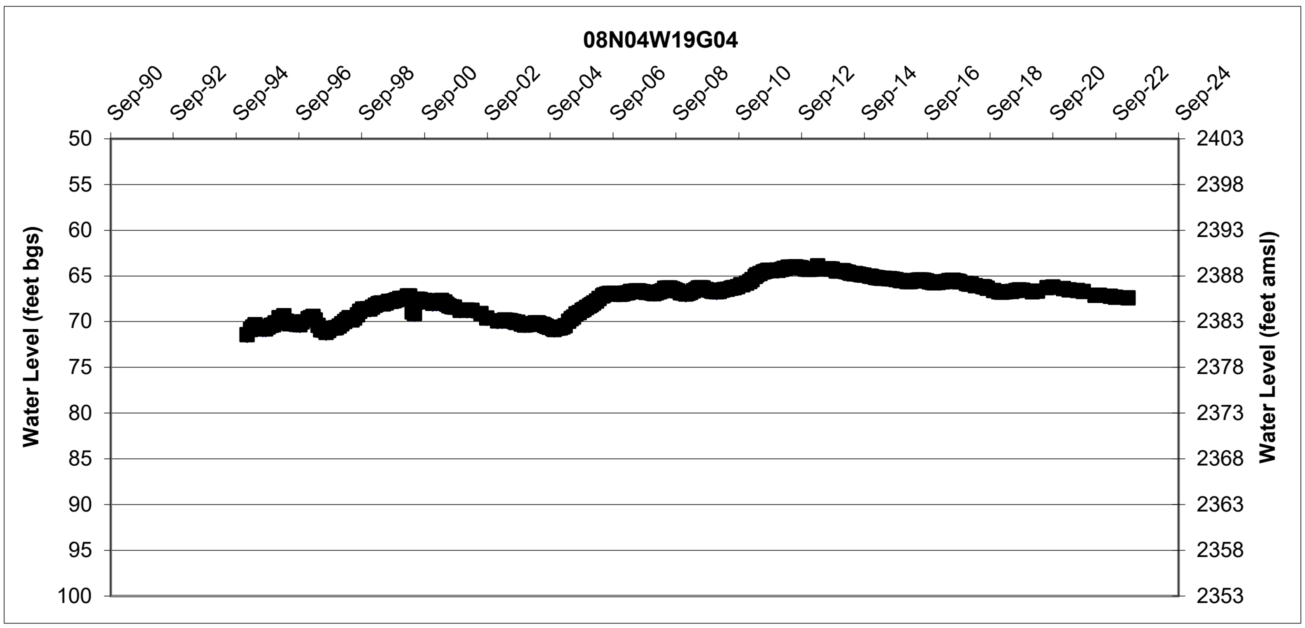


Alto Transition Zone
Location of
Water Level Monitoring Wells

FIGURE 3-6

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)
Water Level (feet amsl)
N01
P0
Q11
Depth: 33.8'(N01) 115' (P02), 51.9' (Q11) bgs
Perfs: unknown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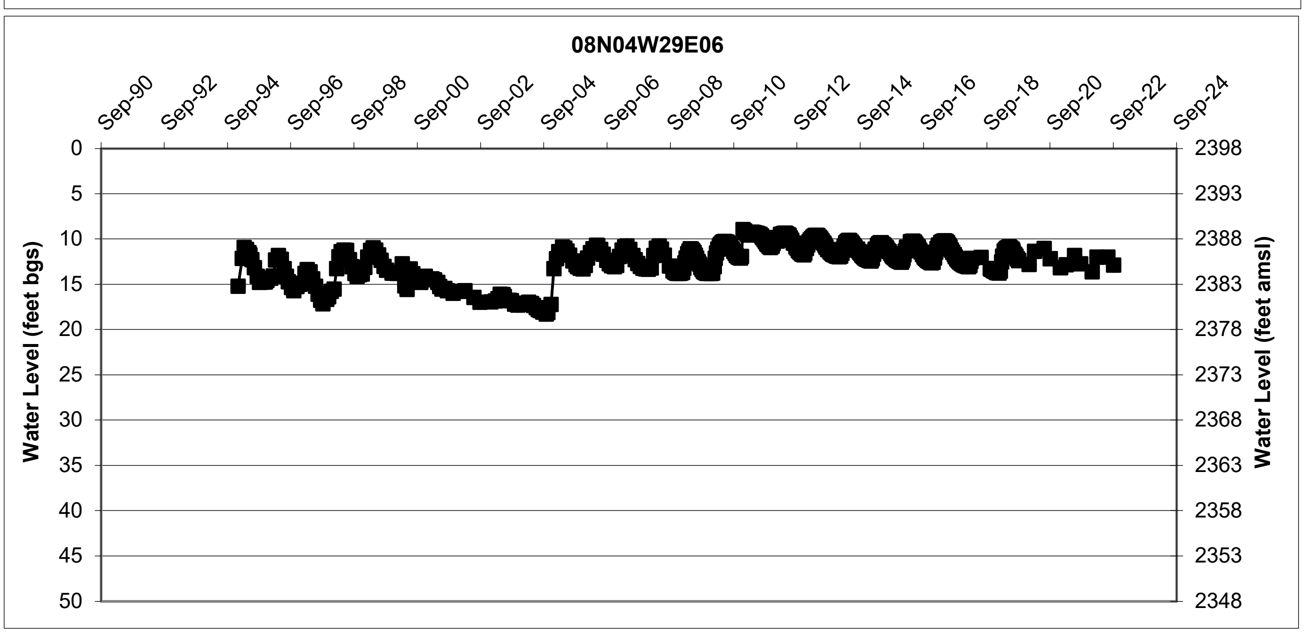
Water Level (feet bgs)
Water Level (feet amsl)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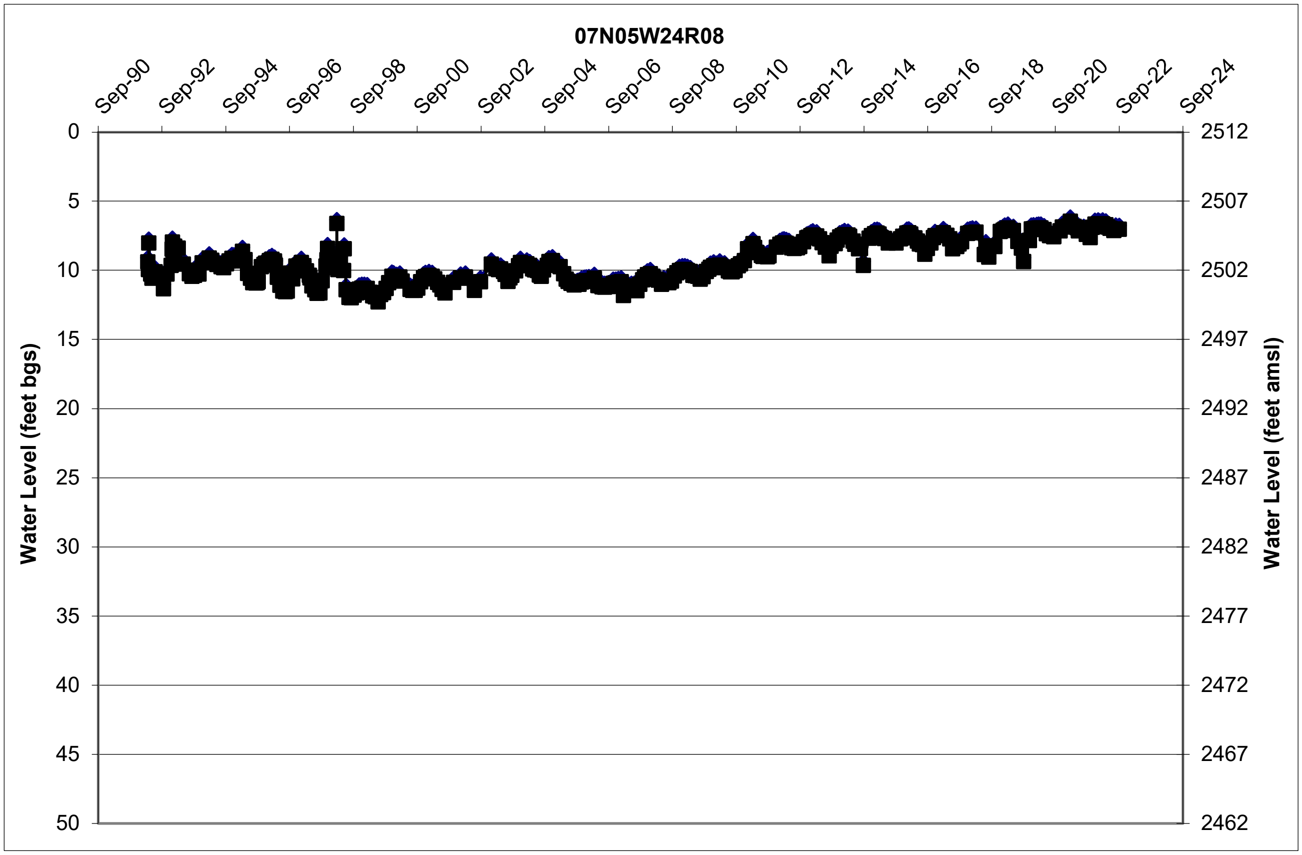
Water Level (feet bgs)
Water Level (feet amsl)


07N05W24R08
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)
2512
2507
2502
2497
2492
2487
2482
2477
2472
2467
2462

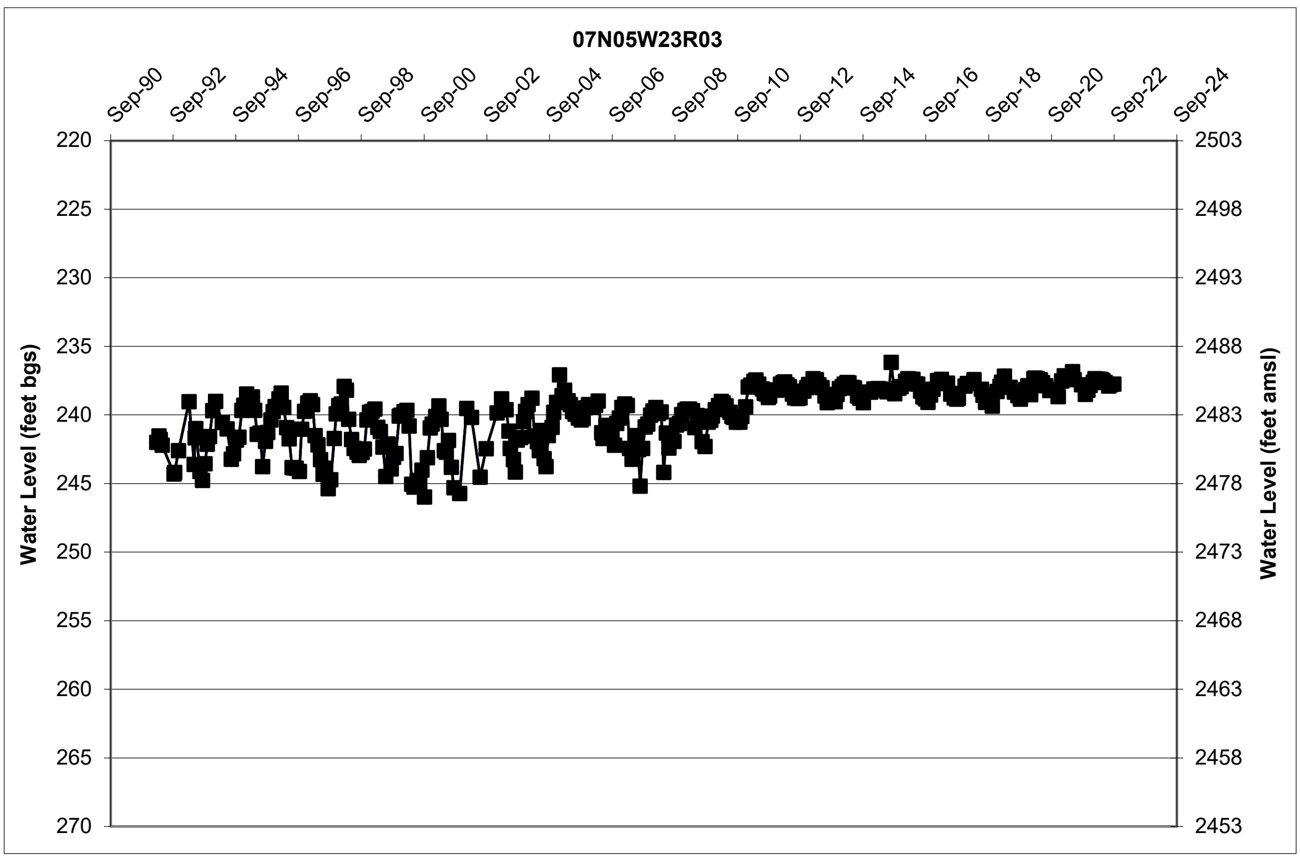
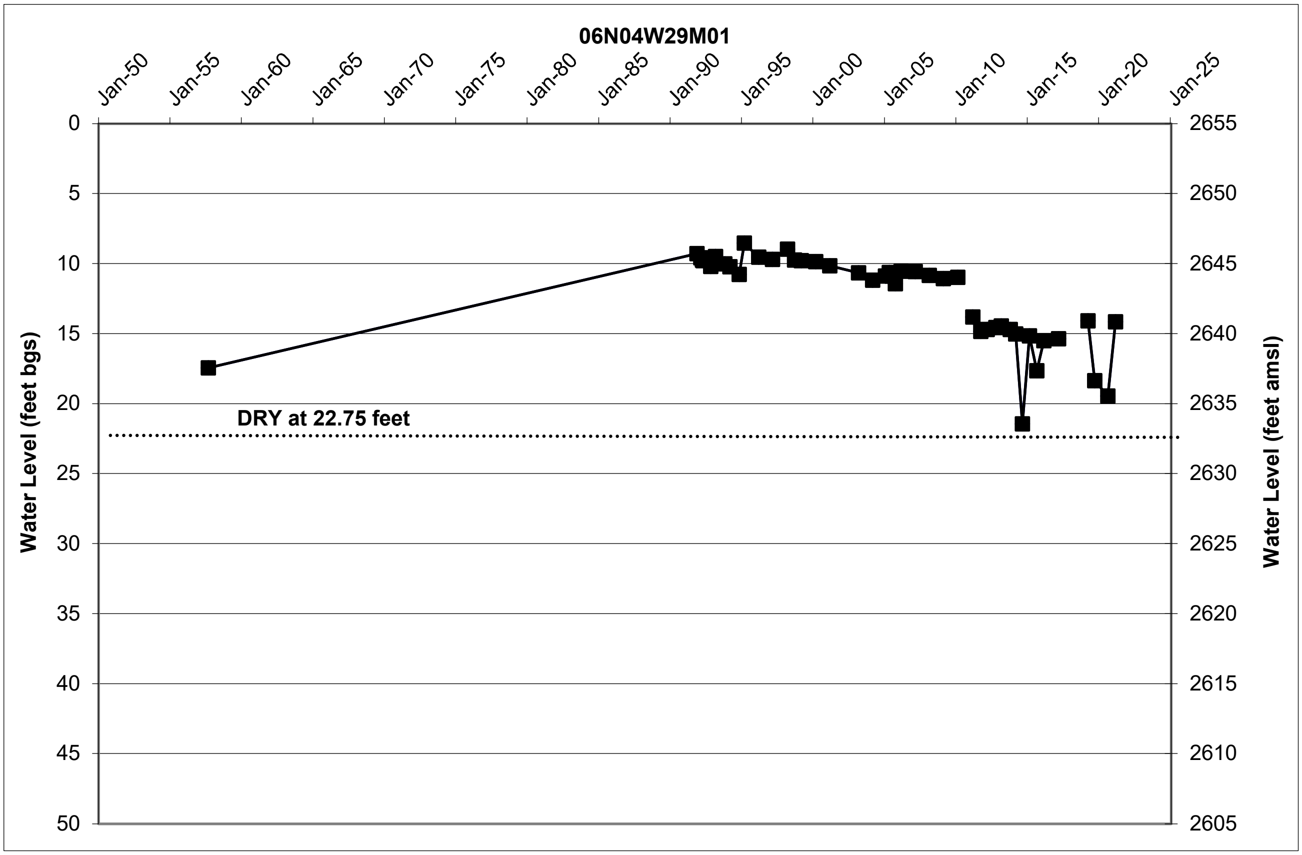

07N05W23R03
Sep-90
Sep-92
Sep-94
Sep-96
Sep-98
Sep-00
Sep-02
Sep-04
Sep-06
Sep-08
Sep-10
Sep-12
Sep-14
Sep-16
Sep-18
Sep-20
Sep-22
Sep-24
Water Level (feet bgs)
220
225
230
235
240
245
250
255
260
265
270
Water Level (feet amsl)
2503
2498
2493
2488
2483
2478
2473
2468
2463
2458
2453

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
0 5 10 15 20 25 30 35 40 45 50
2655 2650 2645 2640 2635 2630 2625 2620 2615 2610 2605
Water Level (feet bgs)
Water Level (feet amsl)
DRY at 22.75 feet

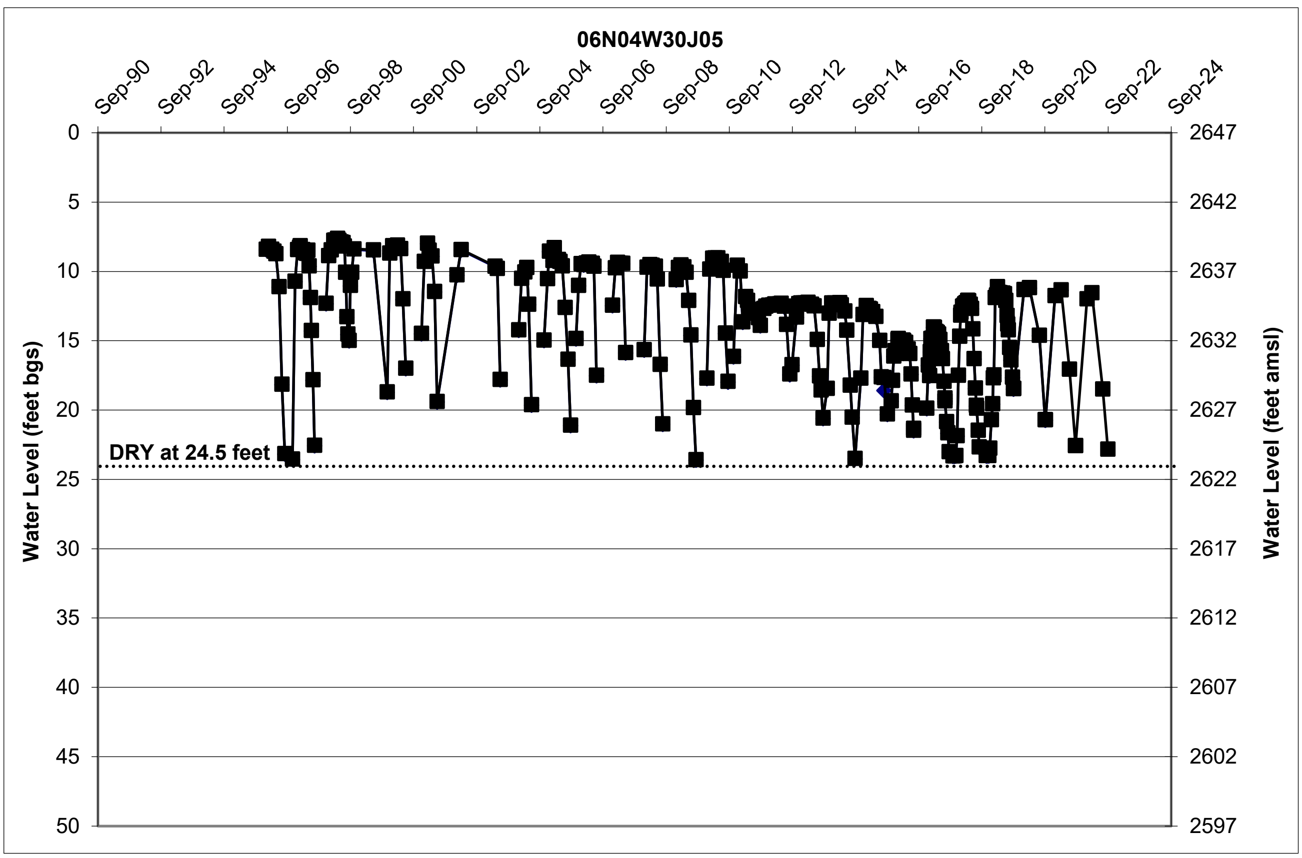
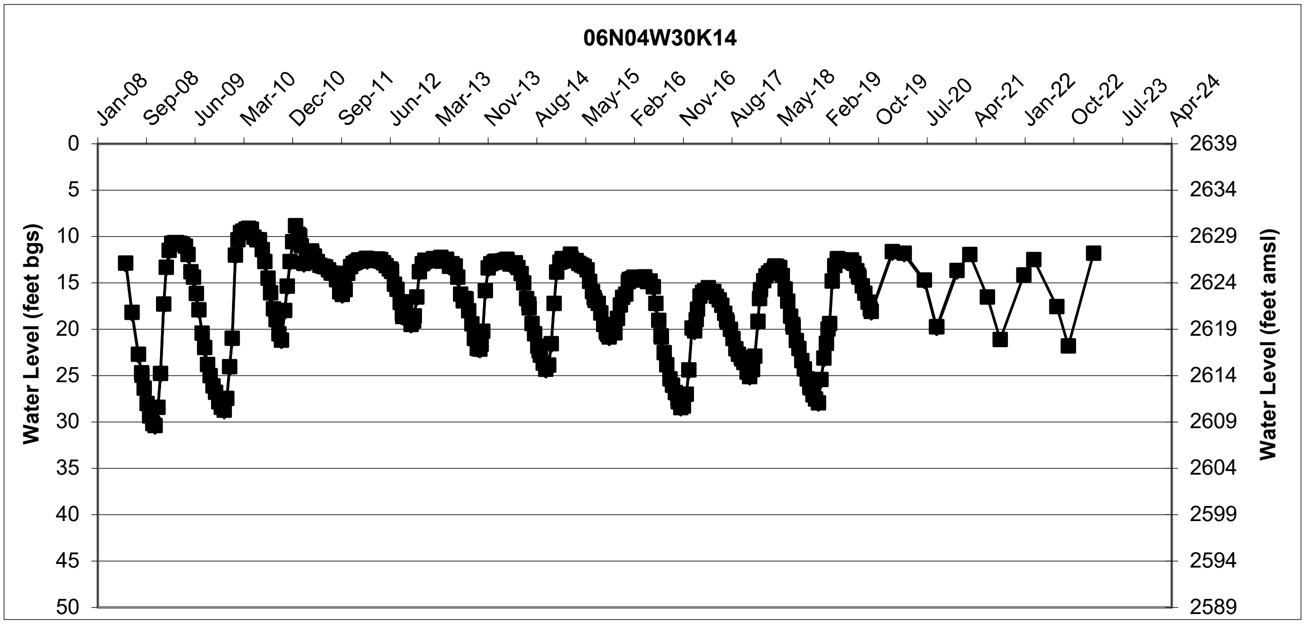
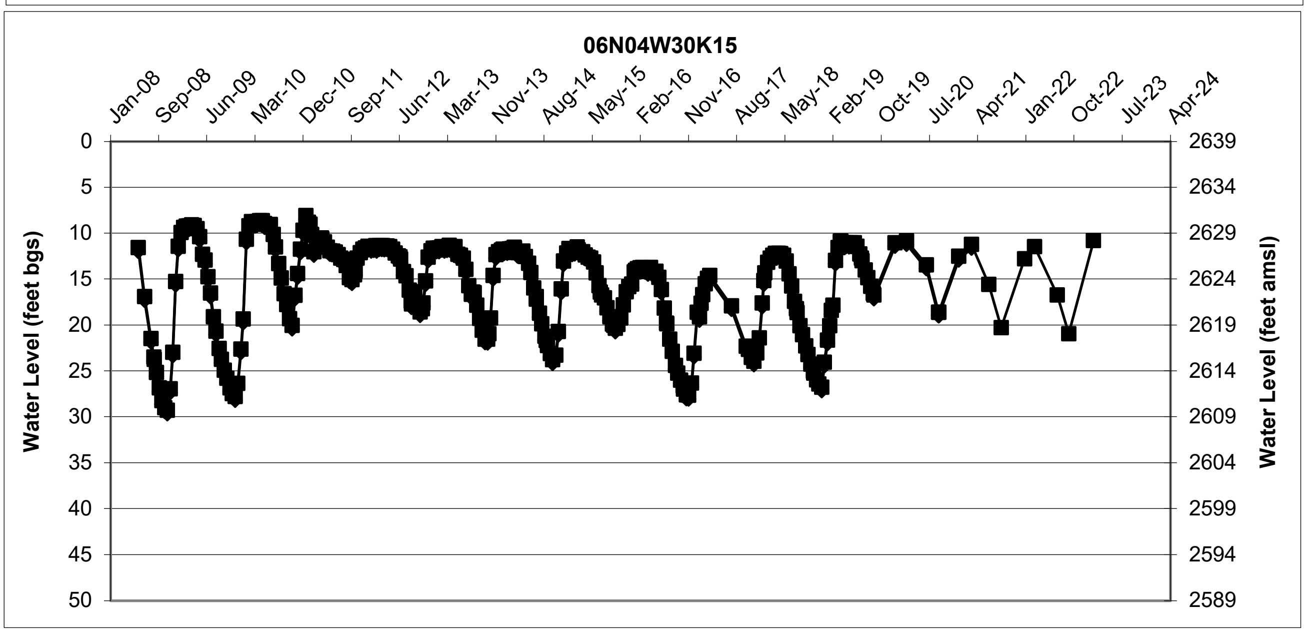
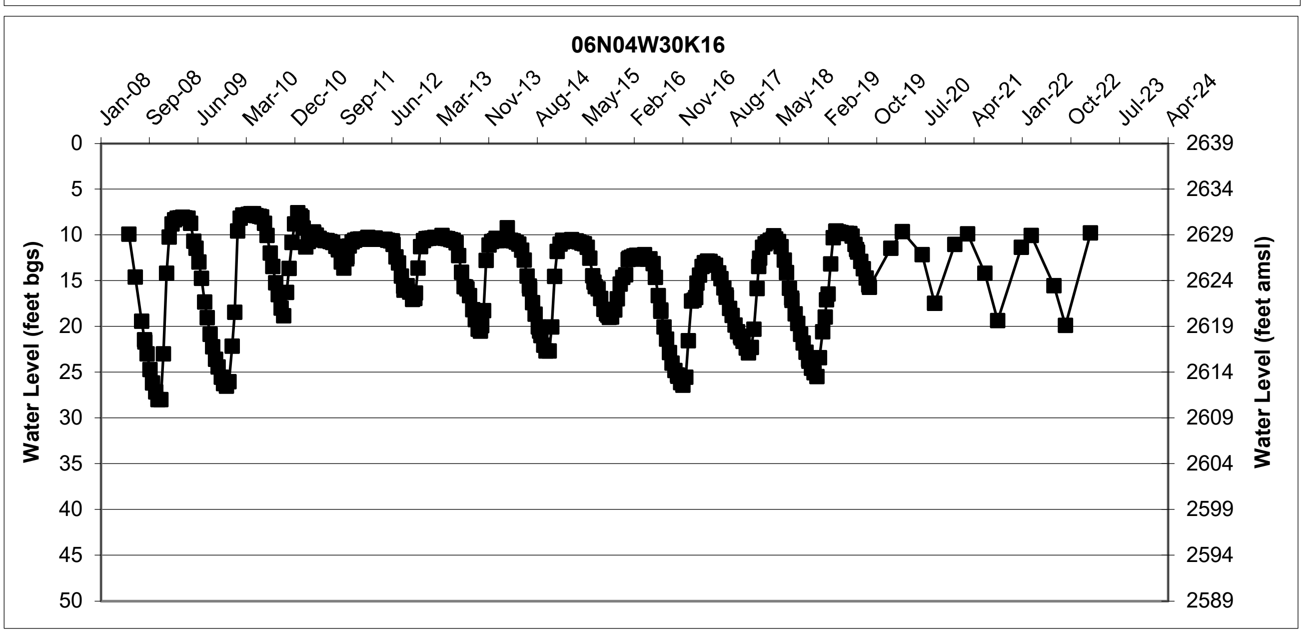

06N04W30J05
Sep-90 Sep-92 Sep-94 Sep-96 Sep-98 Sep-00 Sep-02 Sep-04 Sep-06 Sep-08 Sep-10 Sep-12 Sep-14 Sep-16 Sep-18 Sep-20 Sep-22 Sep-24
0 5 10 15 20 25 30 35 40 45 50
2647 2642 2637 2632 2627 2622 2617 2612 2607 2602 2597
Water Level (feet bgs)
Water Level (feet amsl)
DRY at 24.5 feet

FIGURE 3-9


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)
0 5 10 15 20 25 30 35 40 45 50
Water Level (feet amsl)
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)
0 5 10 15 20 25 30 35 40 45 50
Water Level (feet amsl)
2639 2634 2629 2624 2619 2614 2609 2604 2599 2594 2589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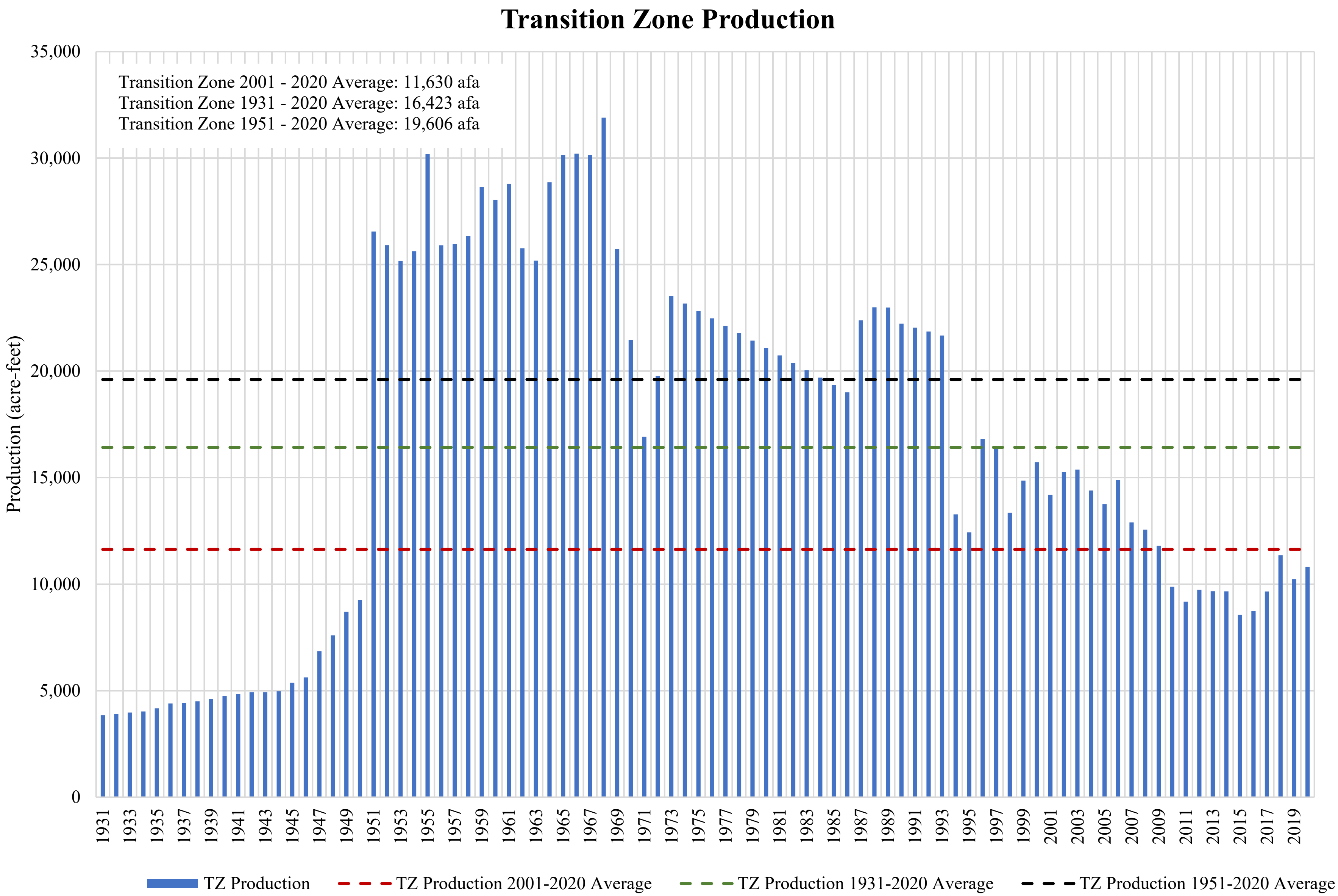
Water Level (feet bgs)
0 5 10 15 20 25 30 35 40 45 50
Water Level (feet amsl)
2639 2634 2629 2624 2619 2614 2609 2604 2599 2594 2589

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

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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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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. Geological Survey Water-Resources Investigation Report 01-4002, Version 3, 137p.

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Thomas Harder & Co., 2010, Analysis of Historical Groundwater Production by the Phelan Pinon Hills Community Services District, Antelope Valley Area of Adjudication: unpublished consultant's report to Smith Trager LLP/Phelan Pinon Hills Community Services District, dated July 13, 2010, 23p.

Todd Groundwater and Applied Geoscience and Engineering (AGE), 2020, Status Update, Oeste Subarea Managed Aquifer Recharge (MAR) Feasibility Studies: unpublished consultant's presentation to Mojave Water Agency, dated August 5, 2020.

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

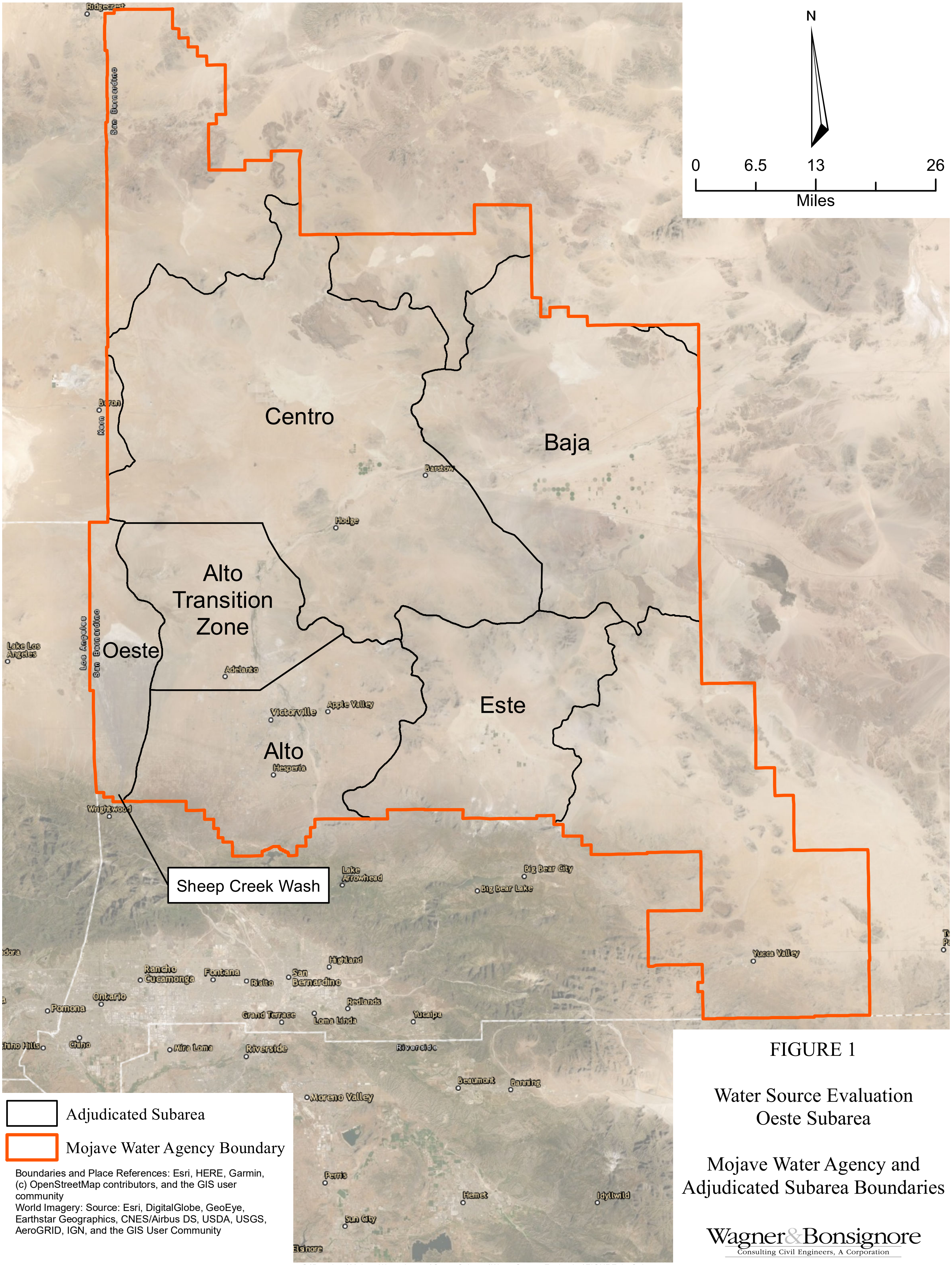


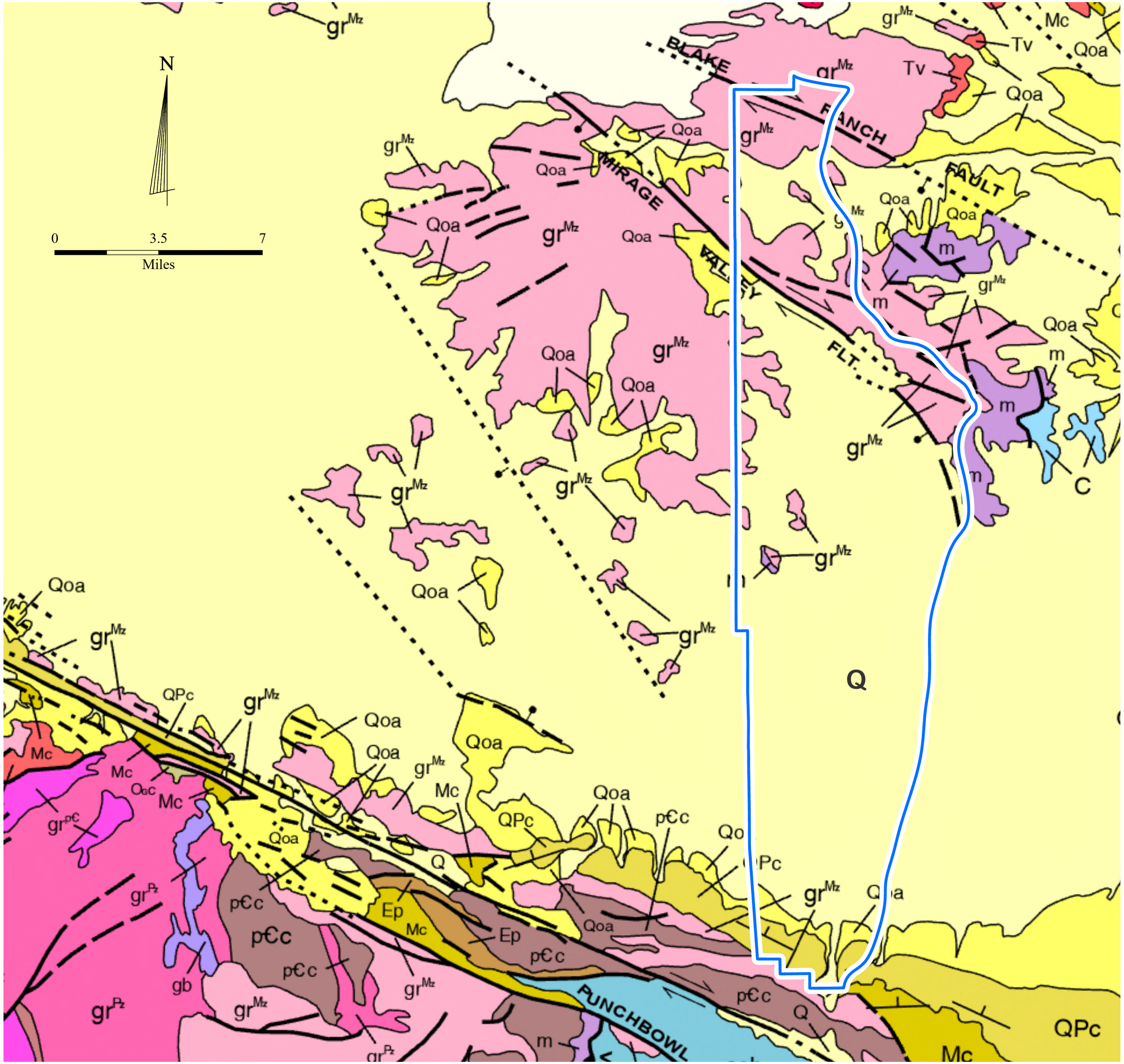
FIGURE 1

Water Source Evaluation
Oeste Subarea

Mojave Water Agency and
Adjudicated Subarea Boundaries

Wagner&Bonsignore
Consulting Civil Engineers, A Corporation

Q:\Drawings\Mojave Water Agency\Oeste Subarea\Water Source Evaluation\FIGURE 1 - Subareas.mxd



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

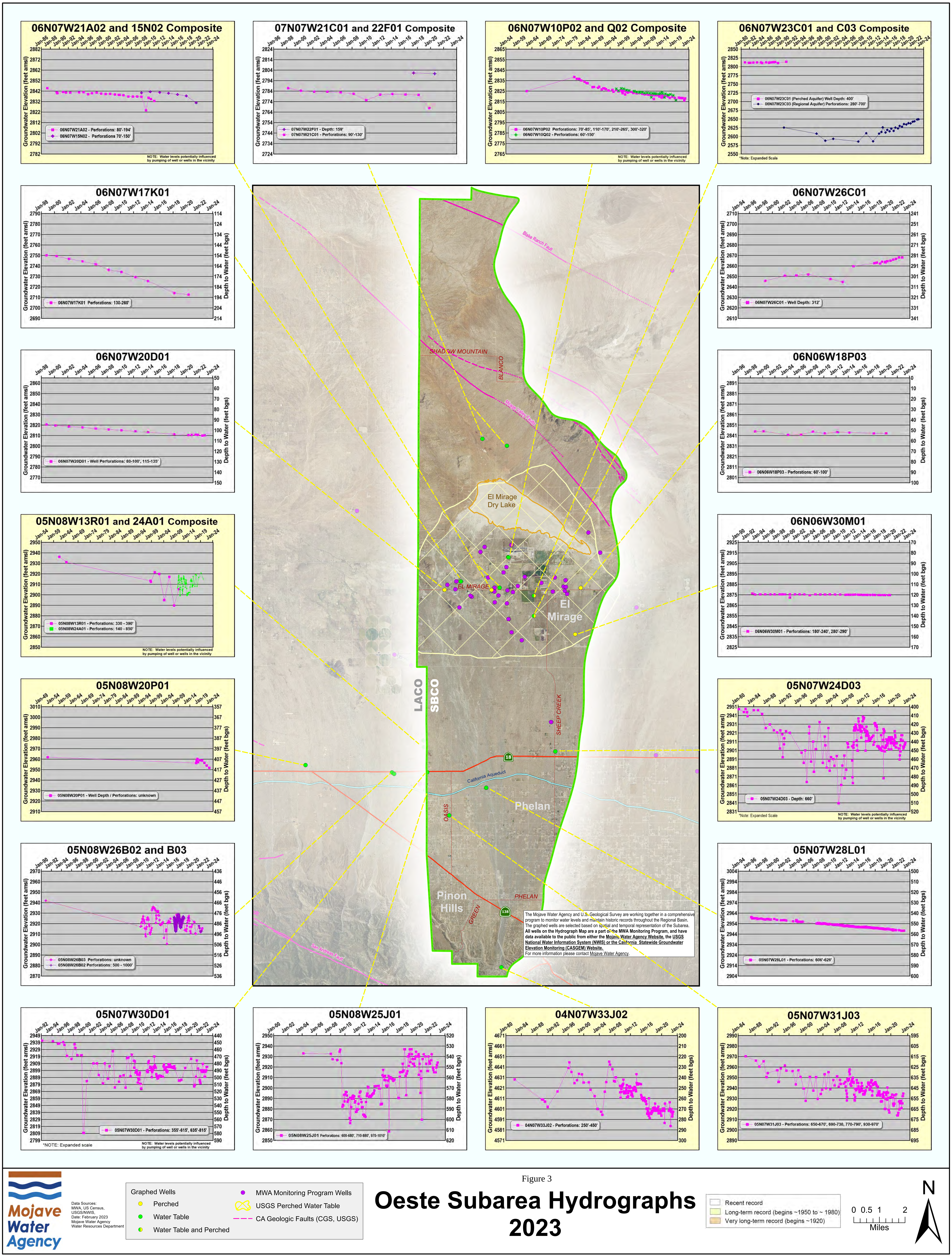
Regional Geology
Oeste Subarea

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.

Path: Q:\Drawings\Mojave Water Agency\Oeste Subarea\General\GIS\Oeste Sub Area\Oeste Sub Area.aprx

October 2023



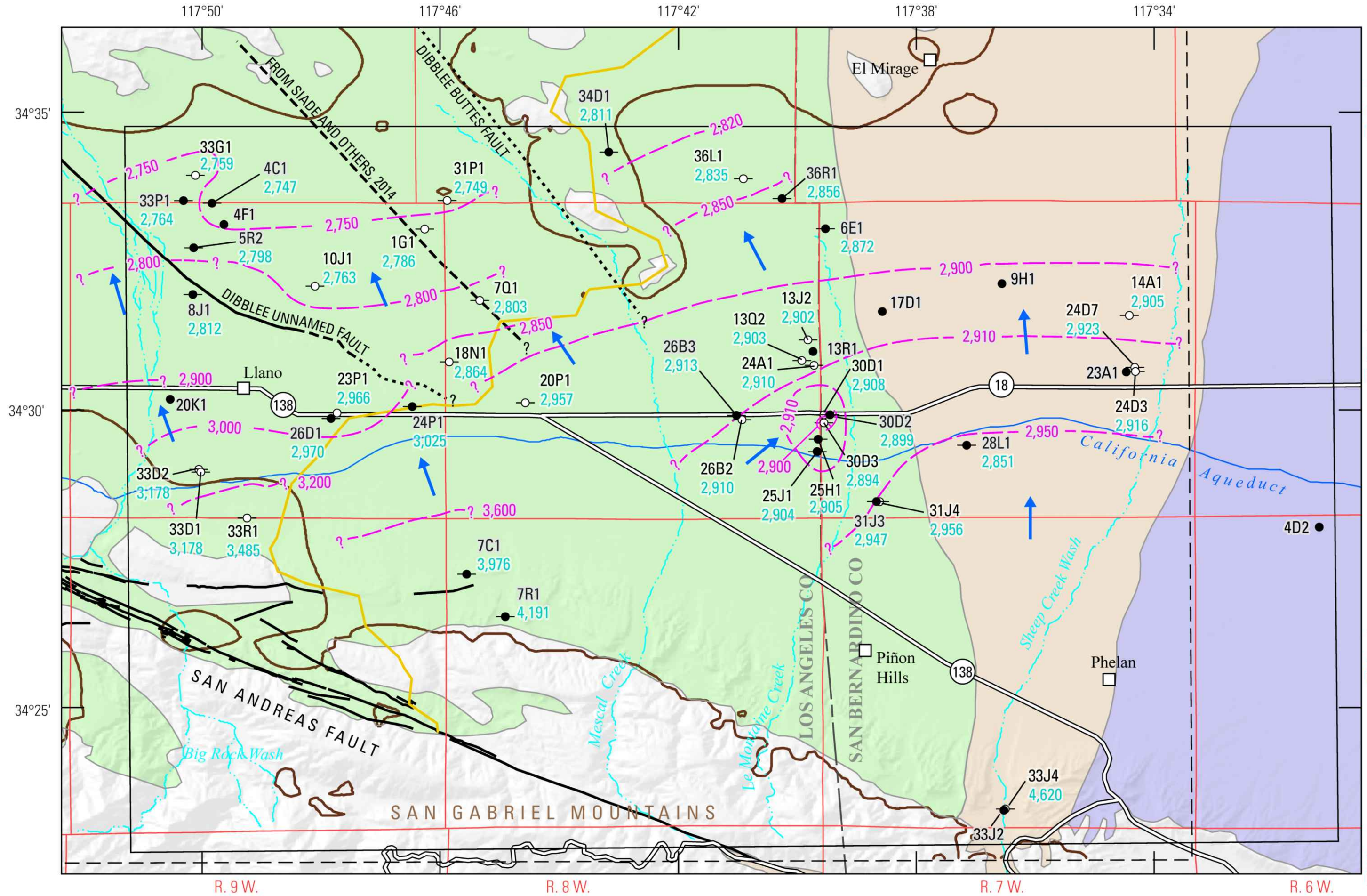
Mojave Water Agency

Data Sources:
MWA, US Census,
USGS/NWIS,
Date: February 2023
Mojave Water Agency
Water Resources Department

Figure 3

Oeste Subarea Hydrographs 2023

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

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.

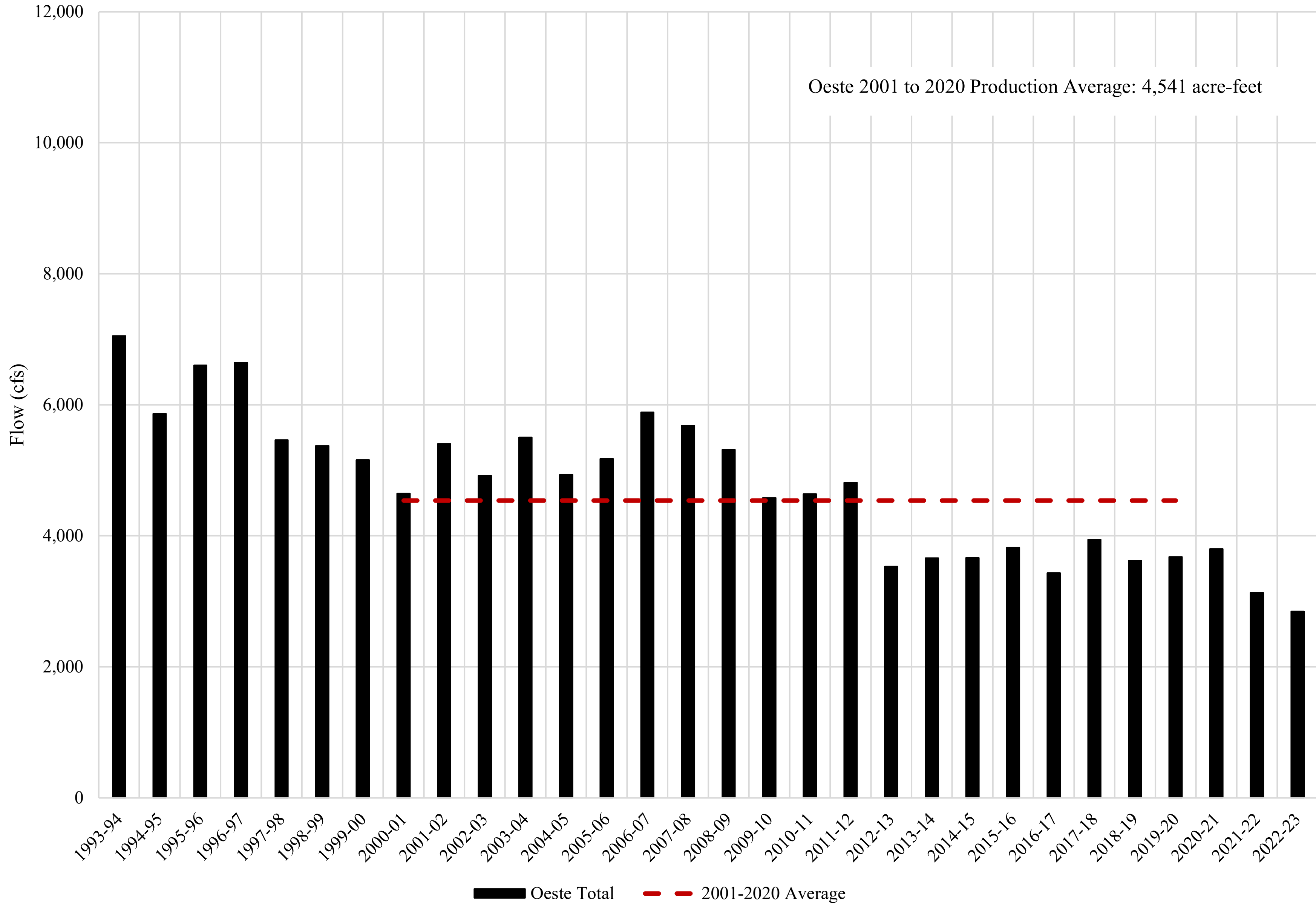
Source: Stamos and others, 2017

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

FIGURE 5

Oeste Production

1993 to 2023



Mojave Basin Area Watermaster

Appendix D

Este Subarea

Water Supply Update

Prepared by:

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Robert C. Wagner, PE

Watermaster Engineer

David H. Peterson, C.E.G, C.Hg

February 28, 2024

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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

<u>Geologic Units and Aquifers</u>

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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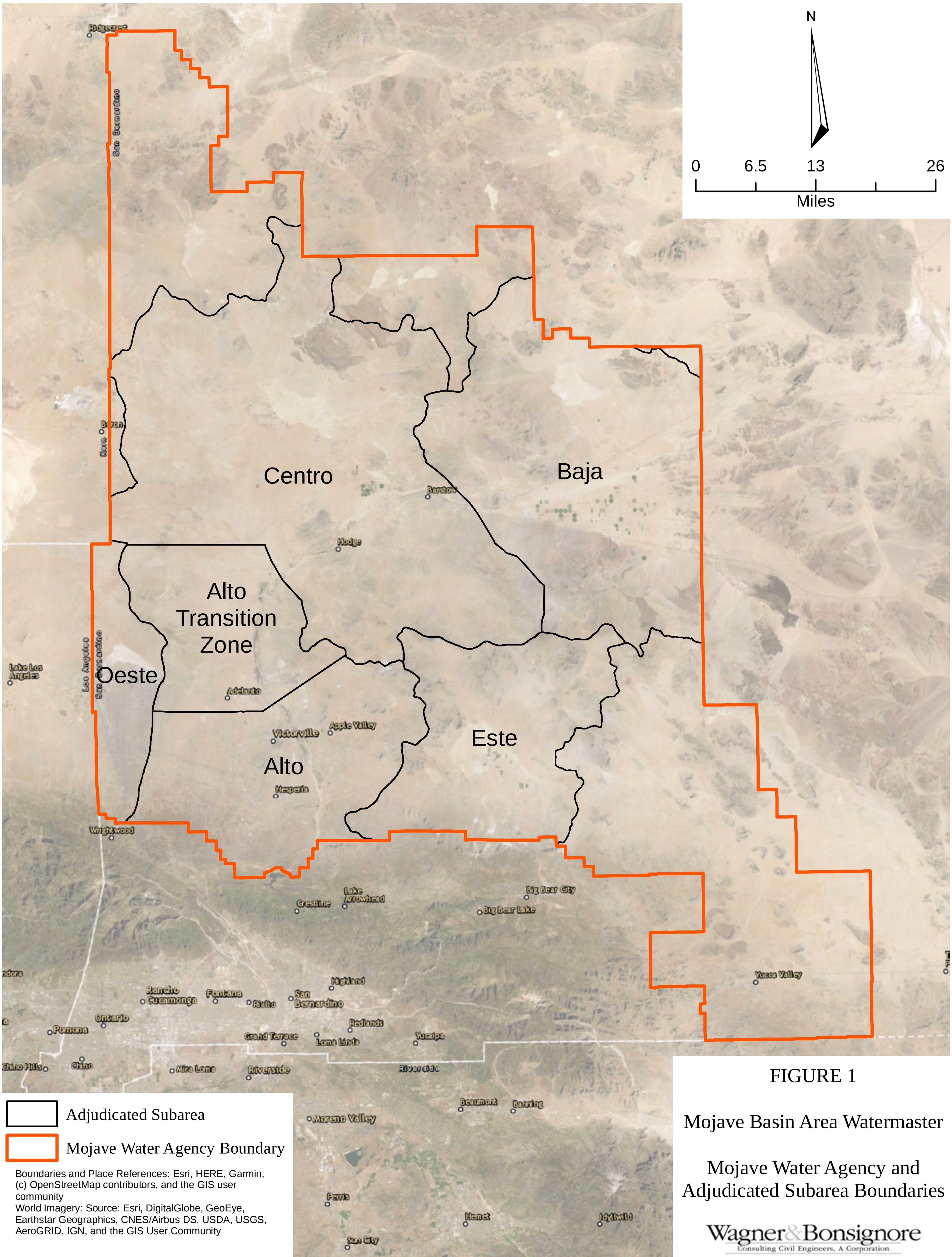


Adjudicated Subarea

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

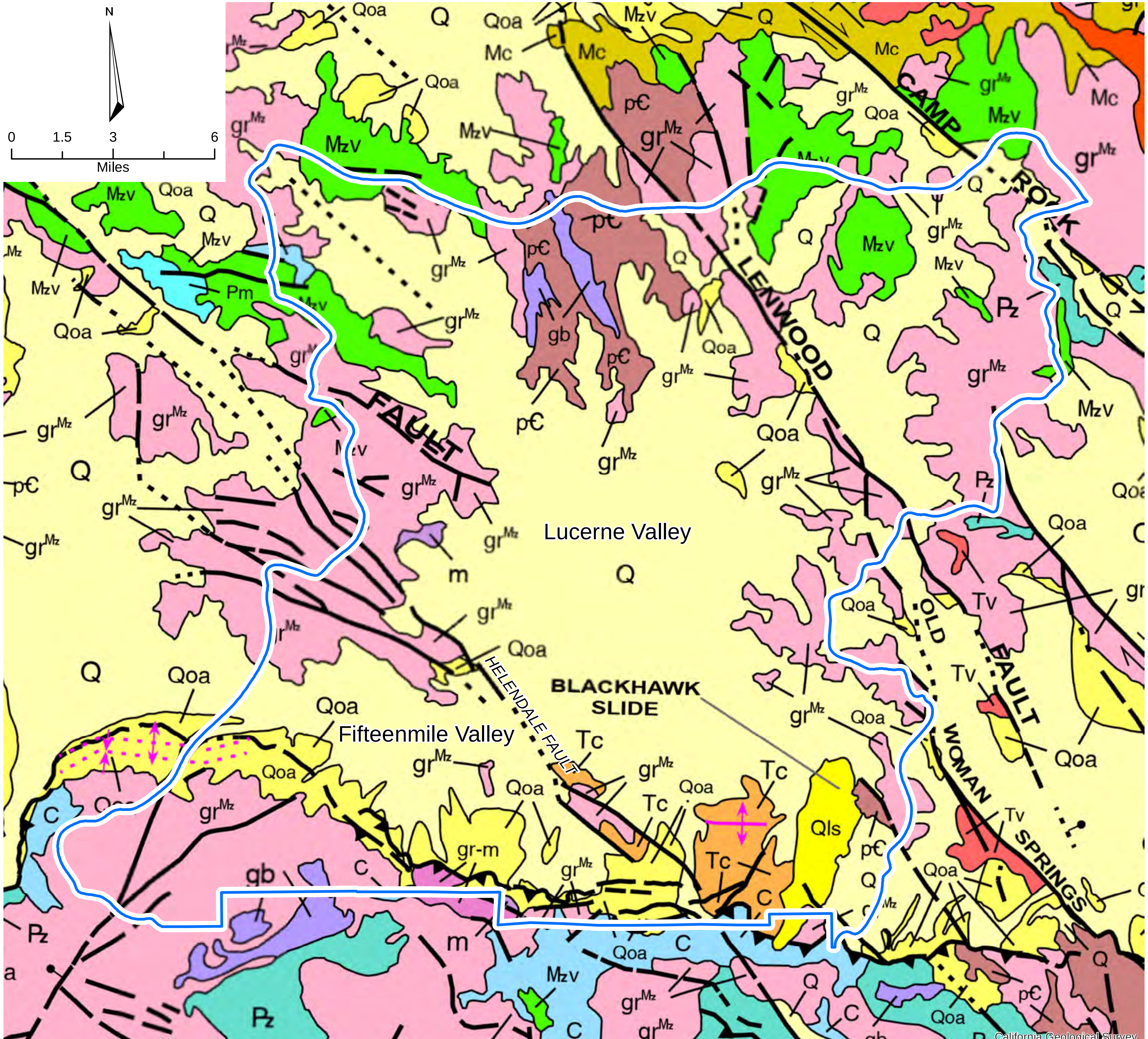
Mojave Basin Area Watermaster

Mojave Water Agency and Adjudicated Subarea Boundaries

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

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

June 2020



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

June 2020

Q:\Drawings\Mojave Water Agency\Este Subarea\Este Water Supply - FIGURE 2 - Regional Geology.mxd

N

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.
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FIGURE 3

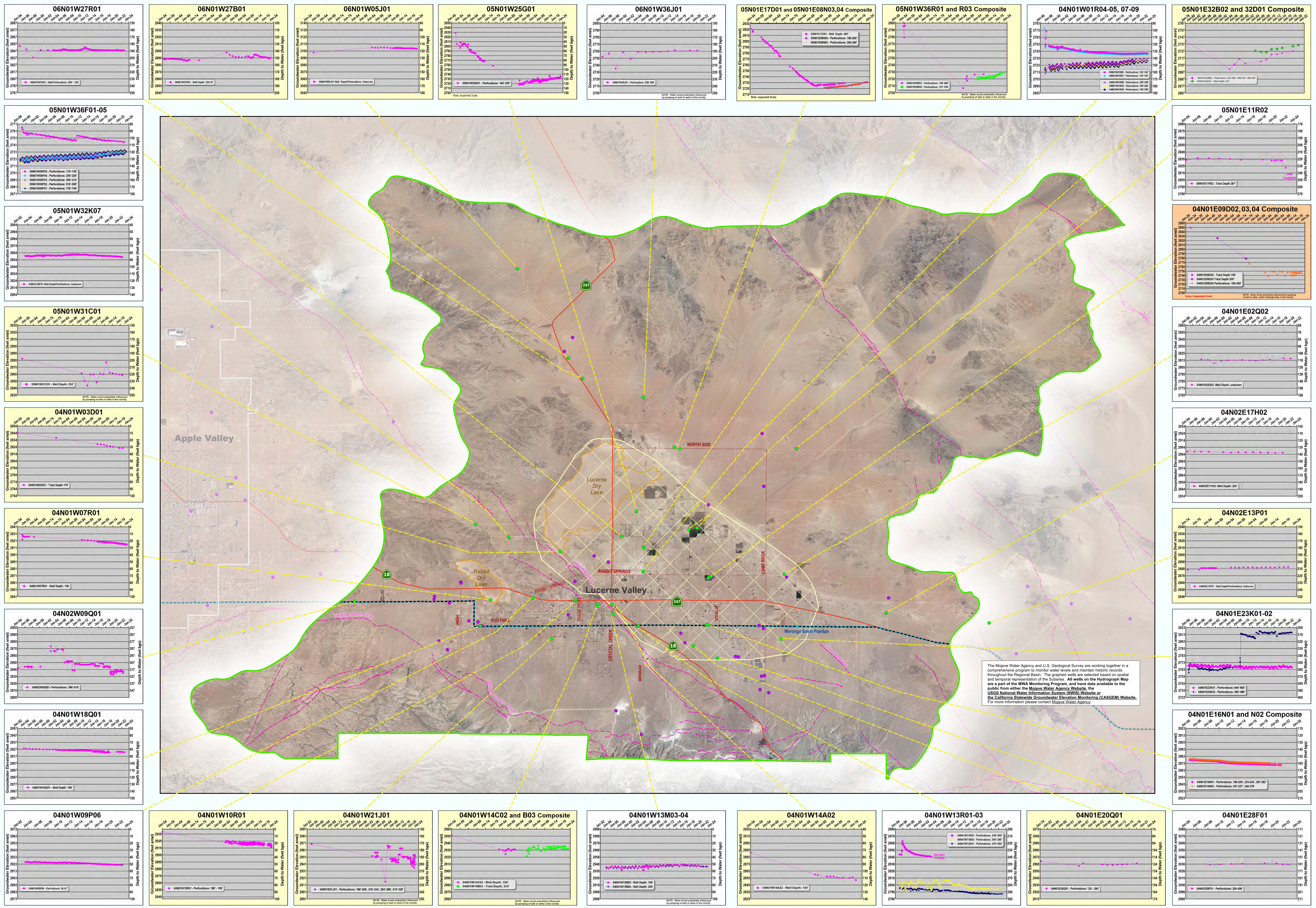
Mojave Basin Area Watermaster

Potential Recharge Locations
Este Subarea

Wagner & Bonsignore
Consulting Civil Engineers, A Corporation

June 2020

Q:\Drawings\Mojave Water Agency\Este Subarea\Este Water Supply - FIGURE 3 - Locations of Recharge.mxd



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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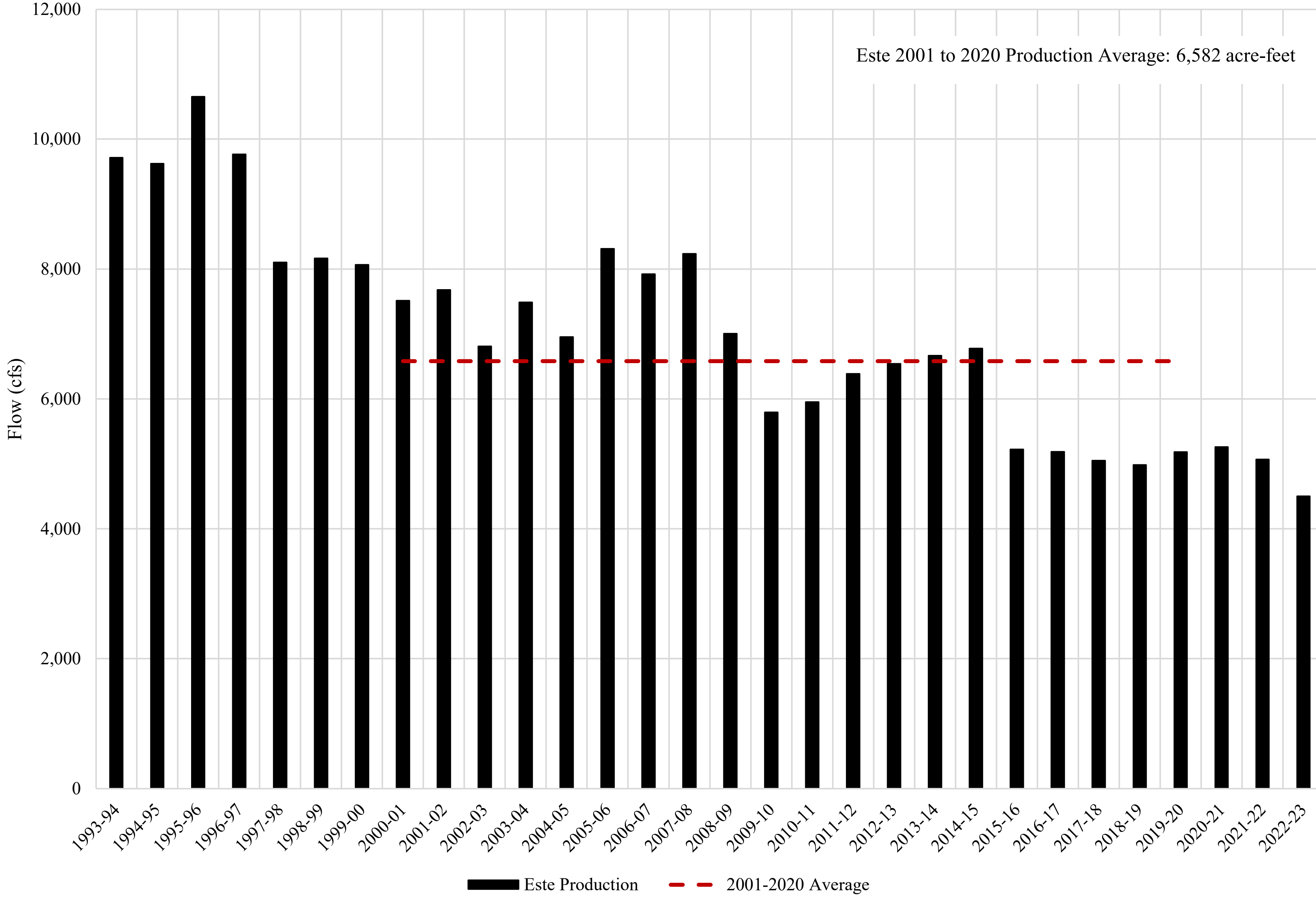
Miles

N

FIGURE 4

Figure 5
Este Production
1993 to 2023



G:\MOJAVE ADJUDICATION - 3020\Analysis\Groundwater Modeling\3020-033M-Baja Este and Oeste Pumping History Through 2023.xlsx

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

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Consulting Civil Engineers, A Corporation

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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: **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.

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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-

[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.

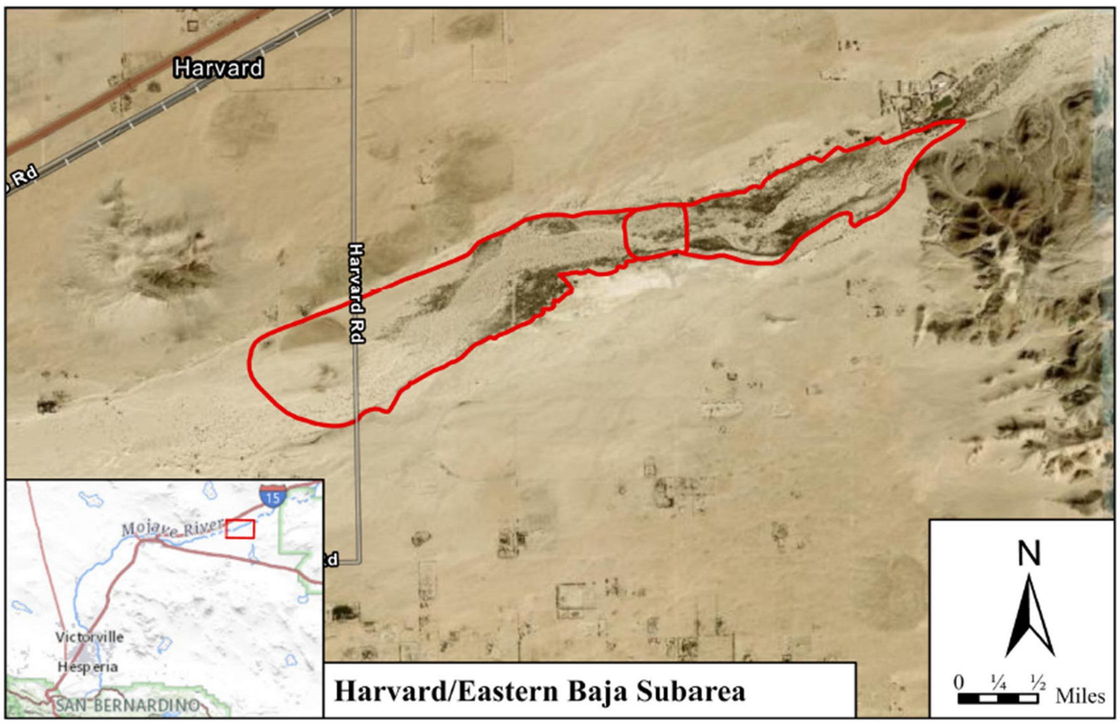


Figure 2. Harvard/Eastern Baja Riparian Zone.

[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.

References

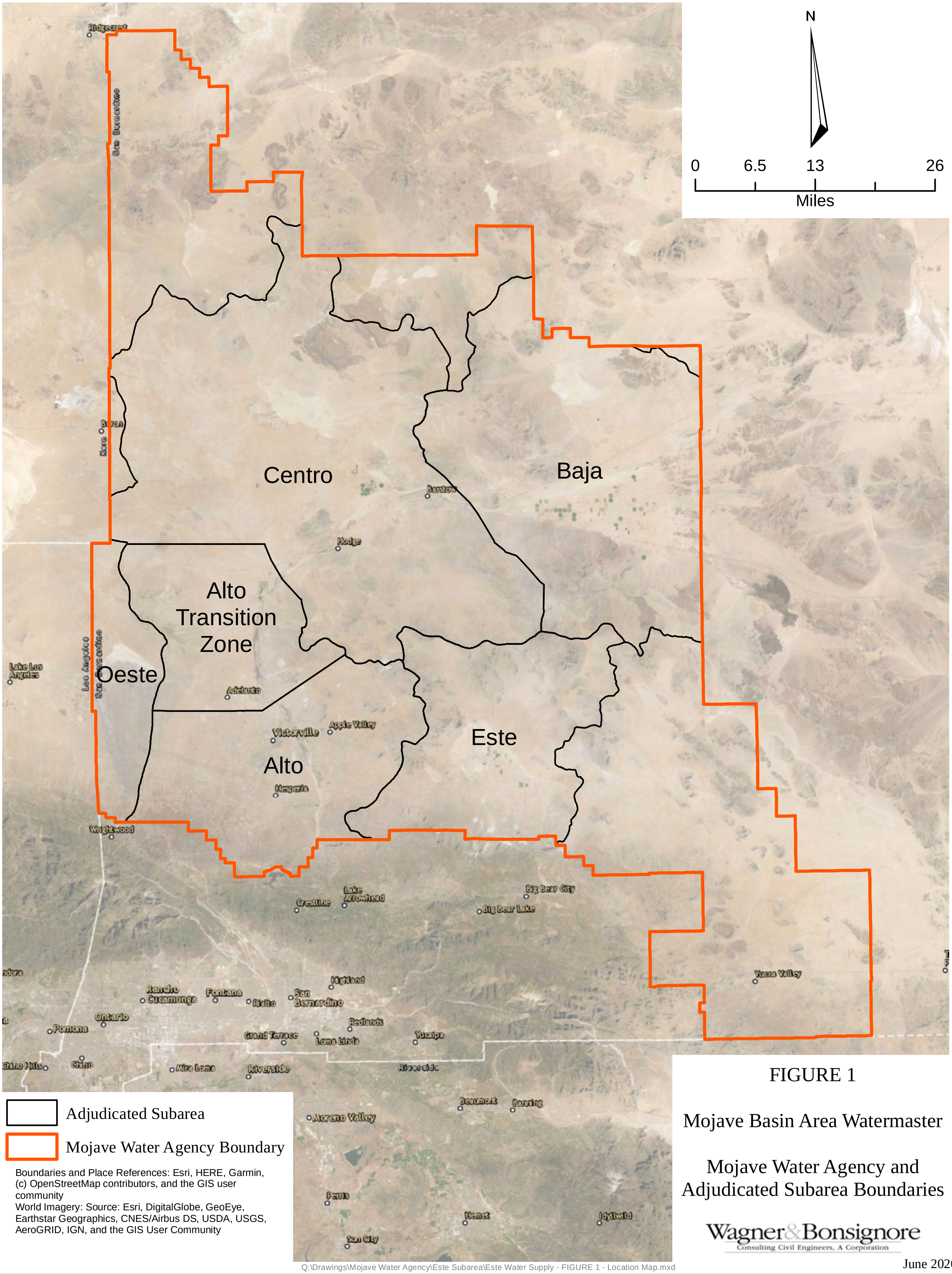
Allen, R., Irmak, A., Trezza, R., Hendrickx, JMH., Bastiaanssen, WGM., & Kjaersgaard, J. (2011). Satellite-based ET estimation in agriculture using SEBAL and METRIC. Hydrological Processes: an international journal, 25(26), 4011-4027. https://doi.org/10.1002/hyp.8408

Todd Engineers (2013). Final Report Hydrogeologic Investigation of Camp Cady Wildlife Area Newberry Springs, CA.

Simulation of Ground-Water Flow in the Mojave River Basin, California, Water Resources Investigations Report, 01-4002, Stamos, 2001

Lines, G.C., and Bilhorn, T.W., 1996, Riparian vegetation and its water use during 1995, along the Mojave River, southern California: USGS

Lines, G.C., 1996, Ground-water Surface water relations along the Mojave River, southern California



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

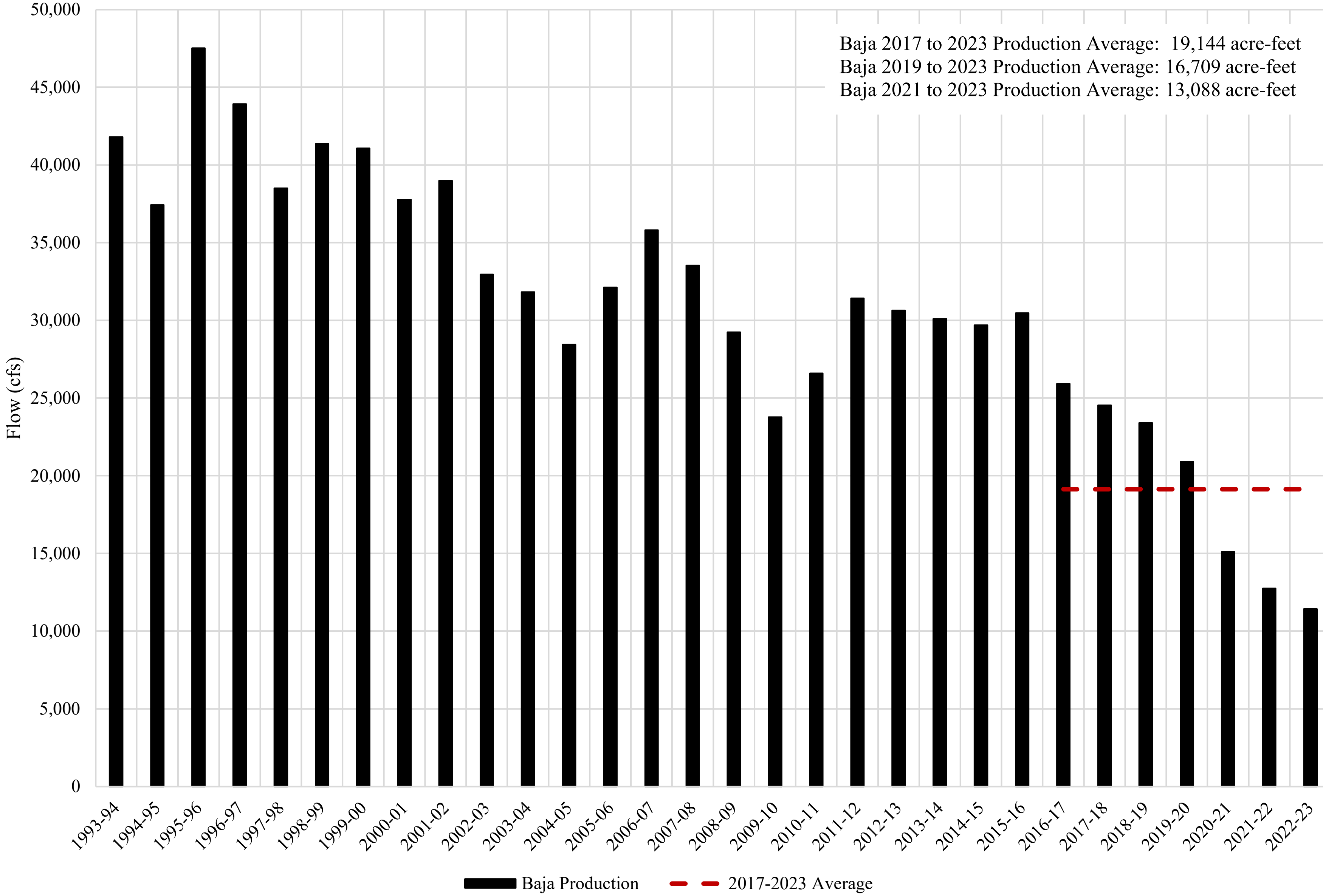
June 2020

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

FIGURE 3

Baja Production

2016 to 2023



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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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Miles

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FIGURE 4

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

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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. & 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 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.

WATER PURVEYOR
ALTO
ALTO TRANSITION ZONE
SEPTIC POPULATION
SEWERED POPULATION
City of Barstow
City of Adelanto
City of Victorville
Town of Apple Valley
City of Hesperia
N
0 11,000 22,000
Feet
FIGURE 1
Mojave Water Agency
Map Showing
Alto Subarea
Sewered and Septic Areas
San Bernardino County, California
Wagner & Bonsignore
Consulting Civil Engineers, A Corporation
DRAFT
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.

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

Path: Q:\Drawings\Mojave Water Agency\GIS\MojaveWatermaster\MojaveWatermaster.aprx

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

Markovich, K. H., Manning A. H., Condon L. E., and McIntosh J. C. 2019. Mountain-Block Recharge: A Review of Current Understanding, Water Resour. Res., 55(11), 8278-8304.

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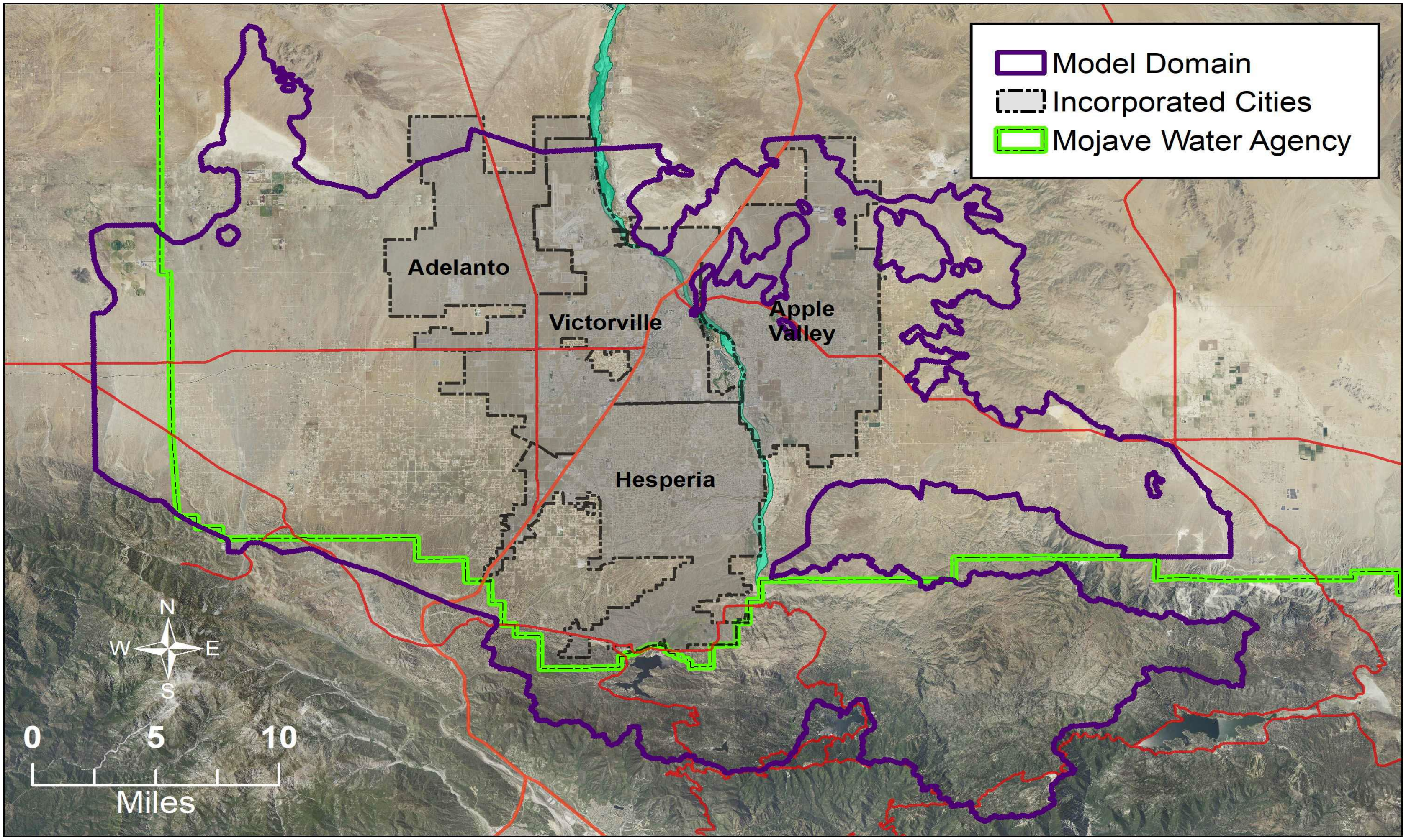
SWS (Schlumberger Water Services), Bookman-Edmonston, and Richard C. Slade and Associates, 2007c. Technical Memorandum #4: Transient Model Development – DRAFT. Upper Mojave River Basin Groundwater Modeling Project. Prepared for Mojave Water Agency, dated September.

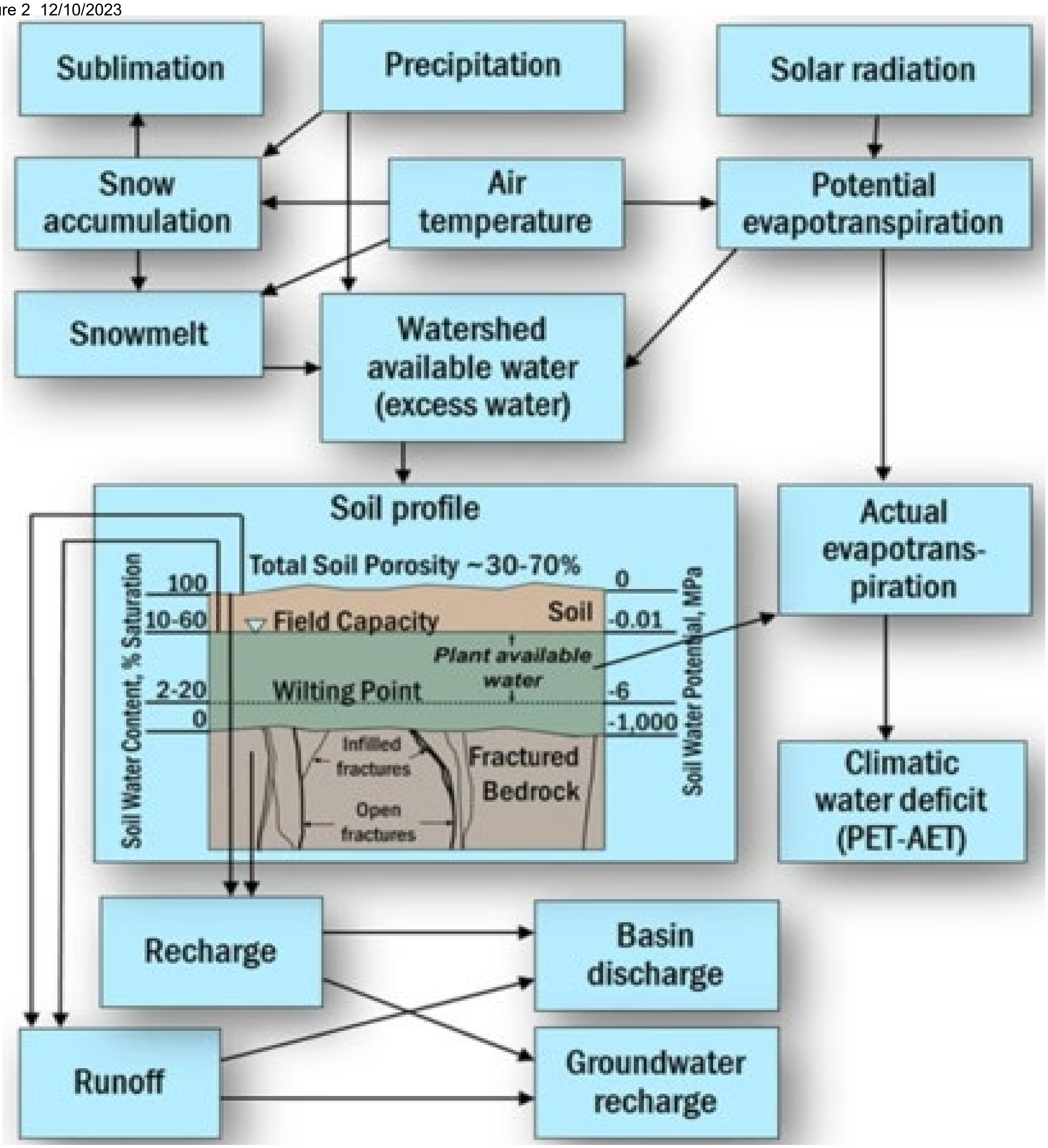
Wood, 2021. Project Completion report, Integrated Surface Water/Groundwater Model, Upper Mojave River Basin Prepared for Mojave Water Agency, dated October 2021.

https://mojavewater-my.sharepoint.com/personal/kcoulibaly_mojavewater_org/Documents/Projects/WagnerRequests/PSY_Calc/Figures/ModelingTMFigures.xlsxFigure 1 12/10/2023



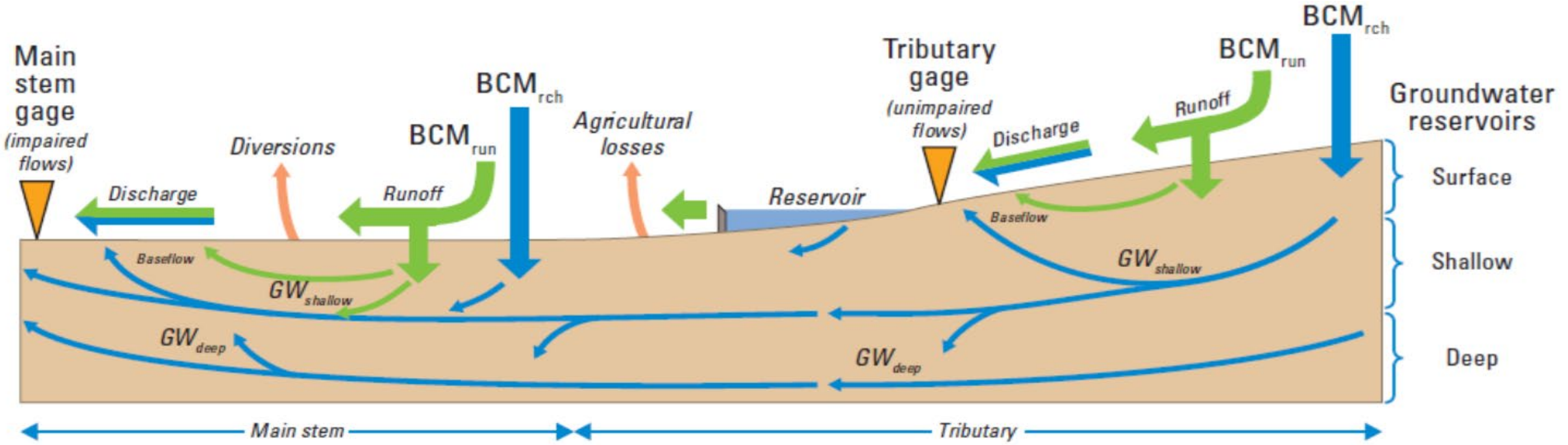
Model Location

By: KMC	Date: 12/04/2023	Project No.: CM20167800
	Mojave Water Agency	Figure 1



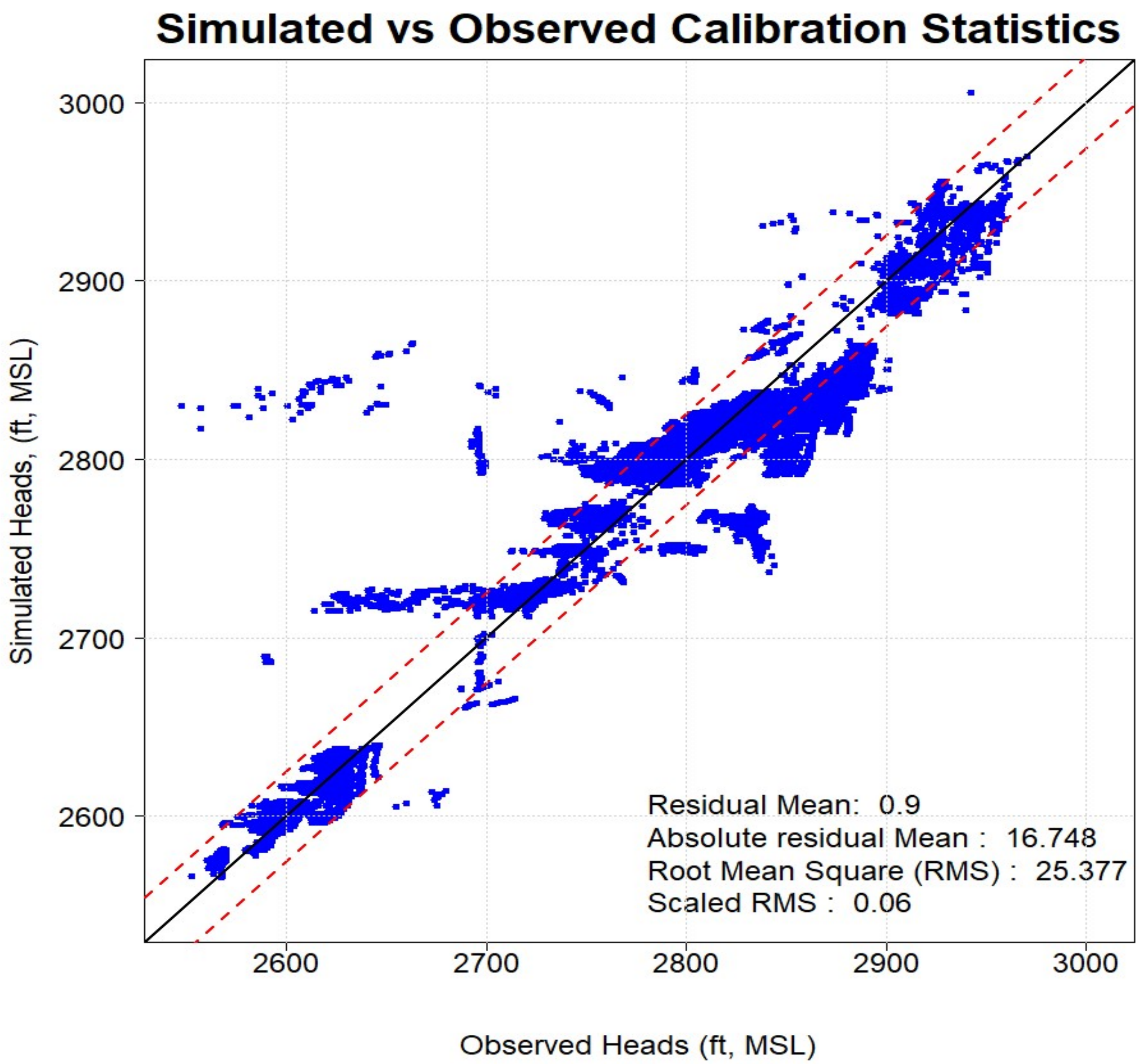
Basin Characterization Model Processes

By: KMC	Date: 12/04/2023	Project .:
	Mojave Water Agency	Figure 2



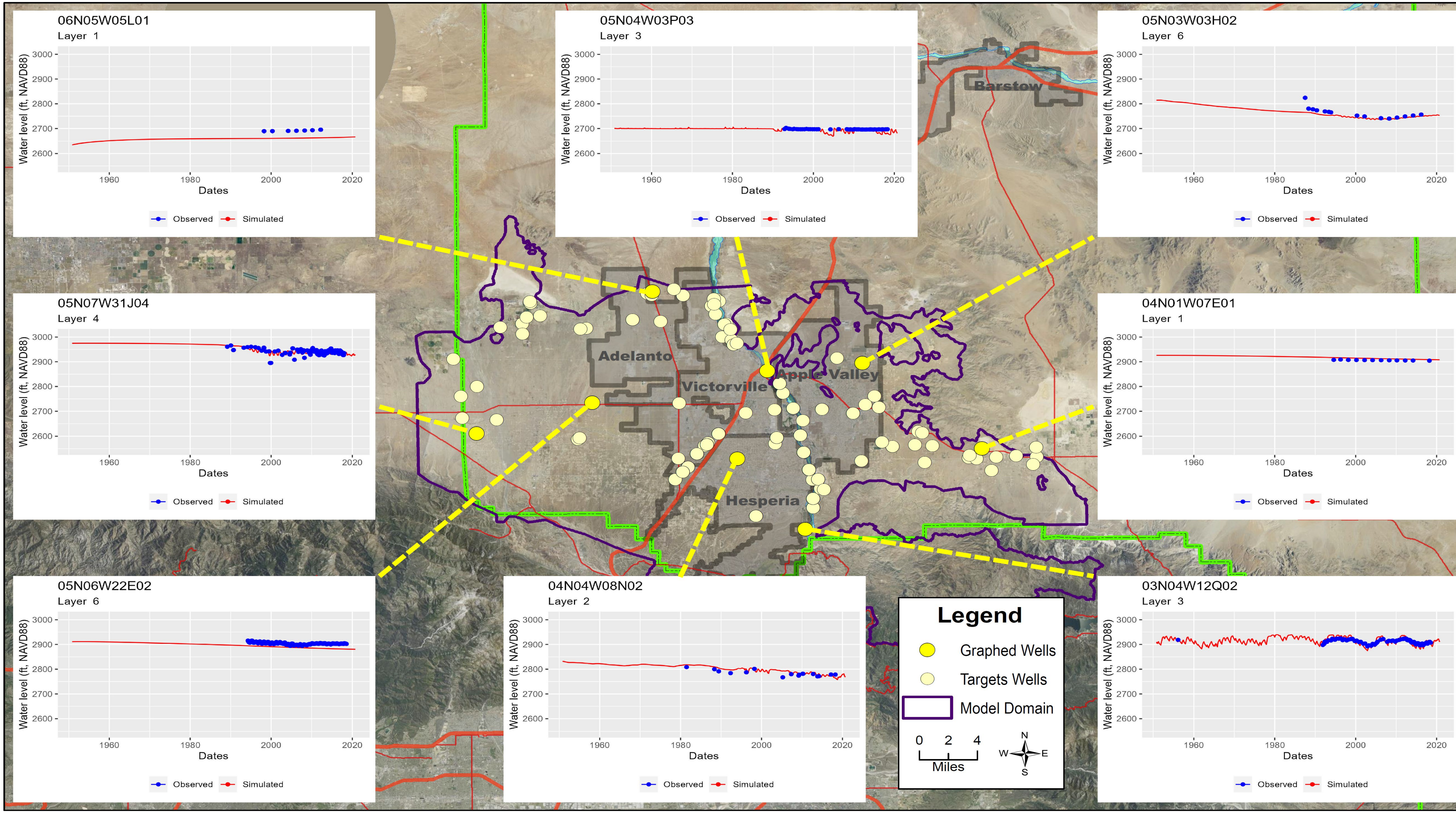
BCM Surface Water/Groundwater Conceptual Model

By: KMC	Date: 12/04/2023	Project No.: CM20167800
	Mojave Water Agency	Figure 3



Simulated vs Observed Goundwater Levels

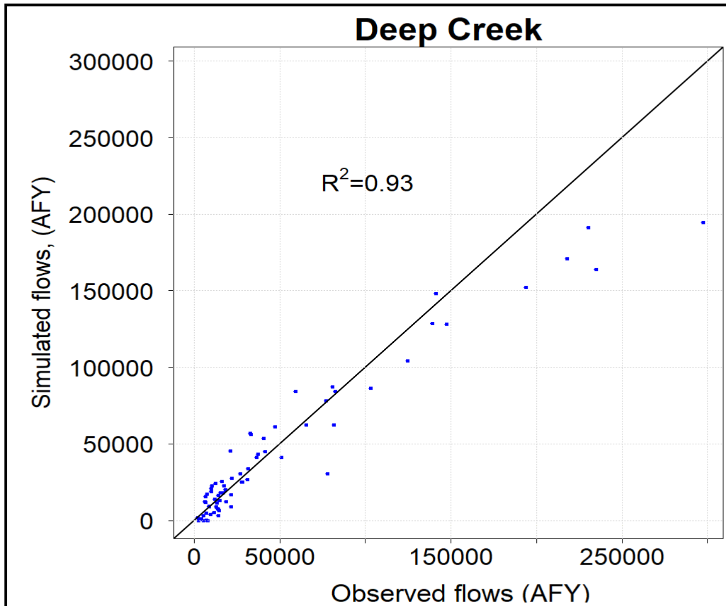
By: KMC	Date: 12/04/2023	Project .:
	Mojave Water Agency	Figure **4**

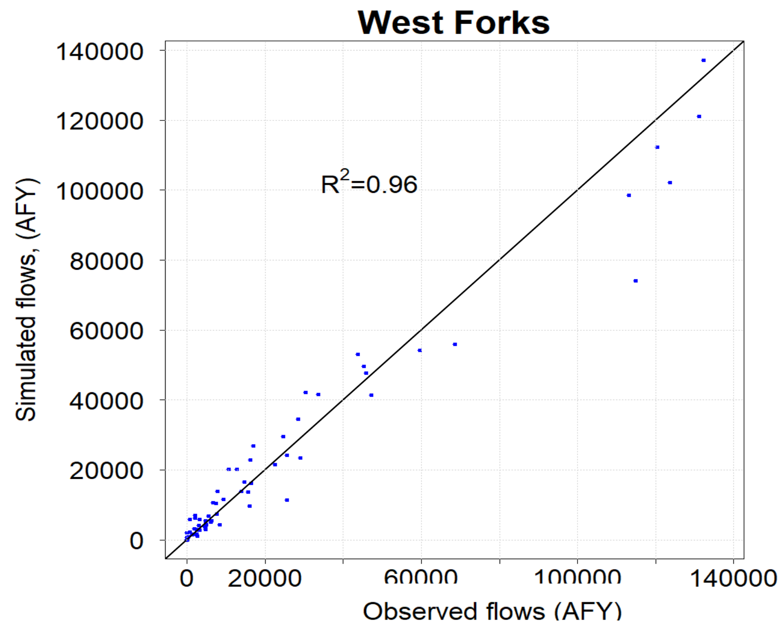


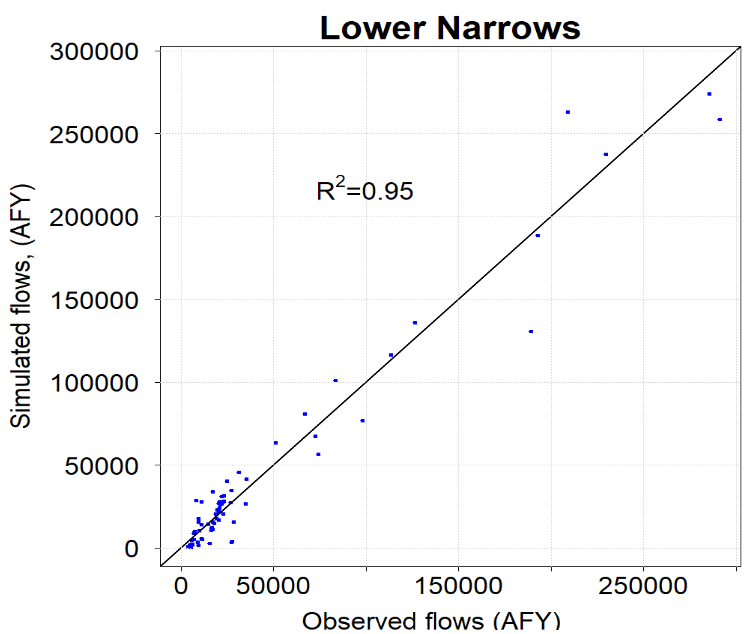
Selected Hydrograph

By: xxx	Date: 01/08/2015	Project No.: IR0000000000
Mojave Water Agency	Figure	5

https://mojavewater-my.sharepoint.com/personal/kcoulibaly_mojavewater_org/Documents/Projects/WagnerRequests/PSY_Calc/Figures/ModelingTMFigures.xlsxFigure 6 12/10/2023

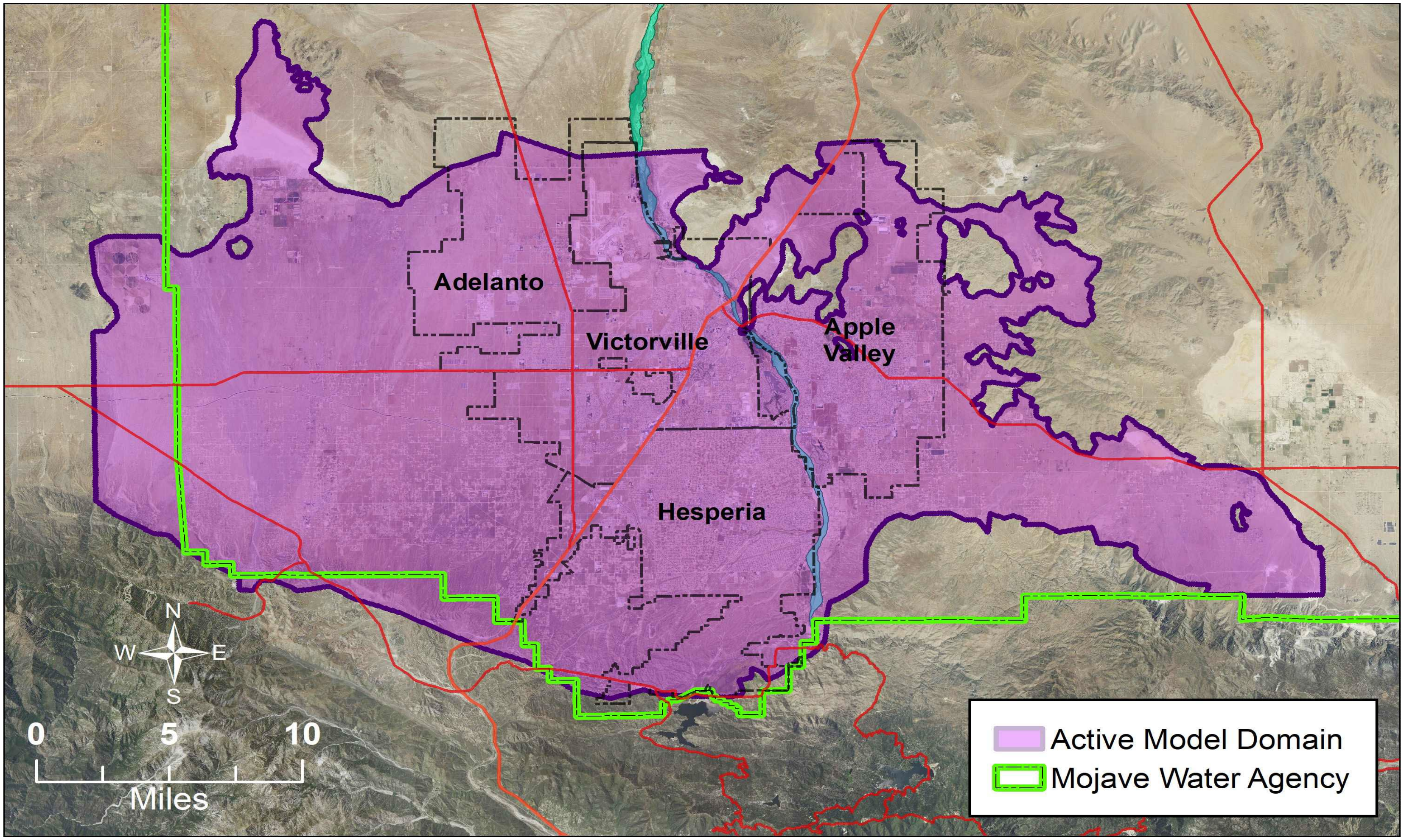






Obserbed vs Simulated Annual Flow

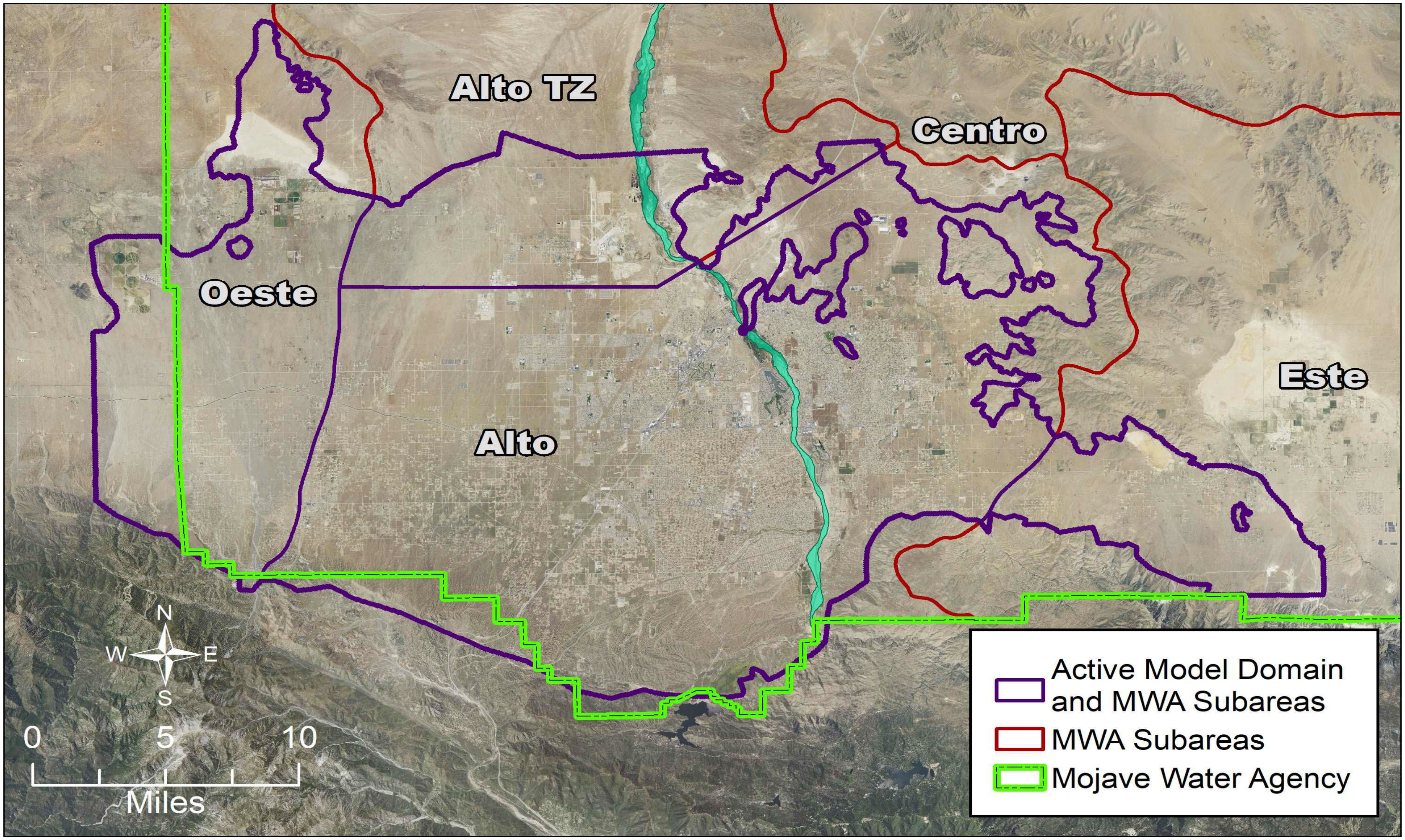
By: KMC	Date: 12/04/2023	Project No.: CM20167800
Mojave Water Agency		Figure 6



Model Water Budget Area

By: KMC	Date: 12/04/2023	Project No.: CM20167800
Mojave Water Agency		Figure 7

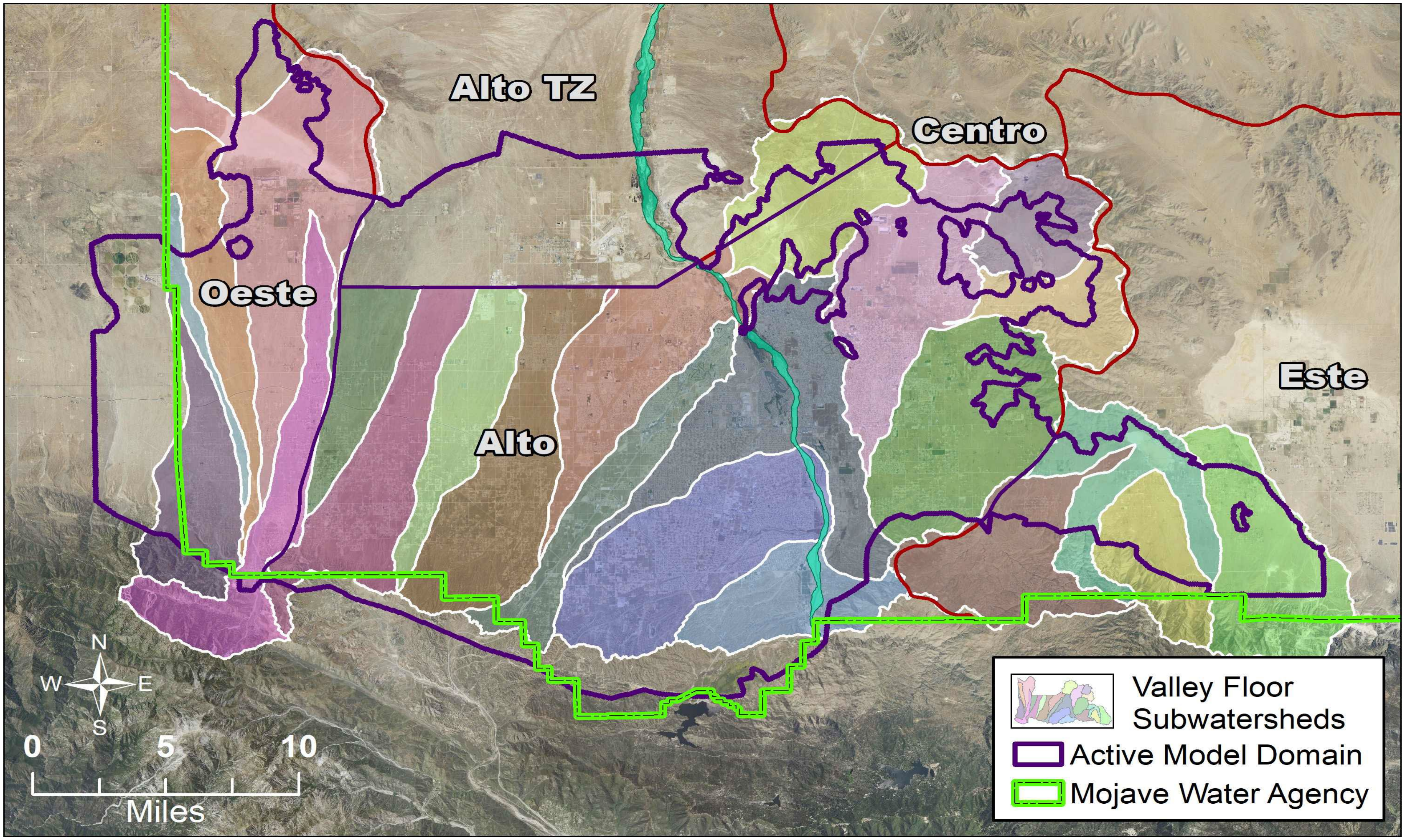
https://mojavewater-my.sharepoint.com/personal/kcoulibaly_mojavewater_org/Documents/Projects/WagnerRequests/PSY_Calc/Figures/ModelingTMFigures.xlsxFigure 8 12/10/2023



Water Budget Subareas

By: KMC	Date: 12/04/2023	Project No.: CM20167800
	Mojave Water Agency	Figure 8

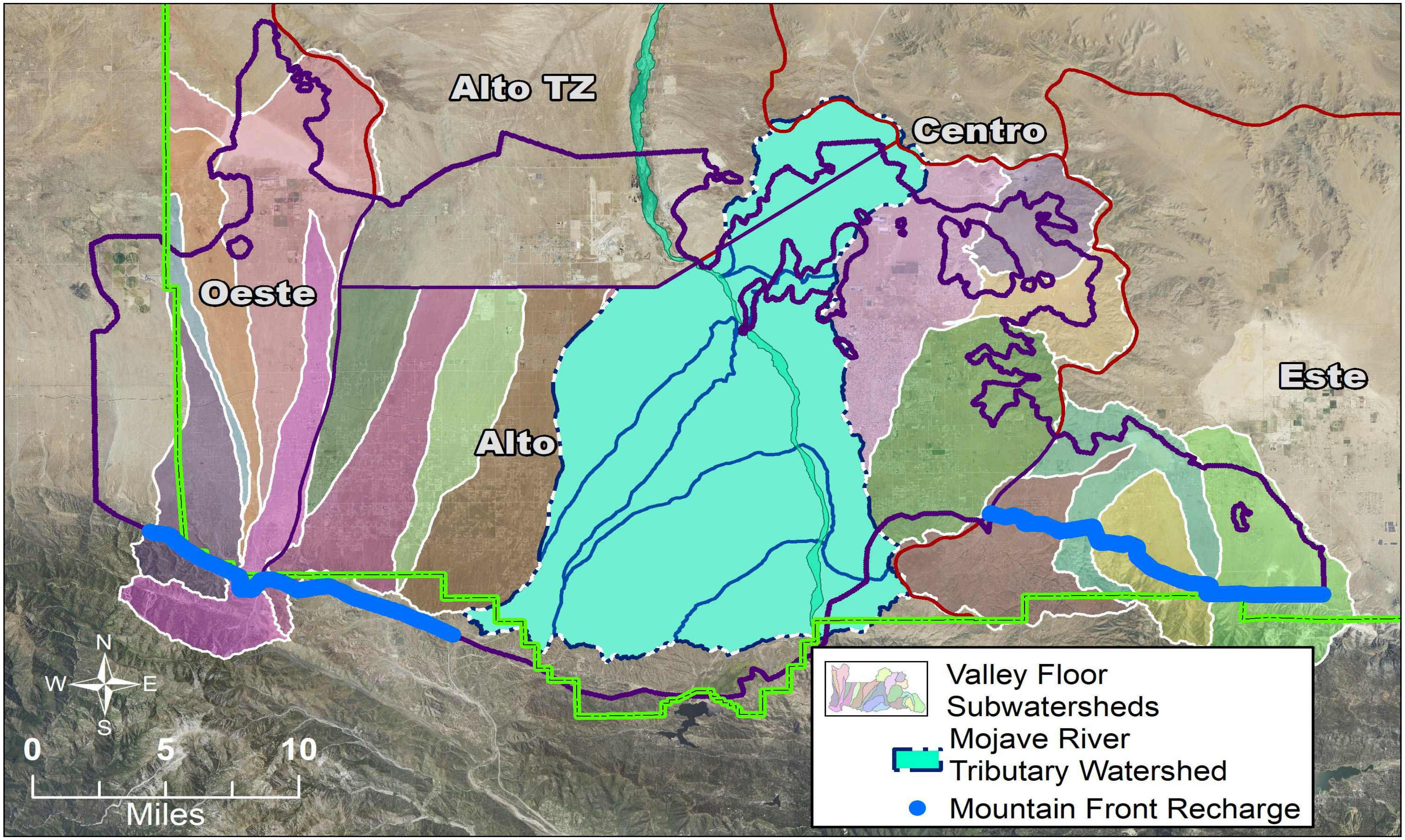
https://mojavewater-my.sharepoint.com/personal/kcoulibaly_mojavewater_org/Documents/Projects/WagnerRequests/PSY_Calc/Figures/ModelingTMFigures.xlsxFigure 9 12/10/2023



Upper Mojave Basin Subwatersheds Used for Mountain Front Recharge Estimates

By: KMC	Date: 12/04/2023	Project No.: CM20167800
	Mojave Water Agency	Figure 9

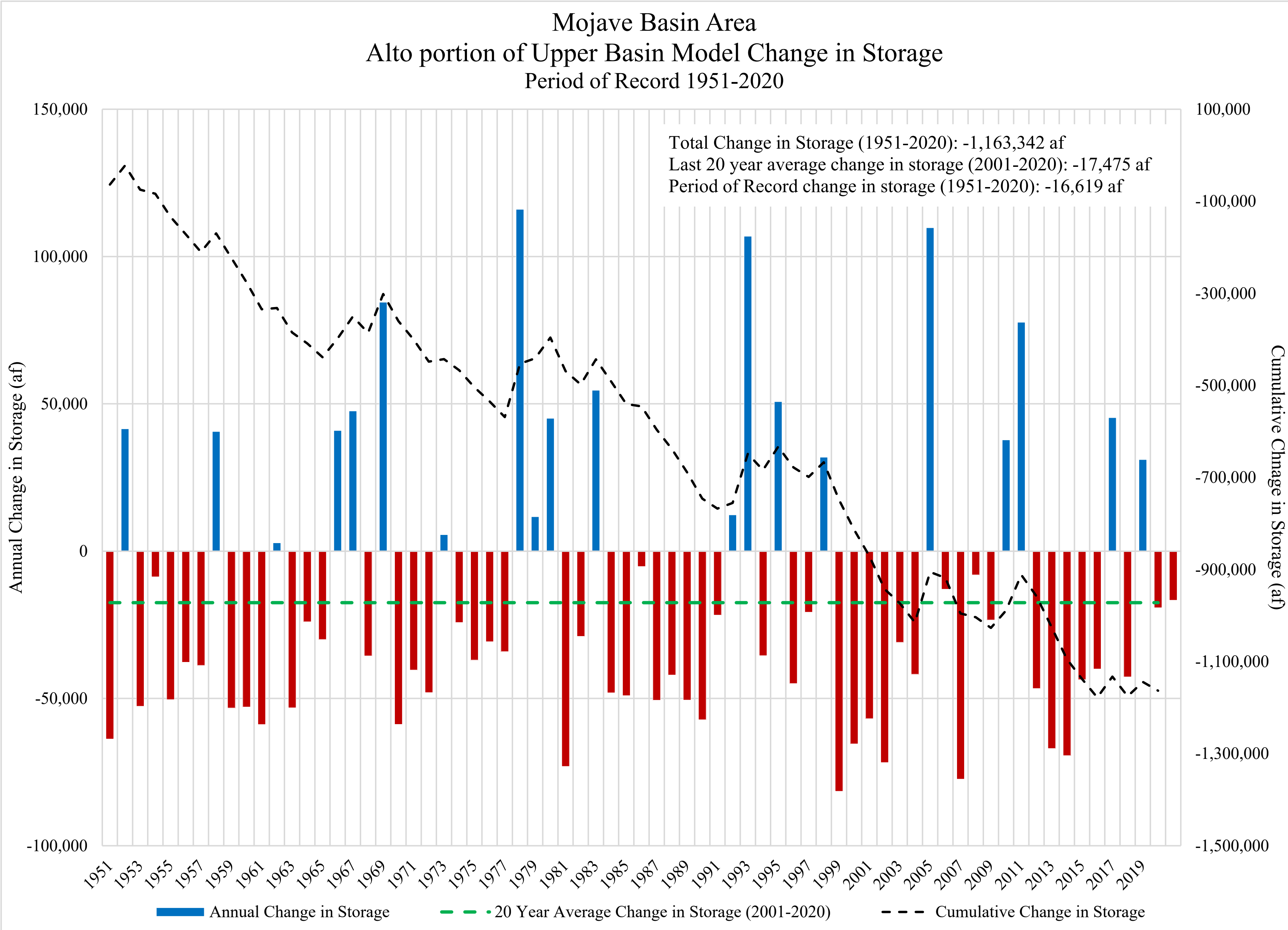
https://mojavewater-my.sharepoint.com/personal/kcoulibaly_mojavewater_org/Documents/Projects/WagnerRequests/PSY_Calc/Figures/ModelingTMFigures.xlsxFigure 10 12/10/2023



Upper Mojave Basin Subwatersheds Draining in the Mojave River (Tributaries)

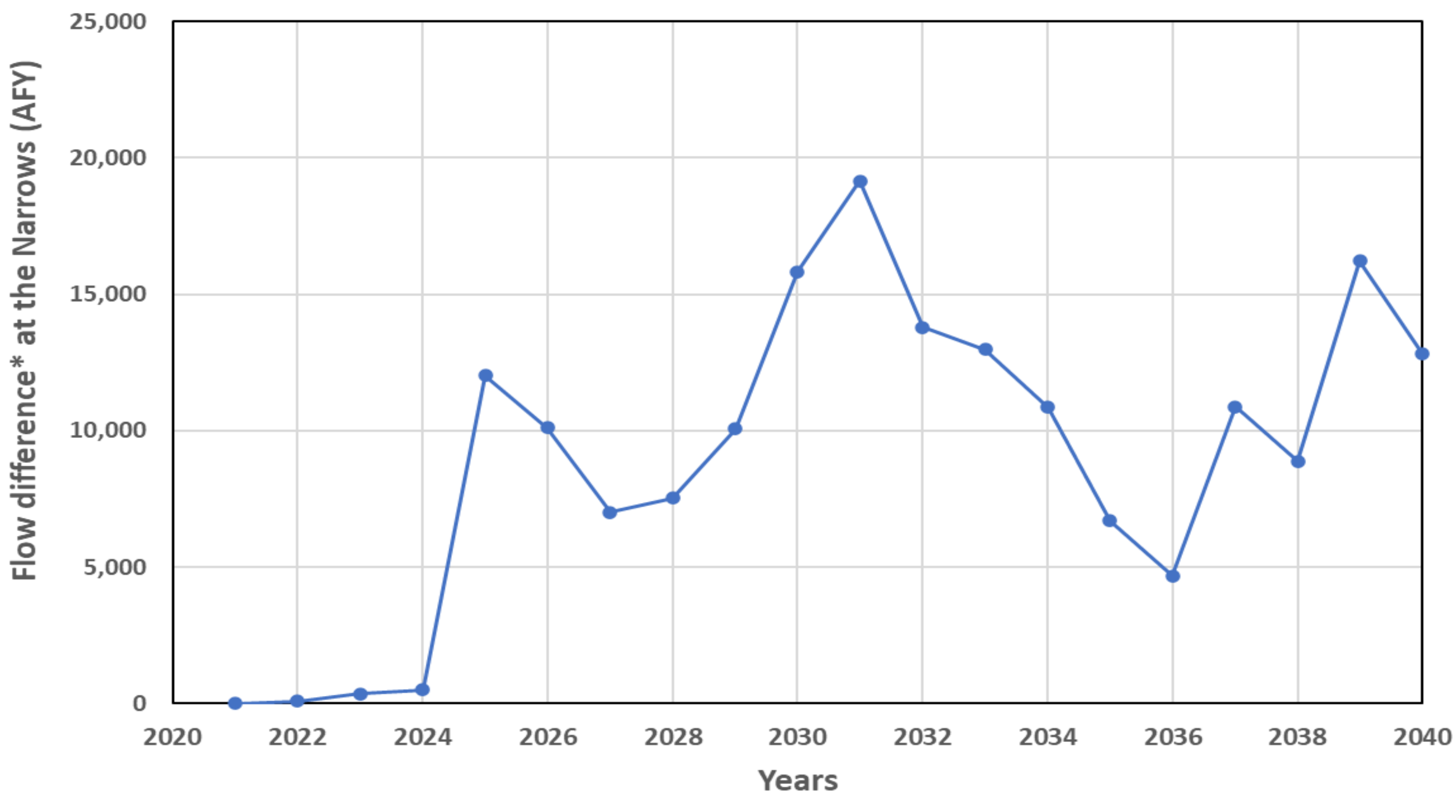
By: KMC	Date: 12/04/2023	Project No.: CM20167800
	Mojave Water Agency	Figure 10

FIGURE 11



G:\MOJAVE ADJUDICATION - 3020\Analysis\Groundwater Modeling\1-Alto\3020-009M-Table 6.1 Summary of Model Parameters Alto-V4.xlsx

https://mojavewater-my.sharepoint.com/personal/kcoulibaly_mojavewater_org/Documents/Projects/WagnerRequests/PSY_Calc/Figures/ModelingTMFigures.xlsxFigure 12 12/10/2023



* 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.	-